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Performance Evaluation of Steel-Nylon Hybrid Fiber Reinforced Concrete in M-25 Grade: An Experimental Study

Avdesh Meena[a] Ravi Kant Pareek[b]

M.tech Scholar, Department of Civil Engineering, Vivekananda Global University, Jaipur

Associate Professor, Department of Civil Engineering, Vivekananda Global University, Jaipur

Abstract

This research paper presents an experimental study on the performance evaluation of Steel-Nylon Hybrid Fiber Reinforced Concrete in M-25 grade. Fiber Reinforced Concrete (FRC) is a composite material that incorporates fibers to enhance the properties of conventional concrete. The addition of fibers improves crack resistance, tensile strength, toughness, and durability of concrete. In this study, steel and nylon 6 fibers were used in different combinations to investigate their impact on the mechanical properties of concrete. The mix design was performed as per IS 10262-2009, and the water-cement ratio was maintained at 0.43 with a 0.75% volume fraction of fibers. The physical and mechanical properties of the materials used were tested and found to meet the relevant Indian Standard specifications. The experimental program included testing of cube specimens for compressive strength, cylindrical specimens for split tensile strength, and beams for flexural strength at 7 and 28 days. The results revealed that the addition of fibers decreased workability but improved compressive, split tensile, and flexural strengths. Mix MS75N25 (75-25% steel-nylon) exhibited the highest compressive and flexural strengths, while mix MS100N0 (100-0% steel-nylon) showed the highest split tensile strength. The research provides valuable insights into the effectiveness of hybrid fiber reinforcement in enhancing the mechanical properties of concrete and its potential for various structural applications.

Key Words: Steel-Nylon Hybrid Fiber, Reinforced Concrete, M-25 Grade

Introduction

Fiber Reinforced Concrete (FRC) is a composite material that combines cement or mortar with randomly dispersed fibers to improve its properties. Regular concrete has limitations such as low tensile strength, poor toughness, and susceptibility to cracking, which restrict its applications. To overcome these weaknesses, additional materials like fibers are added to enhance concrete performance.

The history of using fibers for reinforcement dates back thousands of years, with ancient civilizations using straw fibers in sun-dried mud bricks to improve crack resistance. In modern times, French gardener Joseph Monier invented FRC in 1849, which led to further research and development in the 1950s by organizations like the Portland Cement Association.

Fibers can be classified based on their material, volume fraction, and size. They can be natural organic fibers (e.g., coconut, flax), natural mineral fibers (e.g., asbestos), man-made fibers (e.g., steel, glass, synthetic), or a combination of these. The volume fraction of fibers refers to the percentage of fiber volume compared to the total concrete volume, and it influences the performance of the concrete. Fibers can also be classified as macro-fibers (longer) or micro-fibers (shorter).

Among the types of fibers, steel fibers are widely used and come in different geometries like cut wire, hooked end, melt extract, and others. Steel fibers improve compressive strength, flexural strength, crack resistance, joint stability, and failure resistance in concrete.

Glass fibers are strong and lightweight and have been used for cladding, formwork, pipes, and panels. However, they may lose strength in an alkaline environment. Synthetic fibers, such as acrylic, aramid, carbon, nylon, polyester, polyethylene, and polypropylene, offer various properties and applications. Natural fibers, like coconut, jute, and wood, are used for low-cost composites but have limited use due to their high water absorption and low elasticity compared to steel or synthetic fibers.

The addition of fibers in concrete improves crack resistance, reduces water seepage, and provides other enhancements. However, excessive fiber volume can lead to concrete segregation and harshness. The aspect ratio (length to diameter ratio) of fibers also affects concrete properties, with an optimum ratio enhancing ultimate strength. The orientation of fibers in the concrete mix plays a crucial role in its workability and tensile strength.

Mixing of fibers should be done carefully to avoid clumping and segregation. Thorough mixing and proper volume of coarse aggregates are essential for good fiber dispersion.

Literature

The literature review provides a summary of various research studies conducted on the mechanical properties of hybrid reinforced concrete using steel and nylon 6 fibers. Ningaraj C. Birajdar and M. M. Magdum conducted an experimental study on the durability of hybrid fiber reinforced concrete. They used Alccofine as partial replacement of cement and water curing to enhance properties like water absorption and compressive strength of M60 grade concrete.

Navilesh and Vivekanand A Gutteder studied the mechanical properties of hybrid fiber reinforced concrete using steel and coconut (coir) fibers. They prepared five different concrete mixes and performed compressive, flexural, and split tensile tests.

R T Annavahini and S Christian Johnson investigated hybrid fiber reinforced concrete using glass and polypropylene fibers. They tested compressive, split tensile, and flexural strength to analyze the impact of different fiber combinations.

K. Mounika and A. Suchith Reddy focused on the performance of hybrid fiber reinforced concrete using polypropylene and steel fibers for M15 grade concrete. They observed the split tensile and compressive strength to optimize the fiber proportions.

Abid S. Mulla and Akshata A. Mulgund studied the mechanical properties of hybrid fiber reinforced concrete using steel and polypropylene fibers with mineral admixture for M30 grade concrete.

Lakshmi Priya and T.Ch.Madhavi investigated the flexural behavior of hybrid fiber reinforced concrete beams strengthened by glass FRP laminate.

Vinayadeep and Brijbhushan examined the strength aspects of hybrid fiber reinforced concrete using glue hooked end steel and polypropylene fibers for M20 grade concrete.

Sudheer Jirobe and Brijbhushan conducted an experimental investigation on the strength and durability properties of hybrid fiber reinforced concrete using creemped steel and polypropylene fibers with different mix proportions.

K.Ravi and A.V.Karvekar evaluated the performance of hybrid fiber reinforced concrete subjected to freezing and thawing effects using different fiber combinations.

C. Chandra et al studied the flexural behavior of solo and hybrid fiber concrete, comparing compressive strength, flexural strength, load-carrying capacity, stiffness, and ductility.

Pey-Shiuan Song et al investigated the mechanical properties of steel-nylon hybrid fiber-reinforced concrete using experimental design and analyzed the contribution of different fiber combinations to compressive and tensile strength.

M. K. Yew et al compared the strength properties of hybrid nylon-steel and polypropylene-steel fiber reinforced high-strength concrete at low volume fraction.

Eswari et al presented regression modeling for strength and toughness evaluation of hybrid fiber reinforced concrete using steel and polyolefin fibers.

Falah A. Almottiri studied the physical properties of steel fiber-reinforced cement composites made with fly ash and recommended fiber-reinforced fly ash concrete as an alternative to plain concrete.

Dr. Mazin Burhan Adeenet al determined the mechanical properties of hybrid steel-nylon fiber reinforced concrete using M20 grade concrete.

S.P. Singh et al investigated the strength and flexural toughness of concrete reinforced with steel-polypropylene hybrid fibers.

Rashid Hameed et al studied the flexural properties of metallic-hybrid-fiber reinforced concrete using two types of fibers: fuzzy metallic straight fiber and carbon steel hook-ended fiber. They varied the fiber content to examine the impact on flexural strength.

These studies collectively provide valuable insights into the mechanical properties and performance of hybrid fiber reinforced concrete using steel and nylon 6 fibers. The different fiber combinations and their effects on strength and durability are important factors for optimizing the concrete mix design for specific applications.

Experimental Programme:

To study the effect of mixing steel (hooked end) and nylon fibers with concrete under compression, flexure, and split tension, 30 cubes, 30 beams, and 30 cylinders were cast, respectively. The experimental program was divided into five mixes, each consisting of 6 cubes, 6 cylinders, and 6 beams of 15x15x15cm, 15(dia) x 30cm, and 10x10x50cm, respectively.

The first mix is the control (Plain) concrete with 0% fiber (PCC).

The second mix consisted of steel-nylon fibers percentages as (100-00)%.

The third mix consisted of steel-nylon fibers percentages as (75-25)%.

The fourth mix consisted of steel-nylon fibers percentages as (50-50)%.

The fifth mix consisted of steel-nylon fibers percentages as (25-75)%.

Materials and Tests:

The materials required and their various properties were determined in this section. The constituents of fiber-reinforced concrete, namely cement, sand, aggregate, steel fiber, nylon fiber, and superplasticizer, were procured and their various properties were determined.

Cement: Ordinary Portland cement of 43 grade was used.

Fine Aggregate: Locally available river sand conforming to IS: 383-1970 was used.

Coarse Aggregate: Broken stone from the local quarry conforming to IS: 383-1970 was used.

Water: Fresh, clean, and potable water from the tap was used.

Fibers: Steel and nylon 6 fibers were used.

Superplasticizer: Commercially available superplasticizer (SIKA 150) was used.

Mix Design for M25 Grade Concrete:

The mix design was carried out as per IS 10262-2009, and the water-cement ratio used was 0.43. The percentage of fibers added was 0.75% by volume of concrete.

Mixing Procedure:

All the materials, including cement, fine aggregate, coarse aggregate, steel (hooked end), and nylon fibers, required for preparing the concrete, were weighed as per mix design. The concrete was mixed thoroughly until a homogeneous mixture was obtained.

Casting of Specimens:

Standard steel molds were used for casting 30 cubes, 30 cylinders, and 30 beams. The molds were cleaned and applied with mineral oil before pouring the concrete. The concrete was filled into the molds in three layers and tamped.

Curing:

After casting, the specimens were stored in the laboratory at room temperature for 24 hours and then submerged in clean water for 28 days.

Tests on Hardened Concrete:

The properties of hardened concrete were tested, including compressive strength, split tensile strength, and flexural strength. The tests were performed at 7 and 28 days for each mix.

Results and Discussions:

Preliminary Testing:

Testing the physical properties of concrete ingredients is crucial to ensure strength and durability. The following tests were carried out on the cement to meet Indian Standard specifications (IS 4031-1988):

The physical properties of the cement used in the experimental program were tested and found to meet the Indian Standard specifications. The fineness of the cement was 0.50%, well below the standard limit of 10%. The specific gravity was 3.12, slightly lower than the standard value of 3.15. The normal consistency was 32.5%, and the initial setting time was 41 minutes, both within acceptable limits. The final setting time was 347 minutes, which was also well below the standard value of 600 minutes. The soundness of the cement was 1.00 mm, meeting the standard requirement of 10 mm. Regarding compressive strength, the cement exhibited satisfactory results, with values of 24.10 N/mm2 at 3 days, 34.56 N/mm2 at 7 days, and 47.92 N/mm2 at 28 days, all surpassing the standard values of 23 N/mm2, 33 N/mm2, and 43 N/mm2, respectively.

As for the fine aggregate, it had a specific gravity of 2.69, water absorption of 1.82%, and a fineness modulus of 2.86. These properties were in line with the experimental requirements. The coarse aggregate comprised two sizes, 20 mm and 10 mm, used in a ratio of 60:40. The specific gravity of the coarse aggregates was 2.74 (20 mm) and 2.72 (10 mm). The water absorption was 0.15% for 20 mm aggregates and 0.17% for 10 mm aggregates. The fineness modulus was 6.66 for 20 mm aggregates and 6.4 for 10 mm aggregates. These properties of the coarse aggregates were also within the desired range. For workability testing, slump cone tests were performed, and the slump values for different mixes were recorded. The results showed that as the fiber content increased in the concrete, the workability decreased. The maximum slump was 78 mm for mix MS0N0 (0-0%), and the minimum was 48 mm for mix MS50N50 (50-50%). Overall, the physical and mechanical properties of the concrete ingredients were suitable for the experimental investigation, meeting the necessary standards and requirements.

In the experimental investigation, cube specimens of M25 grade concrete were tested for compressive strength at 7 and 28 days, cylindrical specimens were tested for split tensile strength, and beams were tested for flexural strength at the same time points. The compressive strength values were recorded in MPa for each mix, showing an increase in compressive strength with the addition of both steel and nylon fibers. The mix with a 75-25% (steel-nylon) ratio exhibited the highest compressive strength. Similarly, the split tensile strength increased in all fiber-reinforced concrete mixes compared to the reference mix without fibers, with the highest increase observed in mix MS100N0 (100-0% steel-nylon). Furthermore, the flexural strength improved with the addition of fibers, and mix MS75N25 (75-25% steel-nylon) displayed the highest flexural strength. It was noted that while the addition of fibers generally reduced workability, the use of superplasticizer effectively maintained workability in all mixes. These results highlight the beneficial effects of steel and nylon fibers in enhancing the mechanical properties of the concrete and their potential in structural applications.

The experimental investigation led to the following conclusions: The slump value decreased with the addition of fibers compared to the reference mix, with the maximum slump observed in mix MN100S0 (100% steel & 0% nylon) and the highest slump loss in mix MS50N50 (50% steel & 50% nylon). However, the use of superplasticizer effectively maintained workability in all mixes. The compressive strength of hybrid fiber-reinforced concrete with 100-0% (steel-nylon) was found to be maximum at a 0.75% volume fraction of fibers by volume of concrete. Additionally, the maximum compressive strength for the combination of both steel and nylon fibers was obtained in mix MS75N25 (75-25% steel-nylon). The presence of steel fibers resulted in a 37.09% increase in compressive strength, while a 28.52% increase was observed in mix MS75N25 compared to the reference mix without fibers. Moreover, all fiber-reinforced concrete mixes exhibited higher compressive strength than the reference mix. The compressive strength showed a direct correlation with the quantity of steel fibers. The split tensile strength increased in all fiber-reinforced concrete mixes, with the highest increase observed in mix MS100N0 (100-0% steel-nylon) and a maximum increase of 20.84%. In the case of hybrid fiber-reinforced concrete, the highest tensile strength was observed in mix MS75N25 (75-25% steel-nylon), while the lowest was observed in mix MS25N75 (25-75% steel-nylon). The increase in tensile strength due to the incorporation of steel fibers was greater than that of using nylon fibers, and the addition of more nylon fibers had a limited impact on splitting tensile strength. Finally, mix MS75N25 (75-25% steel-nylon) exhibited the highest flexural strength, and all mixes showed increased flexural strength compared to the reference mix MS0N0. The maximum increment in flexural strength was observed in mix MS75N25, with a 20.31% increase compared to the reference mix. It is concluded that the addition of nylon fibers contributed to the increase in flexural strength, and the combination of steel and nylon fibers proved to be beneficial for enhancing the flexural strength of the concrete specimens.

References

1. Ningaraj C. Birajdar and M. M. Magdum "Durability Of Hybrid Fibre Reinforced Concrete". International Journal of Engineering Sciences & Research Technology.vol 6 issue 7,July 2017
2. Navilesh and Vivekanand A Gutteder "A Study on Hybrid Fiber Reinforced Concrete". International Research Journal of Engineering and Technology (IRJET) Volume: 04 Issue: 06 , June -2017
3. R T Annavahini and S Christian Johnson"Experimental Investigation on Hybrid Fibre Reinforced Concrete". International Journal of Innovative Research in Science, Engineering and Technology. Vol. 6, Issue 6, June 2017
4. K. Mounika and A. Suchith Reddy"Performance of Supplementary Cementitious Material based Hybrid Fibre Reinforced Concrete". International Journal of Innovative Research in Science, Engineering and Technology. Vol. 6, Issue 6, June 2017
5. Abid S. Mulla and Akshata A. Mulgund "An Investigation On Mechanical Properties Of Hybrid Fiber Reinforced Concrete". International Research Journal of Engineering and Technology Volume: 03 Issue: 05 , May-2016
6. Lakshmi Priya and T.Ch.Madhavi "Flexural Behaviour of Hybrid Fiber Reinforced Concrete Beams Strengthened by Glass FRP Laminate". International Journal of Innovative Research in Science, Engineering and Technology. Vol. 5, Issue 5, May 2016
7. Vinayadeep and Brijbhushan "Strength aspects of hybrid fiber reinforced concrete". International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 08 ,Nov-2015.
8. Sudheer Jirobe and Brijbhushan "Experimental investigation on strength and durability properties of hybrid fiber reinforced concrete". International Research Journal of Engineering and Technology. Volume: 02 Issue: 05 ,Aug-2015
9. K.Ravi and A.V.Karvekar " Performance evaluation of hybrid fibre reinforced concrete subjected to freezing and thawing effect". International Journal of Research in Engineering and Technology. Vol 3 issue 11, nov 2014.
10. C Chandra et al, "Flexural behavior of solo and hybrid fibre concrete- a comparative study", International Journal of Engineering Sciences & Research Technology, Vol. 2 Issue7, July 2013.
11. Pey-Shiuan Song, et al, "Investigating mechanical properties of steel- nylon hybrid fiber-reinforced concrete by using experimental design", Journal of C.C.I.T., Vol.42, No.1, May, 2013.

12. Parveen and Ankit Sharma, “Structural behaviour of fibrous concrete using polypropylene fibres”, International Journal of Modern Engineering Research (IJMER), Vol.3, Issue.3, May-June, 2013 pp-1279-1282.

13. Karthik M.P. and Maruthachalam D., “Mechanical properties of hybrid fibre reinforced concrete with available of rural fibres”, International Journal of Engineering Sciences & Research Technology, April, 2013.

14. Kavita S Kene et al, “Experimental study on behavior of steel and glass fiber reinforced concrete composites”, Bonfring International Journal of Industrial Engineering and Management Science, Vol. 3, Issue 4, Jul-Aug 2013, pp.1408-1411.

15. Er. Darole J. S et al, “Effect of hybrid fiber on mechanical properties of concrete”, International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 4, Jul-Aug 2013, pp.1408-1411.

16. Amit Rana, “Some Studies on Steel Fiber Reinforced Concrete”, International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 1, January 2013.

17. Vikrant S. Vairagade et al, “Experimental investigation on hybrid fiber reinforced concrete”, International Journal of Engineering Research and Applications (IJERA),Vol. 2, Issue 3, May-Jun 2012, pp.1037-1041.

18. Jain D. And Kothari A., “Hair fibre reinforced concrete”, Research Journal of Recent Science, Vol. 1(ISC-2011), 128-133 (2012).

19. M. K. Yew et al, “Strength properties of hybrid nylon-steel and polypropylene-steel fibre reinforced high strength concrete at low volume fraction”, November 2011.

20. S. Eswari et al, “Regression modeling for strength and toughness evaluation of hybrid fibre reinforced concrete”, ARPN Journal of Engineering and Applied Sciences, VOL. 6, NO. 5, May 2011.

21. Falah A. Almottiri, “Physical properties of steel fiber reinforced cement composites made with fly ash”, Jordan Journal of Civil Engineering, Volume 5, No. 2, 2011.

22. Dr. Mazin Burhan Adeen et al, “Determination of mechanical properties of hybrid steel-nylon fiber reinforced concrete”, Modern Applied Science, Vol. 4, No. 12; December 2010.

23. S.P. Singh et al, “Strength and flexural toughness of concrete reinforced with steel – polypropylene hybrid fibres”, Asian journal of civil engineering (building and housing), Vol. 11, NO. 4 (2010), pp 495-507.

24. Rashid Hameed et al, “Study on the flexural properties of metallic-hybrid-fibre reinforced Concrete”, Maejo International Journal of Science and Technology, Maejo Int. J. Sci. Technol. 2010, 4(02), 169-184.

25. Rana A. Mtasher, “Strength Prediction of Polypropylene Fiber Reinforced Concrete”, Eng. & Tech. Journal, Vol.29, No.2, 2010.

26. Jain D. And Kothari A., “Hair Fibre Reinforced Concrete”, Research Journal of Recent Sciences, Vol. 1(ISC-2011),128-133,2010.

27. Ryan Barborak & P.E., “Fibre reinforced concrete (FRC) DMS-4550 Tip Sheet”, Construction and Bridge Divisions, January 2011.

28. American Concrete Institute. Report on Fiber Reinforced Concrete. ACI 544.1R-96, 1996.

29. Bentur A. And Mindess S., Fibre Reinforced Cementitious Composites, Elsevier Science Publishing Ltd., New York, United State of America, 1990.

30. James J. Beaudoin, Handbook of Fiber-Reinforced Concrete: Principles, Properties, Development and Applications, Noyes Publications, New Jersey, United State of America, 1990.

31. ACI Committee 544, “State-of-the-Art Report on Fiber Reinforced Concrete”, May 1982, pp 411-413.

32. Shetty M. S., “Concrete Technology-Theory and Practice”, S. Chand and Company, New Delhi, (1982), pp 526 & 528.

33. Goldfein, S., “Fibrous Reinforcement for Portland Cement,” Modern Plastics, Vol. 42, No. 8, 1965, pp. 156-160.

IS Codes

1. IS: 2386-1963 Indian standards code of practice for methods of test for Aggregate for concrete Indian Standard Institution, New Delhi.
2. IS: 383-1970Indian standards specification for coarse and fine aggregates from natural sources for concrete Bureau of Indian Standards, New Delhi.
3. IS: 1199:1959 Methods of sampling and analysis of concrete, Bureau of Indian Standards, New Delhi.
4. IS: 5816:1999 Splitting tensile strength of concrete-Method of test, Bureau of Indian Standards, New Delhi.
5. IS 9103:1999 Specification for admixtures for concrete (First Revision).
6. IS: 456:2000 Plain and reinforced concrete- code of practice.
7. IS 8112-1989 Specification for 43 grade ordinary Portland cement (First Revision).
8. IS: 10262:2009 Recommended guidelines for concrete mix design, Bureau of Indian Standards, New Delhi.