JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

A COMPREHENSIVE EXAMINATION OF THE MECHANICAL PROPERTIES AND FLEXURAL CHARACTERISTICS OF HARDENED HIGH STRENGTH FIBER REINFORCED CONCRETE (HSFRC)

[1]Mrs. Rakhi Nimbhore, [2]Mrs. Komal Viral Panchal, [3]Mrs. Monali A. Kalekar

[1]Lecturer, [2]Lecturer, [3]HOD
[1]Department of Civil Engineering
[1]Thakur Polytechnic, Kandivali (E), Mumbai, INDIA

Abstract: This review paper delves into the study of utilizing various shapes of steel fibers to augment the flexural capacity of high-strength concrete beams, in addition to enhancing compressive and tensile strength. The flexural tensile strength, also known as the modulus of rupture (MOR), holds significant importance in assessing deflection, determining minimum flexural reinforcement, and predicting the onset of visible cracks in concrete structures subjected to bending. Conventionally, it's widely accepted that the theoretical compressive strength is approximately ten times the tensile strength, suggesting a fixed relationship between these two parameters. However, as the compressive strength increases to higher levels, the ratio of tensile to compressive strengths tends to decrease. Over the past few decades, research on high-strength concrete (HSC) has primarily focused on addressing issues like premature deterioration of reinforced concrete structures, flexural strength, tensile strength, and fatigue strength, caused by severe environmental conditions and mechanical loading. This has emerged as a significant concern in both conventional and high-strength concrete structures. The incorporation of steel fibers in HSC has been extensively explored to enhance flexural strength and other mechanical properties. Recent studies have demonstrated that steel fibers substantially mitigate the brittleness of concrete while improving its engineering properties, including tensile strength, flexural strength, impact resistance, fatigue resistance, load-bearing capacity after cracking, and toughness.

***IndexTerms* - High Strength Concrete; Fibre Reinforced Concrete, Strength Properties, FlyAsh, Silica fume**

I. INTRODUCTION

Concrete is an artificial material that is molded into the desired size and shape before it hardens. It comprises aggregates, sand, and either gravel or crushed stone, bound together by a cementitious paste. Renowned for its versatility, durability, sustainability, and cost-effectiveness, concrete has become the most widely used construction material globally. It boasts various properties, including compression strength, tensile strength, flexural strength, and shear strength, which safeguard structures against corrosion and damage caused by external loads and environmental factors. In recent years, there has been a growing demand for high-strength concrete (HSC), particularly for constructing tall buildings and critical structures like nuclear power plants. Different types of concrete mixes, such as nominal mix for standard and HSC, lightweight concrete, air-entrained concrete, high-performance concrete, self-consolidated concrete, shotcrete concrete, and pervious concrete, cater to various construction requirements. Nominal mixes are commonly used for typical construction projects, while HSC mixes involve thorough laboratory testing and analysis to determine the optimal mix proportions for desired strength and properties. Various tests, such as cylinder tests for tensile strength, beam tests for flexural strength, and cube tests for compressive strength, are conducted to finalize the appropriate mix proportions. HSC exhibits properties like low shrinkage, low permeability, high strength, and high modulus of elasticity, enabling it to withstand heavier loads compared to normal-strength concrete. Flexural and tensile strength are crucial parameters for both normal and HSC, with flexure tests assessing the concrete's ability to withstand bending failure. These tests measure flexural strength and modulus, defining the maximum stress at the outermost fiber on either the compression or tension side of the specimen.

II. FIBER REINFORCED CONCRETE

Flexural strength after cracking is increasingly recognized as a critical characteristic of fiber-reinforced concrete (FRC), as it directly influences the structural performance and durability of concrete elements. Consequently, understanding how different types of fibers, at varying dosages, can effectively mitigate cracking is of paramount importance. Over the years, numerous standards have been developed to govern the use of FRC, with ongoing refinements to accommodate advancements in materials and technologies. Despite these standards, researchers continue to investigate the post-cracking behavior of FRC across a spectrum of loading conditions, seeking to enhance its performance and applicability in real-world scenarios. Among the various types of fibers studied, steel and polypropylene fibers have garnered significant attention from researchers due to their favorable properties and widespread use in construction applications. These fibers exhibit unique characteristics that contribute to the enhancement of concrete's flexural strength and ductility, thereby offering improved resistance against cracking and enhanced structural integrity. By exploring the behavior of FRC reinforced with different types and dosages of fibers, researchers aim to provide valuable insights into optimizing material selection and mix design, ultimately advancing the understanding and utilization of fiber-reinforced concrete in the construction industry.

III. PREVIOUS STUDY

The flexural performance and serviceability characteristics of glass fiber-reinforced polymer concrete (GFRP) beams, fabricated using both normal- and high-strength concretes (NSCs and HSCs), were investigated in a study cited [1]. The crack widths were found to be influenced by the bar diameter and surface configuration, while deflections were not significantly affected. Another study [2] explored how confined conditions and the age of concrete affect its mechanical properties, particularly flexural tensile strength. Flexural testing of strengthened beams was examined with variations in interface preparation techniques, with observations made on the branching and propagation of flexural cracks along the interface in certain cases [3]. Additionally, research [4] demonstrated that steel fiber reinforcement improved the linear load-deflection relationship of concrete beams, with specimens containing higher fiber content exhibiting deflection-hardening behavior. Moreover, the addition of steel fibers to concrete was found to enhance its compressive, split tensile, and flexural strength while reducing crack formation [5]. Furthermore, studies [6] highlighted the size-dependent nature of flexural strength, with predictions made using Bazant's size effect law. Steel fibers were noted to provide high compressive and flexural strength, as well as ductility, under both ambient and elevated temperatures [7]. Additionally, the residual flexural strength of steel fiber-reinforced concrete (SFRC) was found to depend on fiber type and dosage, with the influence of size effects being complex [8]. Concrete strength was observed to decrease with increasing temperature, with the type of cooling affecting residual compressive and flexural strength [9]. SFRC beams with 1% fiber volume fraction exhibited higher load-carrying capacity and enhanced ductility [10]. It was recommended that the residual flexural strength be considered in the design and construction of SFRC structures [11]. Furthermore, the proportionality equations relating flexural tensile strength to compressive strength reliability were investigated, with the power model deemed more reliable [12]. The addition of steel fibers to concrete was found to increase compressive strength and toughness [13]. Various studies reported improvements in flexural strength, fracture toughness, thermal shock resistance, and impact loading with the addition of steel fibers to concrete [17]. Moreover, the modulus of rupture was positively affected by the addition of fibers to concrete [18]. While fibers enhanced toughness and strain at peak stress, they slightly reduced Young's modulus [19]. Uni-axial compression tests on fiber-reinforced concrete specimens showed increases in compressive, split tensile, flexural strength, and modulus of elasticity [21]. However, the addition of steel fibers did not eliminate the spalling tendency of high-performance concrete when exposed to elevated temperatures [22], although polypropylene fiber-reinforced self-compacting concrete exhibited significant spalling resistance under similar conditions [23]. Additionally, steel fibers and polymer content were found to increase shear strength, with beams able to sustain loads equal to the cracking load even under large deflections [24]. Moreover, fibers were effective in improving rigidity and reducing crack width in certain concrete beams, leading to a shift from brittle to ductile failure modes with increased fiber content under bending loads [24].

IV. INFLUENCE OF FIBER TYPE AND CONTENT

The selection of fiber type and content plays a pivotal role in determining the mechanical properties and overall performance of High Strength Fiber Reinforced Concrete (HSFRC). Various types of fibers, including steel fibers, polypropylene fibers, and glass fibers, exhibit distinct characteristics and behaviors when incorporated into concrete matrices.

Steel fibers are widely used in HSFRC due to their high tensile strength and ductility, which contribute to improved crack resistance and flexural performance. These fibers effectively enhance the post-cracking behavior of concrete and increase its toughness, making it suitable for applications requiring high structural integrity and durability. Polypropylene fibers, on the other hand, offer benefits such as corrosion resistance and thermal stability. They are commonly used in HSFRC to mitigate plastic shrinkage cracking and improve freeze-thaw resistance in cold climates. Glass fibers, known for their high stiffness and low density, provide additional reinforcement to concrete matrices and contribute to enhanced flexural strength and modulus of elasticity.

The optimal fiber content for HSFRC depends on several factors, including the desired mechanical properties, specific application requirements, and compatibility with other concrete constituents. Extensive research and experimentation are often conducted to determine the ideal fiber dosage that maximizes the benefits of reinforcement while maintaining workability and homogeneity of the concrete mix.

Moreover, the combination of different fiber types in HSFRC blends allows for synergistic effects that can further enhance mechanical properties and performance characteristics. Hybrid fiber systems, consisting of a combination of steel, polypropylene, or glass fibers, offer a balanced approach to reinforcing concrete and addressing multiple performance requirements simultaneously.

Overall, the influence of fiber type and content on HSFRC underscores the importance of thoughtful material selection and mix design considerations in achieving desired strength, durability, and flexural properties. By understanding the unique attributes of different fiber types and optimizing their content in concrete formulations, engineers and researchers can tailor HSFRC to meet the specific needs of diverse construction applications and ensure long-term structural performance.

V. EFFECT OF CURING CONDITIONS

Curing conditions exert a significant impact on the mechanical properties and overall performance of High Strength Fiber Reinforced Concrete (HSFRC). Proper curing is essential for promoting hydration reactions, ensuring adequate strength development, and enhancing the durability of concrete structures. This section delves into the various factors affecting curing, including curing methods, duration, and temperature, and their implications on the strength and flexural behavior of HSFRC.

The choice of curing method greatly influences the rate of moisture retention and temperature control during the early stages of concrete curing. Common curing methods include moist curing, steam curing, and curing with curing compounds or membranes. Moist curing, involving the application of water to the concrete surface and the use of wet coverings to maintain moisture, is widely practiced for HSFRC to facilitate proper hydration and prevent premature drying. Steam curing accelerates the curing process by supplying heat and moisture to the concrete, resulting in rapid strength gain and reduced curing time. However, careful monitoring of temperature and humidity levels is essential to prevent thermal cracking and ensure uniform curing throughout the concrete mass. Additionally, curing compounds or membranes can be applied to the concrete surface to create a barrier against moisture loss and promote optimal curing conditions, particularly in outdoor or exposed environments.

The duration of curing is another critical factor that influences the development of mechanical properties in HSFRC. Extended curing periods allow for continued hydration and calcium silicate gel formation, leading to increased strength and durability. However, the specific duration of curing may vary depending on factors such as cement type, water-cement ratio, ambient conditions, and desired strength requirements. Inadequate curing duration can result in reduced strength, increased permeability, and susceptibility to cracking, compromising the long-term performance of HSFRC structures.

Temperature also plays a crucial role in curing, as it directly affects the rate of cement hydration and subsequent strength development. Optimal curing temperatures typically range between 20°C and 25°C, as higher temperatures can accelerate hydration but may also lead to thermal cracking and reduced durability. Conversely, lower temperatures may slow down the curing process and delay strength gain, particularly in cold climates. Careful temperature control and monitoring are essential to ensure consistent curing conditions and achieve the desired mechanical properties in HSFRC.

In summary, the effect of curing conditions on HSFRC underscores the importance of adopting appropriate curing methods, optimizing curing duration, and controlling curing temperature to maximize strength, durability, and overall performance. By adhering to best practices for curing, engineers and researchers can effectively enhance the mechanical behavior and long-term sustainability of HSFRC structures.

VI. Applications and Future Perspectives

High Strength Fiber Reinforced Concrete (HSFRC) holds immense potential for various applications in the field of structural engineering, offering superior mechanical properties and durability. One of the primary applications of HSFRC is in the construction of high-rise buildings, where its enhanced strength and crack resistance can effectively withstand vertical and lateral loads, ensuring the structural integrity of tall structures. Additionally, HSFRC finds extensive use in bridge construction, where its high flexural strength and resistance to environmental factors make it an ideal material for bridge decks, girders, and other critical components.

Moreover, the versatility of HSFRC opens up opportunities for its utilization in a wide range of infrastructure projects, including tunnels, dams, and marine structures. Its ability to withstand harsh environmental conditions, such as exposure to saltwater or chemical agents, makes it suitable for marine applications where traditional concrete may deteriorate rapidly.

Looking ahead, there are several potential areas for future research and development to further enhance the mechanical behavior of HSFRC and expand its applications in the construction industry. One avenue of research involves optimizing fiber types and content to achieve superior performance characteristics, such as increased tensile strength, ductility, and durability. Exploring innovative fiber materials and manufacturing techniques could lead to the development of HSFRC with enhanced properties and reduced environmental impact.

Furthermore, advancements in mix design, curing methods, and construction techniques can contribute to the widespread adoption of HSFRC in various structural applications. Research initiatives focused on understanding the long-term performance of HSFRC under different loading conditions and environmental exposures can provide valuable insights into its durability and service life.

Collaborative efforts between academia, industry, and government agencies are essential to drive research and development initiatives in the field of HSFRC. By fostering interdisciplinary collaborations and knowledge exchange, researchers can accelerate the pace of innovation and address the challenges associated with implementing HSFRC in real-world construction projects.

In conclusion, the diverse applications of HSFRC in structural engineering, coupled with ongoing research efforts to enhance its mechanical behavior, highlight the promising future of this advanced construction material. With continued advancements and innovation, HSFRC has the potential to revolutionize the construction industry and contribute to the development of safer, more sustainable infrastructure worldwide.

VII. Conclusion

The flexural tensile strength of concrete plays a crucial role in the design of flexural members. The incorporation of fibers into concrete mixtures enhances various mechanical properties such as compressive strength, split tensile strength, and flexural strength at 28 days compared to conventional mixes. The addition of steel fibers to concrete results in elevated flexural strength and compressive strength. In particular, steel fiber-reinforced beam specimens containing fiber content exceeding 0.50% exhibit deflection-hardening behavior, indicating improved resistance to deformation. Furthermore, the presence of steel fibers and polymer content in concrete contributes to an increase in shear strength, enhancing the material's ability to resist lateral forces.

In conclusion, the mechanical behavior of High Strength Fiber Reinforced Concrete (HSFRC) is influenced by various factors, including fiber type and content, curing conditions, and environmental parameters. Extensive research and experimentation have demonstrated the significant impact of these factors on the strength, flexural properties, and durability of HSFRC. The choice of fiber type and content plays a crucial role in determining the performance of HSFRC, with different fibers offering unique advantages in terms of strength, ductility, and crack resistance. Additionally, curing conditions significantly affect the hydration process and subsequent development of mechanical properties in HSFRC, highlighting the importance of proper moisture retention, temperature control, and curing duration. Future research directions may focus on further optimizing fiber combinations, refining curing techniques, and exploring innovative additives to enhance the mechanical behavior and expand the applications of HSFRC in structural engineering. By addressing these key considerations and embracing advancements in materials science and construction technology, HSFRC has the potential to revolutionize the design and construction of durable, resilient, and sustainable concrete structures.

REFERENCES

1. K.R.Venkatesan, P.N.Raghunath, K.Suguna, "Flexural Behavior of High Strength Steel Fibre Reinforced Concrete Beams", ACI Structural Journal, December 2013, Vol 110, S88, pp.1077- 1088.
2. Mohd. Ahmed *, Javed Mallick, Mohd. Abul Hasan, "A study of factors affecting the flexural tensile strength of concrete", Elsevier, Journal of King Saud University – Engineering Sciences (2016), Vol. 28, pp. 147–156
3. M.A. Al-Osta a,⇑, M.N. Isa a, M.H. Baluch a, M.K. Rahman.., "Flexural behavior of reinforced concrete beams strengthened with ultra-high performance fiber reinforced concrete", Elsevier, Construction and Building Materials Vol.134 (2017) pp.279–296
4. Qi Cao a,b, Yinliang Cheng c, Mingli Cao a,⇑, Quanqing Gao a.., "Workability, strength and shrinkage of fiber reinforced expansive self-consolidating concrete", Elsevier, Construction and Building Materials (2017) Vol.131,pp. 178–185
5. Aiswarya Sukumar, Elson John, , "Fiber Addition And Its Effect On Concrete Strength .International Journal Of Innovative Research In Advanced Engineering (Ijirae) Issn: 2349-2163 Volume 1 Issue 8 (September 2014)
6. Nicholas A. Brake ⇑, Hamid Allahdadi, Fatih Adam "Flexural strength and fracture size effects of pervious concrete", Elsevier, Construction and Building Materials (2016) Vol.113,pp. 536–543.
7. D. Choumanidis a, E. Badogiannis b,⇑, P. Nomikos a, A. Sofianos a.., "The effect of different fibres on the flexural behaviour of concrete exposed to normal and elevated temperatures", Elsevier ,Construction and Building Materials (2016) Vol. 129,pp. 266–277
8. Technical Report no. 63.., "Guidance for the Design of steel – Fiber –Reinforced Concrete", Published March 2007, ISBN 1-904482-32-5 The Concrete Society
9. Metin Husem_.., "The effects of high temperature on compressive and flexural strengths of ordinary and high- performance concrete" Elsevier, Department of Civil Engineering, Karadeniz Technical University, 61080 Trabzon, Turkey Received 29 April 2004; received in revised form 10 October 2005; accepted 5 December 2005
10. K.R.Venkatesan, P.N.Raghunath, K.Suguna.., "Flexural Behavior of High Strength Steel Fibre Reinforced Concrete Beams" . ISSN: 2319-5967 ISO 9001:2008 Certified International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 4, Issue 1, January 2015
11. Jong-Han Lee 1., "Influence of Concrete Strength Combined with Fiber Content in the Residual Flexural Strengths of Fiber Reinforced Concrete", Composite Structures (2017), doi: http://dx.doi.org/10.1016/ j.compstruct.2017.01.052.
12. Ahmed, M., El Hadi, K.M., Abul Hasan, M., Mallick J. Ahmed, A., 2014. Evaluating the co-relationship between concrete flexural tensile strength and compressive strength, Int. J. Struct. Eng.5 (2).
13. Kılıc， a, C.D. Atis_ b,*, A. Teymen a, O. Karahan b, F. O¨ zcan c, C. Bilim d, M. O¨ zdemir a…, "The influence of aggregate type on the strength and abrasion resistance of high strength concrete". Elsevier, Cement & Concrete Composites 30 (2008) 290–296 ISSN: 2249-8753 (Online), ISSN: 2321-6476 (Print)
14. Amudhavalli, N.K. and Mathew, J. (2012) 'Effect of silica fume on strength and durability parameters of concrete', International Journal of Engineering Sciences & Emerging Technologies, Vol. 3, No. 1, pp.28–35.
15. Weimin Song 1,* and Jian Yin 2 .., "Hybrid Effect Evaluation of Steel Fiber and Carbon Fiber on the Performance of the Fiber Reinforced Concrete", Materials 2016, 9, 704; doi:10.3390/ma9080704 www.mdpi.com/journal/materials
16. K.R.Venkatesan1*, K.Suguna2 and P.N.Raghunath3 .., "Steel Fibre Reinforced Concrete Beams under Flexure", Asian Journal of Applied Sciences (ISSN: 2321 – 0893) Volume 03 – Issue 01, February 2015
17. M.C. Nataraja, T.S. Nagaraj and S.B. Basavaraja. (2005) Reproportioning of Steel Fibre Reinforced Concrete Mixes and their Impact Resistance, Cement and Concrete Research, 35(12), 2350-2359.
18. V. S. Gopalaratnam and R. Gettu, "On the characterization of flexural toughness in fiber reinforced concretes," Cement and Concrete Composites, vol. 17, no. 3, pp. 239–254, 1995
19. Ghosni, N, Samali, B & Valipour 2014, 'Flexural behaviour of high strength concrete composite incorporating long hooked-end steel fibres' in ST Smith (ed.), 23rd Australasian Conference on the Mechanics of Structures and Materials (ACMSM23), vol. I, Byron Bay, NSW, 9- 12 December, Southern Cross University, Lismore, NSW, pp. 327-332. ISBN: 9780994152008. Neves, R.D and Fernandes de Almeida, J. C. O, "Compressive Behaviour of Steel Fiber Reinforced Concrete."Structural Concrete.2005.6.No 1.
20. Vairagade, V.S and Kene, K.S," Introduction to Steel Fiber Reinforced Concrete on Engineering Performance of Concrete."International Journal of Scientific & Technology Research Volume 1, Issue 4, May 2012.
21. Shah , S and Rangan(1994), "Effect of Fiber addition on concrete strength", Indian Concrete Journal.
22. K.K. Sideris, P. Manita, E. Chaniotakis, Performance of thermally damaged fibre reinforced concretes,Constr.Build.Mater.23(2009)123 2– 1239,http://dx.doi.org/10.1016/j.conbuild mat.2008.08.009.
23. K.K. Sideris, P. Manita, Residual mechanical characteristics and spalling resistance of fiber reinforced self- compacting concretes exposed to elevated temperatures, Constr. Build. Mater 41(2013) 296–302, http://dx.doi.org/ 10.1016/j.conbuildmat.2012.11.093.
24. Uttam B. Kalwane, Yuwaraj M. Ghugal and Ajay G. Dahake, Shear strength of polymer modified steel fiber reinforced concreteThe Indian Concrete Journal – 2016.