IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

AN OVERVIEW ARTICLE ON INCORPORATING HUMAN HAIR AS FIBRE REINFORCEMENT IN CONCRETE

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ABSTRACT

This review paper aims to provide a comprehensive overview of the use of human hair as a fiber reinforcement in concrete. Hair, being a readily available and renewable waste material, has gained attention as a potential sustainable alternative for enhancing the mechanical properties of concrete. This paper examines the various aspects of incorporating human hair fibers in concrete, including its effects on workability, strength, durability, and the microstructural properties of the composite material. The review also discusses the challenges and opportunities associated with using human hair fibers in concrete, along with potential applications and future research directions. The findings presented in this review paper will contribute to the understanding of the feasibility and effectiveness of utilizing human hair as a sustainable fiber reinforcement in concrete production.

Keywords: Human hair, Mortar, Fiber reinforcement, Sustainability, Mechanical properties.

1. INTRODUCTION

Fiber reinforced concrete (FRC) is a type of concrete that incorporates fibrous materials to enhance its structural properties. The use of fibers as reinforcement dates back to ancient times, where materials such as horsehair were added to straw and mortar in mud bricks. In the early 1900s, asbestos fibers were commonly used in concrete, but concerns over health risks led to the discontinuation of their use. The concept of composite materials gained prominence in the 1950s, and fiber reinforced concrete became a topic of significant interest. To replace asbestos, alternative materials such as glass, steel, and synthetic fibers were introduced as reinforcement in concrete. Fiber reinforced concrete typically consists of short fibers that are randomly oriented and evenly distributed within the concrete matrix. These fibers improve the concrete's mechanical properties, such as tensile strength, toughness, and crack resistance. The fibers act as a reinforcement network, providing additional structural integrity and preventing the propagation of cracks. The development and use of different types of fibers in concrete reinforcement continue to evolve. Researchers and engineers explore the characteristics and performance of various fibers to optimize the properties of fiber reinforced concrete for specific applications. By incorporating fibers, concrete can achieve enhanced durability and performance, making it a valuable material in the construction industry. Overall, fiber reinforced concrete offers a versatile

and effective solution for improving the structural capabilities of concrete, and ongoing research aims to explore new fiber materials and optimize their performance in various construction applications.

Fibers, as small reinforcing elements in concrete, possess certain characteristic properties that can greatly influence the mechanical properties of the material. The type, length, and percentage of fibers added to concrete play a significant role in determining its behavior.

- Concrete is inherently weak in tension and exhibits a brittle nature. The addition of fibers aims to enhance its tensile strength and improve overall material properties. The utilization of fibers in concrete serves several purposes:
- Crack Control: Fibers help control cracking caused by plastic shrinkage and drying shrinkage. By bridging the cracks and distributing stress, fibers can mitigate crack formation and limit their width.
- Permeability Reduction: The presence of fibers reduces the permeability of concrete, resulting in reduced water bleeding. This improves the durability of the concrete by minimizing the ingress of harmful substances.
- Enhanced Performance: Fibers contribute to increased ductility, impact strength, shatter resistance, and abrasion resistance of the concrete. This leads to a more robust and durable construction material.
- Reinforcement of Mortar Fraction: Fine fibers within the concrete strengthen the mortar component, thereby delaying crack propagation and improving the overall crack resistance.

By incorporating fibers into concrete, these benefits can be achieved, resulting in a more reliable and resilient construction material. The choice of fiber type, length, and dosage should be carefully considered to optimize the desired mechanical properties and performance characteristics of the fiber-reinforced concrete. Ongoing research and development continue to explore new fiber materials and their effects on concrete behavior to further enhance its structural capabilities.

Figure 1: Example of an image of fiber reinforced concrete

2. WHY HUMAN HAIR AS A FIBER?

Hair is utilized as a fiber reinforcing material in concrete due to the following reasons:

- High Tensile Strength: Hair exhibits a relatively high tensile strength, comparable to that of copper wire of similar diameter. This property makes it suitable for reinforcing concrete and improving its resistance to cracking and structural integrity.
- Environmental Sustainability: Hair is a non-degradable material that poses challenges in terms of waste management. By using hair as a fibrous reinforcement in concrete, it serves the dual purpose of minimizing environmental concerns associated with hair disposal and utilizing it in a sustainable construction material.
- Abundance and Cost-Effectiveness: Hair is readily available in abundance, making it a cost-effective option for fiber reinforcement in concrete. Its availability in large quantities contributes to the affordability and accessibility of hair as a reinforcing material.

- Mortar Reinforcement and Crack Prevention: When hair is incorporated into concrete, it reinforces the mortar fraction, enhancing its mechanical properties. Additionally, hair helps in preventing the propagation of cracks within the concrete matrix, thereby improving its durability and performance.

The utilization of hair as a fiber reinforcement in concrete presents an opportunity to address environmental concerns, take advantage of its mechanical properties, and provide a cost-effective solution for enhancing concrete performance. Ongoing research and development efforts continue to explore the potential benefits and optimal usage of hair fibers in concrete applications.

3. COMPOSITION AND PROPERTIES OF HAIR

The hair thread has a highly organized cylindrical structure which is formed by inert cells of keratin, following a very precise and pre-defined design. In terms of raw elements, on an average, hair is composed of 20.85% oxygen, 50.65% carbon, 17.14% nitrogen, 5.0% sulphur and 6.36% hydrogen. Keratin gives the hair flexibility, strength and durability. Cortex keratin is liable for this property and its long chains are compressed to form an even structure which, also being strong is flexible. And the physical properties of hair involve elasticity, resistance to stretching and hydrophilic power. The resistance to breakage is a role of the thickness of the thread, of the cortex condition. Hair fiber has an elastic characteristic, and it may go through enough stretching either dry or wet. When dry, the hair thread can stretch 20-30% of its length and in contact with water; this may reach up to 50%.

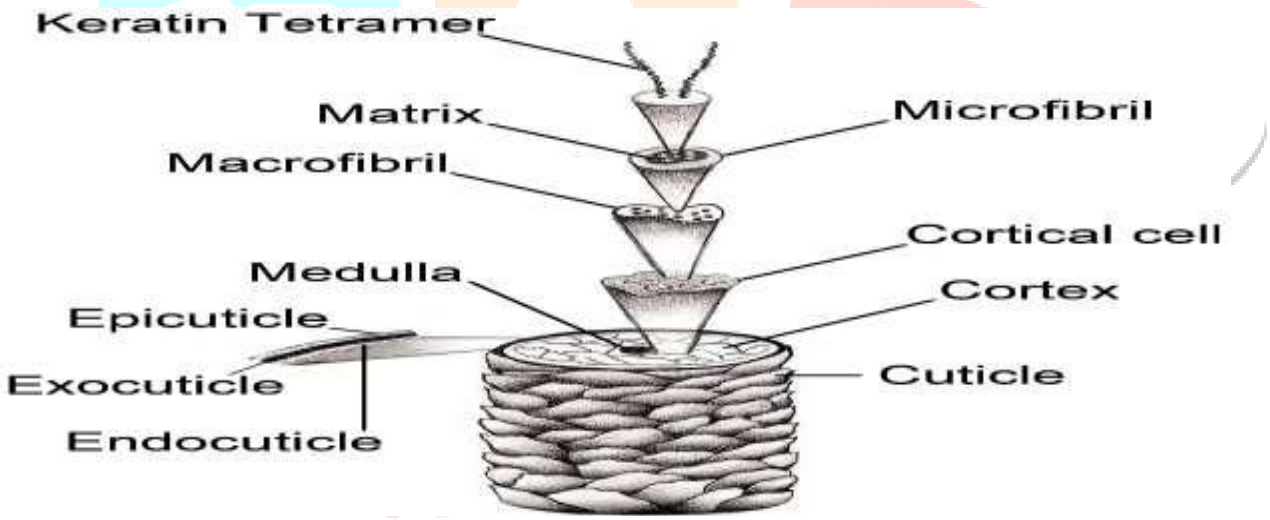

Figure 2: Schematic of hair fiber structure

4. TREATMENT OF HAIR FIBER

To prepare the hair for use in concrete cubes, the following steps are to be undertaken:

- **Separation:** The hair collected from beauty parlors and salons should be separated from any accompanying waste material. This ensures that only clean hair is used in the concrete mixture.
- **Washing:** Once separated, the hair needs to be thoroughly washed to remove any impurities. Acetone can be used as a cleaning agent to achieve this.
- **Drying:** After washing, the hair is dried under sunlight or through other appropriate means. This step ensures that the hair is completely dry and free from moisture. Proper drying prevents odor or decay issues and allows for safe storage.
- **Sorting:** The dried hair is then sorted based on its quality, color, and length. This step ensures that the hair fibers used in the concrete mixture meet the desired specifications. Random samples may be taken to check the diameter and length of the hair fibers, ensuring their suitability for reinforcement purposes.

By following these steps, the hair fibers can be properly prepared and treated before incorporating them into the concrete specimens. This preparation process helps ensure the quality and effectiveness of the hair fibers as a reinforcing material in the concrete mix.

5. LITERATURE REVIEW

Several research studies have focused on the incorporating human hair as fibre reinforcement in concrete. The following provides an overview of various studies conducted in these areas.

Uday et al.(2011) The concept of using fibrous materials in building materials dates back to the Biblical period when the Romans incorporated horse hair as a reinforcing material. In recent times, the development of Fiber Reinforced Concrete (FRC) has provided a technical solution to improve the shortcomings of mortar and concrete. The addition of synthetic fibers in concrete and mortar has been investigated in this experimental study to examine its effect on the ultimate strength and behavior of the materials. The fiber content, expressed as a volume ratio, is the main parameter considered. The study aims to find a practical solution by combining a low ratio of conventional reinforcement with synthetic fibers, which can increase beam strength without causing congestion of the reinforcement. Fibers in the concrete act as crack arresters and greatly enhance ductility. A total of 240 full-scale specimens with varying fiber content (ranging from 0% to 1.5% by volume) were casted and subjected to symmetrically applied loads until failure. The development and propagation of cracks, load at first crack, and mode of failure were observed during the tests. The results were compared to control samples, and it was confirmed that the addition of synthetic fibers to concrete and mortar is a viable approach to enhance their properties.

S. Ahmad et al.(2011) The present study aimed to investigate the effect of human hair fibers (HHF) on the compressive strength, crushing strength, and cracking control of concrete, with the objective of achieving economic and environmental benefits. Concrete prisms were prepared with varying percentages of HHF (0%, 1%, 1.5%, 2%, and 2.5% by weight of cement). Additionally, fly ash was incorporated as a partial replacement for cement at 10% by weight, and the same HHF percentages were used to create Hair Fiber Reinforced Fly Ash Concrete (HFRFAC). Brick powder was added at 6% in HFRFAC to produce Hair Fiber Reinforced Fly Ash Brick Powder Concrete (HFRFABC). Furthermore, 1.5% lime powder was mixed with HFRFAC to form Hair Fiber Reinforced Fly Ash Lime Powder Concrete (HFRFALC). Three cubes were tested for each combination to assess their properties. The results revealed a significant improvement in the mechanical properties of the concrete with the addition of HHF. The lime combination with 2% HHF exhibited the highest strength. These findings demonstrate the potential of using human hair fibers as a reinforcement material to enhance the performance of concrete, offering economic benefits and reducing environmental concerns.

Akash et al.(2017) This literature review provides an overview of incorporating human hair as fiber reinforcement in concrete and highlights its potential applications in various construction scenarios. The findings indicate that the addition of hair fibers reduces crack formation and propagation, making hair fiber reinforced concrete suitable for seismic resistant and crack resistant constructions, as well as road pavement constructions. The maximum improvement in properties was observed with the addition of 2% hair fibers by weight of concrete. The inclusion of human hair fibers not only enhances compressive strength but also improves binding properties, controls micro cracking, and increases spalling resistance. However, it should be noted that there is a limitation of 10% addition of hair fibers due to workability issues and the risk of concrete segregation. Overall, the review emphasizes the promising potential of human hair as a sustainable and effective reinforcement material in concrete applications.

K.L. Gokul et al.(2018) Over the past two decades, the rehabilitation of existing pavements has gained significant attention, and the use of fiber reinforced concrete has emerged as a popular method. Fiber reinforced concrete offers an economical solution for addressing issues such as flexural failure and micro cracks. Human hair, being a non-degradable fiber, can be effectively utilized as a reinforcement material in concrete overlays. The incorporation of human hair fiber in concrete overlays proves beneficial for cell filling and whitetopping pavement rehabilitation techniques, which aim to address functional deficiencies in deteriorated bituminous pavements. The study focuses on investigating the mechanical properties of whitetopped and cell-filled concrete overlays that incorporate human hair fibers. Both laboratory experiments and field trials were conducted to draw conclusions based on the findings. The results provide valuable insights into the effectiveness of human hair fiber-reinforced concrete overlays in pavement rehabilitation applications.

Rayed Alyousef (2018) This study assesses the impact of reinforcing concrete structures with human hair fibers (HHF) on the mechanical properties of the concrete matrix. The results indicate a significant increase in compressive, flexural, and splitting tensile strength as the percentage of HHF added to the mixture by weight of cement is increased. The curing times for the concrete specimens also show an impact, with variations observed as HHF content increases. However, a decline in compressive strength is observed compared to improvements in splitting tensile and flexural strength, suggesting changes in the behavior of the concrete due to the addition of HHF. Furthermore, the study demonstrates that the use of human hair fibers as reinforcement can reduce cracking patterns and enhance the mechanical properties of concrete structures. Overall, the findings validate the potential of HHF as a supplementary material for Fiber Reinforced Concrete (FRC) and highlight its ability to improve concrete strength and delay issues related to cracking.

Raghav et al.(2020) The utilization of human hair waste as a reinforcing material in fiber reinforced concrete has shown significant improvements in various concrete properties. Through tests and observations, it has been observed that as the percentage of hair fibers by weight of cement in the concrete increases, there is a remarkable increase in the concrete's properties. The human hair fiber concrete exhibits higher compressive strength and better split tensile strength compared to conventional concrete. The maximum increase in strength is typically achieved with the addition of 1.5% hair fibers in all the concrete mixes. Additionally, the incorporation of hair fibers reduces crack formation and propagation, making it suitable for seismic resistant constructions. The addition of human hair fibers not only enhances tensile and compressive strength but also improves binding properties, controls micro cracking, and increases spalling resistance. The reduction in crack width is also a notable benefit. Overall, the utilization of human hair waste in fiber reinforced concrete presents a promising approach for enhancing the performance and durability of concrete structures.

C.Neeladharan et al.(2020) Fiber reinforcement is an effective method for controlling cracking caused by pasty condensation in concrete. The survey of fiber effectiveness in controlling condensation in mortar has shown promising results that can be extrapolated to concrete applications. In this study, different sizes of human hair fibers (10mm and 50mm) were added to M20 grade concrete at varying percentages. The compression test results revealed that the addition of 1% of 10mm human hair increased the compressive

strength of concrete by 12% compared to normal concrete, while the addition of 2% resulted in a 20% increase. On the other hand, the addition of 1% of 50mm human hair led to an 8% reduction in compressive strength, and the addition of 2% resulted in a 32% reduction. It was observed that the 10mm hair fibers demonstrated higher compressive strength compared to the 50mm fibers, indicating their greater efficiency and ability to withstand loads. Overall, these findings highlight the potential of human hair fibers as a viable reinforcement option for enhancing the properties of concrete and controlling cracking.

Kanwal et al.(2020) The study investigated the effect of adding different percentages of human hair fiber (HHF) to concrete and assessed its impact on compressive strength and split tensile strength. The results showed that the maximum compressive strength was achieved with 1.5% HHF, which was 5% higher than the strength of normal concrete. The split tensile strength of all the mixes increased with the addition of HHF, and the concrete made with 1.5% HHF exhibited higher strength compared to the concrete with 1.0% and 0.5% HHF. Based on these findings, treated human hair can be effectively used for mixing and curing of concrete. The addition of HHF also improved the binding properties of the concrete and reduced the occurrence of voids and cracks. These results highlight the potential of human hair fiber as a reinforcing material in concrete applications.

Pranap et al.(2021) The addition of human hair and steel fibers in concrete beams, known as HFRC and SFRCB respectively, results in a failure pattern characterized by the formation of multiple cracks. However, SFRCB exhibits drawbacks such as steel fiber corrosion and high cost. Steel fibers used in concrete are prone to corrosion due to moisture, temperature, chloride ingress, carbonation, and chemical compounds in concrete, which can lead to faster corrosion of reinforcement compared to conventional reinforced concrete. Nonetheless, the tests conducted demonstrate a significant improvement in concrete properties with increasing percentages of human hair fibers. In M40 concrete with 3% human hair fibers, there is a notable increase in compressive strength, flexural strength, and split tensile strength compared to plain cement concrete. Moreover, the addition of human hair fibers enhances the moment and load carrying capacity, ductility characteristics, energy absorption capacities, and stiffness of the beams, making it particularly advantageous for structures located in earthquake-prone regions by providing occupants with sufficient warning and time to evacuate safely before structural failure occurs.

Shohag et al. (2022) This paper explores the application of male human hair fibers as fiber reinforcement in plain concrete, investigating their effects on compressive strength and split tensile strength. Various lab tests were conducted to achieve the objectives. The results showed that the highest variations in compressive strength and split tensile strength of concrete were observed with the addition of 2% and 1.5% male human hair fibers, respectively, after 28 days. Based on these findings, it can be concluded that the use of male human hair fibers as fiber reinforcement in plain concrete contributes to achieving satisfactory strength compared to plain concrete.

Srivastava et al. (2023) The high production of non-biodegradable waste and its ecological impact is a major concern today. Human hair, a waste product that is typically disposed of in landfills or through incineration, contributes to environmental pollution. However, incorporating human hair fibers as reinforcement in concrete has been tested and shown satisfactory results. In a study comparing normal concrete with different percentages and lengths of human hair fibers (HHF), several conclusions were drawn. Concrete with 1.5% HHF at a length of 50 mm exhibited the highest compressive strength. Impact strength showed an approximately 40% increase with the addition of HHF up to 1.5%, after which strength tended to decrease. Nonetheless, compared to normal concrete, the inclusion of human hair fibers significantly improved strength. In terms of split tensile strength, concrete with 1% HHF at a length of 50 mm outperformed other levels, with an approximately 21% increase in tensile stress compared to the control concrete. These findings highlight the potential of utilizing human hair waste as a sustainable reinforcement material in concrete, contributing to both waste reduction and improved concrete performance.

Niranjan et al. (2023) This study investigated the effects of incorporating sisal fiber in Stone Matrix Asphalt (SMA) and Bituminous Concrete (BC) mixes. The results showed that all three types of fillers used in BC met the required specifications, making them suitable and cost-effective. The addition of fibers up to 0.3% in BC increased the Marshall Stability value, while further fiber addition did not significantly improve stability compared to SMA. SMA with 0.3% fiber exhibited reduced drain down, increased tensile strength, and minimized deformation under static load. The optimal binder and fiber contents were determined, and the use of sisal fiber in SMA showed promising results for flexible pavement applications. Overall, incorporating sisal fiber in SMA improved the performance and properties of the mix, providing potential benefits for flexible pavement construction.

Ajay et al.(2023) The study compared the properties of concrete made with manufactured sand to that of concrete made with conventional sand. It was found that concrete with manufactured sand exhibited lower water absorption and permeability, indicating better durability. The manufactured sand concrete also showed improved resistance to chloride ion penetration and acid-alkaline attacks, resulting in reduced weight loss. Additionally, it demonstrated enhanced impact and abrasion resistance compared to traditional sand concrete. These findings suggest that manufactured sand can be a suitable replacement for conventional sand in concrete construction, supporting sustainable development initiatives and offering potential for full substitution.

Károly et al.(2023) Macro synthetic fibre reinforcement has gained widespread usage in various concrete structures, including tramlines, tunnels, industrial floors, and precast elements. The incorporation of synthetic fibres as reinforcement in concrete offers benefits such as reduced casting time, decreased labor requirements, and increased ductility. In many cases, the use of macro synthetic fibres allows for the complete elimination of steel reinforcement, leading to more environmentally friendly and sustainable structures. Synthetic fibres have lower CO2 emissions compared to traditional steel reinforcement due to their production, transportation, and labor processes having lower environmental impact. The uniform distribution of fibres in concrete enhances the residual flexural strength, making them suitable for cast-in-place elements like tramlines, shotcretes, and industrial floors. Additionally, the use of synthetic fibres in precast concrete elements has become more prevalent, primarily due to the advantages of shortened construction time. Precast FRC elements, such as tunnel segments, wall and roof elements, and tramline components, benefit from the application of synthetic fibres. The design process for these structures must consider static loads, dynamic loads, and potential fatigue effects from cyclic loading. Furthermore, precast elements need to be designed for temporary conditions like demoulding, lifting, transportation, and placement on-site. Advanced finite element analysis software specialized for concrete and fibre reinforced concrete structures enables effective handling of these effects. This paper presents the opportunities offered by macro synthetic fibres and the design considerations for fibre reinforced concrete structures, supported by global references.

Masakazu Terai (2023) This study aimed to develop low-cost, environmentally friendly building materials by incorporating natural plant and animal fibers as reinforcing materials in geopolymers. The motivation behind this research was the high cost and limited availability of steel reinforcement, especially in developing countries. The use of natural fibers in construction materials can provide an alternative solution while addressing carbon dioxide emissions and environmental concerns associated with steel production. The study conducted fundamental experiments on different types of plant fibers (sisal, coir, and bamboo) and animal fibers (horse hair, pig hair, and sheep wool) in combination with geopolymers. Various strength properties such as compression, tension, and bending were evaluated for hardened fiber-reinforced cement composites with different fiber types, lengths, and proportions. The findings contribute to the development of low-cost and sustainable building materials using natural fibers and geopolymers as a potential alternative to steel reinforcement in concrete structures.

6. SUMMARY

The utilization of human hair waste as a reinforcing material in fiber reinforced concrete has shown significant improvements in various concrete properties, according to several studies. The addition of hair fibers enhances both compressive and split tensile strength, with the maximum increase typically achieved with the addition of 1.5% hair fibers. Human hair fiber concrete also exhibits improved binding properties, controls micro cracking, and increases spalling resistance. It reduces crack formation and propagation, making it suitable for seismic resistant constructions. The reduction in crack width is also a notable benefit. The studies also highlight the potential of human hair fibers as a sustainable and effective reinforcement material in concrete. The incorporation of hair fibers reduces crack formation and propagation, making it suitable for seismic resistant and crack-resistant constructions. However, workability issues and the risk of concrete segregation limit the addition of hair fibers to around 10%. Additionally, research has explored the use of natural plant and animal fibers, such as horse hair, pig hair, and sheep wool, as reinforcing materials in geopolymers. These natural fibers, combined with geopolymers, have shown promising results in enhancing the strength properties of cement composites. Moreover, the use of synthetic fibers, such as macro synthetic fibers, has gained widespread usage in various concrete structures, including tramlines, tunnels, industrial floors, and precast elements. Macro synthetic fibers offer benefits such as reduced casting time, decreased labor requirements, and increased ductility. They also have lower CO2 emissions compared to traditional steel reinforcement, contributing to more environmentally friendly and sustainable structures. In summary, the incorporation of human hair fibers and other natural or synthetic fibers in concrete has shown potential in enhancing its properties, improving durability, and reducing environmental concerns. These findings contribute to the development of more sustainable and cost-effective construction materials.

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