A SYNOPSIS

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OPTIMIZATION OF BRAIDED STRUCTURES FOR CIVIL ENGINEERING APPLICATION

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SYNOPSIS

"OPTIMIZATION OF BRAIDED STRUCTURES FOR CIVIL ENGINEERING APPLICATION"

Reinforcement bars, also known as rebar or reinforcing steel, are steel bars that are commonly used in reinforced concrete structures to provide strength and durability. Reinforced concrete is a composite material that combines the strength of concrete with the tensile strength of steel. Rebars are typically made of carbon steel and have a ribbed surface to provide better bonding with the surrounding concrete. The ribs on the surface of the bars increase the frictional resistance between the steel and concrete, preventing slippage and ensuring better load transfer between the two materials.

The main purpose of reinforcement bars is to withstand tensile forces applied to the concrete structure. While concrete is strong in compression, it is weak in tension. By incorporating reinforcement bars into the concrete, the tensile forces are transferred to the steel bars, which can handle the tension effectively. This combination of concrete and steel creates a structural system that can withstand a wide range of loads and environmental conditions.

Conventional reinforcement bars have several limitations that can affect the performance and durability of reinforced concrete structures. Some of these limitations include:

1. Corrosion: One of the most significant limitations of conventional rebar is its susceptibility to corrosion. When exposed to moisture and environments, such as chloride ions from saltwater or carbon dioxide from air pollution, the steel bars can corrode. Corrosion leads to the formation of rust, which expands and weakens the bars, ultimately compromising the structural integrity of the concrete.

2. Weight and Handling: Conventional rebars are heavy and can be challenging to handle, transport, and install on construction sites. The weight and bulkiness of the bars make construction processes more labor intensive and time consuming.

3. Design Limitations: The use of conventional rebar can impose certain design limitations. For example, the size and shape of the rebar can limit the complexity of concrete structures and architectural designs. It can be challenging to incorporate rebar into intricate or curved shapes, leading to design constraints.

4. Thermal Expansion: Steel has a higher coefficient of thermal expansion than concrete. Temperature variations can lead to differential expansion and contraction between the steel rebar and the concrete, causing internal stresses and potential cracking within the structure.

5. Electromagnetic Interference: Conventional rebar can create electromagnetic interference (EMI) that can affect electronic devices and systems. In sensitive environments, such as hospitals, laboratories, or data centres, the use of rebar may require additional measures to mitigate EMI.

Alternative reinforcement methods and materials have been developed to navigate around some of these constraints. One of the best alternatives to it is fiber-reinforced polymers (FRP). Rebar made of fiber-reinforced polymer (FRP) have a number of advantages over traditional steel rebar, overcoming some of the drawbacks associated with using steel reinforcement. Here are some advantages of using FRP rebar

1. Corrosion Resistance: FRP rebars are non-metallic and do not corrode like steel rebar. This makes them highly resistant to deterioration caused by moisture, chloride ions, and other aggressive chemicals. As a result, structures reinforced with FRP rebar have a longer service life and require less maintenance and repair.

2. Light Weight: FRP rebars are significantly lighter than steel rebar, typically weighing about one-fourth the weight of steel for the same strength. The lightweight nature of FRP rebar simplifies handling, transportation, and installation on construction sites. It can also reduce the dead load of the structure, leading to potential cost savings in the design and construction of the supporting elements.

3. High Strength-to-Weight Ratio: FRP rebars have a high strength-to-weight ratio, meaning they are stronger than steel rebars of the same weight. This allows for the design of more slender and lightweight structures without compromising strength and safety.

4. Non-Magnetic and Non-Conductive: FRP rebar are non-magnetic and non-conductive, which makes them suitable for applications in sensitive environments, such as medical facilities or areas with electromagnetic interference (EMI) concerns. They do not interfere with electronic devices, and their non-conductive nature can enhance electrical safety.

5. Thermal Insulation: FRP rebar have lower thermal conductivity compared to steel rebar. This property helps in reducing thermal bridging and can contribute to improved energy efficiency in buildings and structures.

6. Design Flexibility: FRP rebar can be easily shaped and customized to meet specific design requirements. They can be manufactured in various sizes, shapes, and configurations, enabling greater flexibility in architectural and structural design. FRP rebar can also be bent on-site, allowing for easier installation around corners and curved elements.

FRP (fiber-reinforced polymer) rebar are made through a manufacturing process that involves the combination of fibers and a polymer matrix. The first step in the manufacturing process is the selection of fibers. The most commonly used fibers in FRP rebar are glass fibers, carbon fibers, or aramid fibers. The choice of fiber depends on the desired mechanical properties, such as strength, stiffness, and corrosion resistance. The selected fibers are impregnated with a polymer resin. The resin can be epoxy, vinyl ester, or other compatible polymer matrices. The impregnation process ensures that the fibers are thoroughly wetted and evenly distributed within the resin, providing a strong bond between the fibers and the matrix. After impregnation, the fibers are aligned and arranged in a specific pattern to optimize the mechanical properties of the final FRP rebar. The aligned fibers are then formed into the desired shape, which is typically a long cylindrical bar. The formed FRP rebar are then subjected to a curing process to harden the polymer matrix. The curing can be done at ambient temperature or in a temperature-controlled environment, depending on the resin system used. The curing process allows the resin to crosslink and form a solid and durable structure.

Textile braiding is one of the fabric manufacturing techniques used to create three-dimensional structures by intertwining textile fibres in a particular pattern to form a flexible and strong structure. The resulting braided textile can be used for various applications, ranging from clothing and accessories to technical and industrial products. Textile braiding offers several advantages, including high flexibility, strength, and elasticity. The braided structures can be customized to have different patterns, densities, and thicknesses, making them suitable for various applications. Braided textiles are commonly used in products such as ropes, cords, cables, hoses, shoelaces, and even medical devices like sutures and stents.

In textiles, there is a wide range of engineered textile structures that are created through the process of textile braiding. These products are designed to offer specific performance characteristics and fulfil various technical requirements. Following are some examples of braided technical textile products:

- *Braided Ropes and Cords:* They are commonly used for applications requiring high strength, flexibility, and load-bearing capacity. They find uses in industries such as marine, construction, sports, and rescue operations.

- *Braided Hoses and Tubing:* They are used for fluid and gas transfer in industries like automotive, aerospace, and medical. It provides reinforcement and strength, allowing for high-pressure applications.

- *Braided Cables and Wiring:* They are used in electrical and electronic systems to provide protection against abrasion and electromagnetic interference (EMI) to enhance the overall durability and flexibility of the cables.

- *Braided Sleeves and Expandable Braids:* They are used for cable management, protection, and bundling to provide abrasion resistance, and insulation, for easy installation and access to cables or wires.

- *Braided Reinforcements for Composites*: They are also used as reinforcements in composite materials. The braided structures enhance the strength, stiffness, and impact resistance of the composites, making them suitable for applications in aerospace, automotive, and sporting goods industries.

- *Braided Tapes and Belts:* They are used in applications that require high tensile strength, dimensional stability, and resistance to abrasion. They find applications in sectors such as conveyor systems, power transmission, and industrial machinery.

- *Braided Medical Textiles:* Braided structures are used in medical devices such as sutures, stents, and grafts. The braiding technique allows for the creation of flexible and biocompatible structures with controlled porosity and mechanical properties.

In the present investigation, an attempt has been made to develop a composite fiber reinforcement bar using braiding technique with a high tenacity material like basalt, Nylon and polypropylene as reinforcement material along with epoxy resin as matrix material.

The thesis entitled, **"OPTIMIZATION OF BRAIDED STRUCTURES FOR CIVIL ENGINEERING APPLICATION"** tries to develop braided fiber reinforced bars which are non-corrosive, high tenacity & lightweight in nature using materials like basalt, nylon and polypropylene for civil engineering application. The thesis mainly comprises of six chapters.

Chapter 1 Introduction

This chapter introduces braiding followed by conventional steel rebar and the problems associated with it. Further what possible attempts can be made and a brief about the attempts going to be made for the current research. The significance and extent of the work that will be done for the thesis is presented in this chapter.

Chapter 2 Literature Review

It provides an extensive survey regarding the history of braiding, its various techniques, structural characteristics and factors affecting it. It also provides various fiber reinforced composite materials, developed in the textile engineering field relevant to civil engineering applications. Evaluation of various functional properties with respect to braid characteristics and its effect is also discussed. Technical and functional properties of various textile fiber that have been used as reinforced material is also discussed in this chapter.

Chapter 3 Material & Methodology

This chapter deals with the type of material used, the process involved in rope manufacturing and the methodology for the preparation of rebars. The following framework will be employed in Chapter 3 to discuss the development of samples and their testing techniques.

3.1 Bi-Axial braiding:- The initial evaluations were done with high-tenacity polyester yarn of 6000 Denier to get practical experience for braiding and braided FRP rods. Using braid over braid techniques, 16 of such yarns were bi-axially braided into the rope. Further using braid over braid methods 3 different diameters of the rope were developed. All three diameters of Polyester braided ropes were further converted into the braided rods by impregnating the solutions of resin and hardener into the braided ropes by keeping the ratio of CTE556 (Epoxy resin): CTAH951 (hardener) at 10:1. Manual coating technique were used. Evaluation was also conducted for its tensile, flexural and impact properties.

3.2 Machine conversion: The existing biaxial braiding machine was further modified to facilitate an additional third axial yarn which will be introduced at zero degree, during braiding. Such a braiding machine is known as Tri-axial braiding. Apart from this, the take-up mechanism was also modified to achieve different take-up rates. Thus, modification was carried out in the existing machine and was made versatile for the manufacturing of biaxial as well as triaxial braided products.

3.3 Raw Material Selection:- High-tenacity textile yarn such as Nylon, PP, and Basalt were used as raw materials for braided rope preparation. Additionally, their blend was also tried.

3.4 Tri-axial Rope & Rod Preparation: The high tenacity yarns procured were used as raw material for the manufacturing of triaxial braided ropes. The diameter of the manufactured ropes was increased by the braid over braid technique. These desired diameter ropes are used as a reinforcement material and were further converted into rods using the method as described in section 3.1.

3.5 Testing for Tri axial rope and rod:- Detailed analysis was carried out during different stages of FRP rod manufacturing. The yarn procured was tested for its linear density and tensile properties. The rope prepared from the material was also evaluated for its linear density, braid geometry and tensile properties. The prepared rods were further analyzed for their diameter, fiber volume fraction, tensile properties. The prepared rods were also subjected to the preparation of cemented blocks and beams, for checking the performance of prepared rods inside the cement structure in terms of bonding and flexural strength respectively

Chapter 4 Result and Discussions

Results obtained from the tests will be compiled & and discussed here with the application area for the various products. Detailed techno commercial comparison also will be made with the conventional steel rebar in this chapter in the following manner.

4.1 Biaxial braided rope and rod characteristics: - Results of biaxially braided rope are discussed here with respect to its linear density and tensile characteristics. Further, prepared biaxially braided rods will be discussed here with their Tensile behavior along with its bending and compression characteristics. Further, their comparison will be made with polyester braided rope and its strength characteristics.

4.2 Tri-axial braided rope characteristics: - Tri-axially braided ropes made from Basalt, PP, Nylon & and their combinations are discussed here for their linear density and Tensile characteristics. Further, their comparison will be made with relevant yarn and its strength characteristics.

4.3 Tri-axial braided rod characteristics:- Tri-axially braided rods made from Basalt, PP, Nylon & and their combinations will be discussed here for their Tensile behavior along with its flexural beam bending and bond test with concrete. Further, their comparison will be made with a similar type of braided rope and its strength characteristics.

4.4 Techno commercial comparison:- This type of tri-axial braided rebar will be mutually discussed for the techno commercial aspect and also will be compared with a similar kind of steel rebars available and used for civil application.

Chapter 5 Conclusions

This chapter summarizes the overall results obtained during the with future scope of work in this chapter.

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Publication

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Patent

- Applied for patent "A BRAIDED REINFORCED BAR AND PROCESS OF MAKING THE SAME" Application No. 202321011881 dated February 21st 2023.

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