CHAPTER 1

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1.1 Introduction to Rebars

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 [1-2]. The main purpose of reinforcement bars is to withstand the 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 various loads and environmental conditions. Conventional reinforcement bars have several limitations that can affect the performance and durability of reinforced concrete structures [2-4]. 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 fibre-reinforced polymer (FRP) has several advantages over traditional steel rebar, overcoming some of the drawbacks associated with using steel reinforcement. Here are some advantages of using FRP rebar [5-7].

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 rebars, 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 has 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.

1.2 Manufacturing Process

FRP (fibre-reinforced polymer) rebar is made through a manufacturing process that combines fibres and a polymer matrix. The first step in the manufacturing process is the selection of fibers. The choice of fiber depends on the desired mechanical properties, such as strength, stiffness, and corrosion resistance. The most commonly used fibers in FRP rebar are glass fibers, carbon fibers, or aramid. 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 fibres 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 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 [8-9].

1.3 Textile Braiding

It 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 [10]. Braided textiles are commonly used in products such as ropes, cords, cables, hoses, shoelaces, and even medical devices like sutures and stents [11]. 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.

1.4 Aim of the Study

In the present investigation, an attempt has been made to develop a composite fiber reinforcement bar using the braiding technique with a high-tenacity textile material like basalt, Nylon and polypropylene as reinforcement material and epoxy resin as matrix material. This work covers both fundamental and applied research associated with BCRs and presents possible directions for further development of high-performance composites. Materials selected for the manufacturing of BCR are commercially successful materials used in the field of technical textiles. Products with different materials and diameters have been prepared and evaluated. To provide condensed information, the work has been divided into six chapters which are entirely dedicated to the work.

Chapter 1 gives a brief Introduction of the whole thesis and the type of work carried out. Chapter 2 shows an extensive survey of literature and work carried out by other researchers in this area. Chapter 3 deals with the selection of raw materials and methods used for the production and evaluation of prepared BCR. Chapter 4, contains different observations of all the prepared samples obtained with different fibres and diameters and their possible attributes. Chapter 5, further uses the observed data for a mathematical model which helps in predicting the behavior of the prepared BCR. Chapter 6, gives a concluding remark of the work. At the end, the thesis provides appendices for explanation of abbreviations, symbols, and references.

As different products have been prepared and studied, to have a comprehensive understanding of the work, chapters 3 and 4 have been further divided into different sections

Section I: Deals with the modification of the existing biaxial braiding machine to facilitate an additional third axial yarn which will be introduced at zero degrees, 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.

Section II: 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 incorporating the previous braided rope as a core material in the preparation of the new rope. This is known as the braid over braid technique.

Section III: This section covers the preparation of composite rods by using the prepared rope of different diameters as a reinforcement material.

Detailed analysis was carried out during different stages of FRP rod manufacturing. The procured yarn 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, fibre volume fraction, and other mechanical 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.