



CHAPTER 6
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The work entitled “Optimization of Braided Structure for Civil Engineering Application” is an attempt to make composite rebars with the help of braiding technology. The composite rebars available contain parallel-laid glass fibres bound together with fiber ridges as reinforcement material. These ridges help in binding the fiber as well as increasing the bond strength with concrete. The diameter of these composite bars is much greater than the steel rebars. To overcome the disadvantage of these rebars and to have better tensile and flexural strength, better bonding with concrete without fibre ridges and all this with lesser diameter, braided composite rods were developed.

These braided composite rods have better inter-yarn bonding due to the intertwining process, at the same time separate fibre ridges have not to be bound as a naturally rough surface is obtained in this process. The prepared BCRs were made using different yarns like Polypropylene, Nylon, and Basalt and their combinations. This was done to study the effect of the type of material on the properties of composite rods. Also rods with different diameters were prepared to understand the effect of diameter on the properties of BCRs. The increase in the diameter was accomplished by the braid over braid technique. The choice of material and the number of layers significantly impact the performance characteristics of braided ropes.

The tensile test results for Polypropylene (PP) braided ropes and rods reveal a consistent increase in their ability to handle greater force as the number of layers increases. This is reflected in the rising rope g/lm (grams per linear meter) values, with the first layer withstanding a force of 513.30 Kgf and the fifth layer handling 1051.51 Kgf. The displacement values remain stable across all layers, indicating that the material maintains a stable elongation under stress. The fiber volume fraction across different layers of PP material shows that fibers constitute approximately 41% of the material in the initial layer, with this fraction changing as the number of layers increases. This allows for customization of the composite material’s properties, making it suitable for a wide range of applications. The rod strength of PP braided composite rods increases

with the diameter, from an ultimate load capacity of 786.12 Kgf for the initial layer with a 5.00 mm rod diameter to a maximum strength of 1889.88 Kgf for the fifth layer with a 7.84 mm rod diameter. However, as the diameter increases, the load-bearing capacity of the PP braided composite rod decreases, attributed to the outer layers bearing more load compared to the inner layers.

Nylon braided ropes and rods exhibit enhanced performance characteristics with each additional layer. The ropes show a significant improvement in load-bearing capacity, as evidenced by the progressive increase in rope g/lm values across layers. The first layer withstood a maximum force of 657.82 Kgf, while the fifth layer handled 1392.05 Kgf. Despite the increase in layers and slight fluctuations, the maximum displacement remains relatively constant, indicating stable elongation under stress. This makes nylon ropes suitable for heavy loads due to their improved force handling capabilities and for heavy-duty applications where strength and minimal stretching are essential. On the other hand, nylon rods demonstrate a substantial increase in ultimate load (2845.35 Kgf) and stress (422.86 MPa), suggesting an effective balance between strength and flexibility. Although the modulus of elasticity is slightly lower at 16.63 GPa, this is due to the increased load-bearing capacity.

The tensile test results for basalt braided ropes and rods reveal a progressive increase in maximum force and rope g/lm values across layers. The first layer withstood a maximum force of 508.32 Kgf with a displacement of 5.38 mm, while the fifth layer handled 1073.11 Kgf with a displacement of 4.67 mm. Despite the increase in layers, the maximum displacement remains relatively constant, suggesting that basalt braided ropes maintain stable elongation under stress. This makes them an excellent choice for applications requiring high tensile strength and stability. The rod strength of basalt braided composite rods increases with the diameter. The initial layer features a rod diameter of 5.00 mm and an ultimate load capacity of 786.12 Kgf. This increases to a maximum strength of 2209.05 Kgf for the fifth layer with an 8.54 mm rod diameter. As the diameter increases, the load-bearing capacity of the basalt braided composite rod decreases. This can be attributed to the fact that with a larger diameter, the outer layers bear more load compared to the inner layers.

The tensile test results for PP + Basalt braided ropes and rods demonstrate an increase in maximum force and rope g/lm values with each additional layer. The first layer

withstood a maximum force of 652.74 Kgf with a displacement of 28.12 mm, while the fifth layer handled 1324.52 Kgf with a displacement of 26.47 mm. This indicates that combining PP with basalt enhances the load-bearing capacity while maintaining stable elongation under stress. As the number of layers increases, the rope's ability to handle greater force also increases, as reflected in the rising rope g/lm values. The fiber volume fraction across different layers of PP + Basalt material indicates that fibers constitute approximately 35% of the material in the initial layer, with this fraction changing as the number of layers increases. The rod strength of PP + Basalt braided composite rods increases with the diameter. The initial layer features a rod diameter of 5.00 mm and an ultimate load capacity of 621.27 Kgf. This increases to a maximum strength of 847.19 Kgf for the fifth layer with a 7.84 mm rod diameter. As the diameter increases, the load-bearing capacity of the PP + Basalt braided composite rod decreases, which can be attributed to the fact that with a larger diameter, the outer layers bear more load compared to the inner layers.

The tensile test results for Nylon + Basalt composite materials in both braided ropes and rods demonstrate superior characteristics. The braided ropes show significant enhancement in tensile properties, with the first layer withstanding a maximum force of 768.33 Kgf and a displacement of 20.34 mm, while the fifth layer handles 1473.11 Kgf with a displacement of 18.22 mm. As the number of layers increases, the rope's ability to handle greater force also increases, reflected in the rising rope g/lm values. The composite rods, with a Nylon to Basalt ratio of 50:50, display the highest ultimate load (2869.29 Kgf) and stress (468.34 MPa) among the composites, with a strain percentage of 18.96%. The modulus of elasticity is 26.76 GPa, indicating exceptional strength and moderate stiffness due to the synergistic effect of Nylon and Basalt. As the diameter increases, the load-bearing capacity of the Nylon + Basalt braided composite rod decreases, attributed to the fact that with a larger diameter, the outer layers bear more load compared to the inner layers. The fiber volume fraction across different layers of Nylon + Basalt material indicates that fibers constitute approximately 49% of the material in the initial layer, with this fraction changing as the number of layers increases.

A comparison between Nylon braided rebars and traditional steel rebars in terms of their performance in a concrete block pullout test, which evaluates bond strength, shows

that the ultimate load capacity of the Nylon rebars is lower than that of the steel rebar. However, the ultimate stress for Nylon rebars is comparable to that of the steel rebar. For example, the fourth layer Nylon rebar handles 227.06 kN and the fifth layer handles 328.73 kN, compared to the steel rebar's 357.16 kN. The ultimate stress for the fourth layer is at 99.68 MPa and the fifth layer at 143.68 MPa.

The data indicates that reinforced beams exhibit significantly higher flexural strength. For instance, the Polypropylene - 4 layer shows a strength of 5.48 MPa and the Polypropylene - 5 layer shows 5.79 MPa. In contrast, the unreinforced beam has a flexural strength of only 3.22 MPa. This translates to an increase in flexural strength of approximately 69.91% for the Polypropylene - 4 layer and 79.27% for the Polypropylene - 5 layer compared to the unreinforced beam. These results underscore the effectiveness of Braided FRP Re-bars in enhancing the flexural strength of concrete beams, which could lead to more resilient structures capable of withstanding greater stress and load as per IS standards.

The proposed mathematical model offers a cost-effective and efficient alternative to traditional experimental testing methods, accurately predicting rope strength by considering key parameters such as yarn strength and braiding configuration. Further refinement of the model could enhance its accuracy and applicability in real-world scenarios, contributing to advancements in material science and engineering. Additionally, the analysis of the relationship between yarns and tensile strength in braided ropes, alongside investigations into composite rods, underscores the significance of accurate mathematical modelling in optimizing composite material properties. Leveraging curve fitting techniques and machine learning, these studies provide practical guidance for enhancing the design and performance of braided ropes and composite materials across various applications, fostering continued advancements in the field.

Together summarising all above braided composite reinforcement bars, it could be suitable for applications where rods are expected to sustain heavy loads without significant stretching. The high tensile strength and stable elongation under stress make it a good choice for applications that require durability and resilience. For instance, they could be used in the construction industry for reinforcing concrete structures, where the rods would need to bear significant loads. The ability of these high performance

materials to maintain a stable elongation under stress would also be beneficial in applications that involve constant or repetitive movement, such as in the manufacturing of heavy-duty industrial equipment or automotive parts. The varying fiber volume fraction across layers allows for customization of the composite material's properties, making it suitable for a wide range of applications.

However, an increase in layer count and diameter doesn't always lead to better performance, emphasizing the need for optimization in design. Similarly, the choice of material greatly affects the performance of braided ropes. Insights from tensile tests and weight characteristics across different layers aid in material selection for various applications. In essence, both material selection and engineering design are pivotal in optimizing the bond strength of FRP bars used in concrete structures, thereby ensuring their durability. The composition and layering of materials significantly influence the rods' flexural and pull-out strength. Notably, braided composite rods, especially those combining PP and Basalt, show potential as an alternative to traditional steel rebars, providing a balanced mix of strength, elasticity, and stiffness. Hence, braided FRP rebars, particularly those integrating different materials, present a promising avenue for improving the durability and structural integrity of concrete structures in civil engineering.