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Experimental Investigation About Textile Reinforced Concrete for Repairing and Strengthening Reinforced Concrete Beams

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Abstract - Textile reinforced concrete (TRC) is a relatively new and innovative composite material developed to provide improved performance characteristics when used in the repair and retrofitting of reinforced concrete (RC) beams. TRC offers superior tensile and flexural strength compared to traditional RC materials and has been widely used in civil engineering projects for repair and strengthening applications. The paper provides an experimental investigation into the performance of TRC when used in the repair and strengthening of RC beams.

Keywords - Textile reinforced concrete (TRC), ABAQUS, finite element, reinforced concrete,

INTRODUCTION

Despite its considerable compressive strength, concrete is generally thought of as a brittle material. Approximately one tenth of its compressive strength is its tensile strength. Due to these characteristics, concrete flexural members cannot support the higher tensile loads that occur naturally during their lifetime. [1] In order to withstand tensile pressures and compensate for its lack of ductility and strength, concrete must be reinforced with materials that are strong in tension, such as continuous reinforcing bars.

Reinforced concrete was originally used in structural building applications in the middle of the nineteenth century [2], and it has continuously evolved ever since. Since plain concrete alone has a high compressive strength but a very low tensile strength, it is typically reinforced with steel bars in order to increase its tensile strength. Corrosion assaults have been shown to weaken the structural integrity of reinforced concrete structures reinforced with steel reinforcement in the past [3]. For steel reinforced concrete structures, EC2 [4] mandates a protective design cover of 30-75 mm. Unfortunately, a structure's self-weight rises in direct proportion to its thickness. Additionally, efforts are made to increase the durability of reinforced concrete structures through the use of stainless steel bars, fiber-reinforced polymer (FRP) bars, epoxy-coated steel bars, fibers, add-mixtures, steel welded-wire fabric, controlled environment, protective surface coatings. In recent years, advancements in technology have allowed for the elimination of many of the problems associated with conventional reinforcing methods, including those related to durability, design control, and cover thickness. Textile Reinforced Concrete is an unique composite material.

There is now widespread understanding of the value of reducing material usage, energy input, consumption, and wasting, even in traditionally expensive industries like construction. TRC, which is made of a fine-grained concrete matrix reinforced by multi-axial noncorrosive textile fibers, being studied as a sustainable option. The durability of its construction is increased while the amount of concrete utilized is decreased. Through TRC, we were able to create corrosion-proof, thin, lightweight, modular, freeform structures [5]. The construction of a pedestrian bridge entirely out of TRC and the development of thin, self-supporting TRC sandwich components are only two examples of realizations. For existing reinforced concrete structures, it has also been shown to be an effective reinforcing material.

II. MATERIALS AND METHODS

Hussein et al. (2013) tested the flexural strengthening of RC beams utilizing TRC under 4-point bending on three small-scale RC beams with a total span of 2.0 m and a shear span of 0.8 m. Until failure, each specimen was subjected to a continuous loading rate of 1 mm/min.

A cover of 25mm worth of 2x10 longitudinal steel bars was welded to either end of the beams for reinforcement. In order to ensure that flexural yielding would be under control of failure, 6 steel bar stirrups were placed tightly together at 75 mm.

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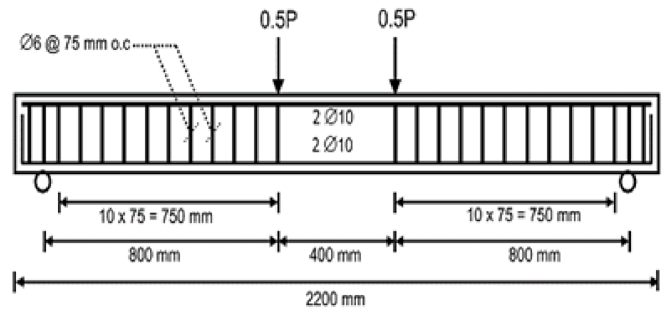
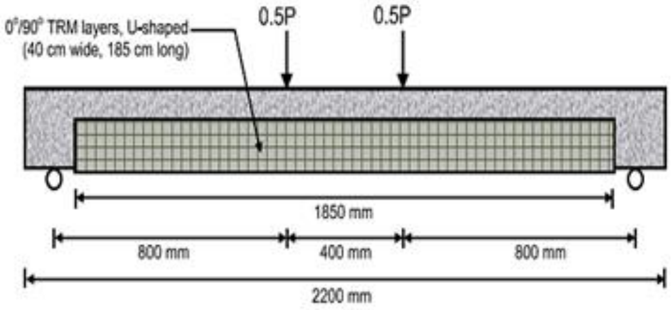
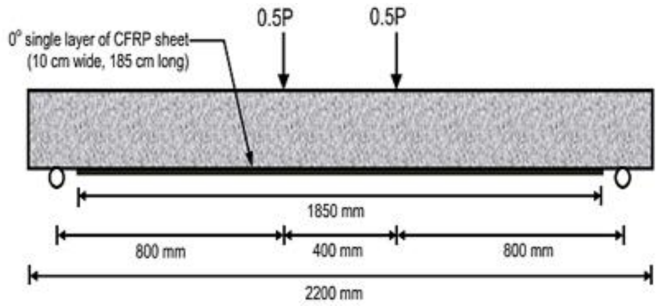


(a)Control beam BF-1



(b)TRC strengthened beams BF-2 & BF-3 & BF-4



(c) FRP-strengthened beam BF-5

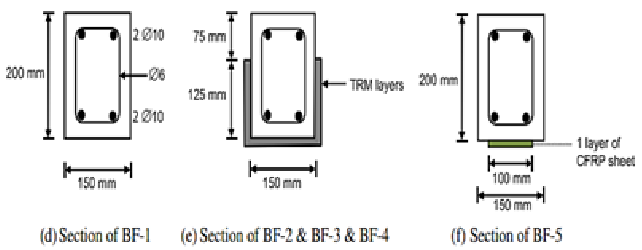


Figure 1. Test Beams Specification

Model of Finite Element

The finite-element model of a reinforced concrete (RC) beam strengthened with a textile-reinforced concrete (TRC) layer can be created using commercial finite-element software such as ABAQUS. The model can be created by defining the geometry of the beam, assigning the material properties for both the RC and TRC layers, and then meshing the model. The material properties of the RC and TRC layers can be specified based on experimentally determined values or simulations.

Finite element type and mesh

The C3D8R element is a three-dimensional, eight-node, reduced integration, hourglass-control, structural solid element. It is used to model large displacements, large rotations, and large deformations in structural analysis. It has hourglass modes in all three directions, allowing for improved accuracy and stability in finite element analysis. The C3D8R element has reduced integration points which can improve accuracy and reduce computational cost. The mesh is a collection of elements arranged in a grid pattern. Each element is connected to other elements, forming a network of nodes and elements. The mesh is used to divide the model into smaller components, which can be more easily analyzed. The mesh can be refined or coarsened to obtain more accurate results.

Can use solid, beam, or structural steel elements to model the reinforcement bars and the fabric. Solid elements are not used because they are hard to calculate. Since the reinforcing bars and textile don't add much to the stiffness of the bend, T3D2 (3-noded quadratic 2-D) truss elements are used instead. ABAQUS's is used to simulate the reinforcement. With the constraints-option, the wire is put into the solid concrete blocks, and its connection to the concrete is thought to be perfect. The only thing that makes the wires stiff is where they are placed. Even though there is no need for a geometric model of the wire's thickness, the cross-sectional area must be given.

Since fine mesh produced more reliable results, its usage became widespread. The largest size of the mesh was 20 millimeters, while the smallest was roughly 10 millimeters. This mesh size was chosen since satisfactory convergence was achieved with it; additional mesh refinement was only explored to the point where it was found that increasing or decreasing the mesh size had no effect on the results.

Experiment

Steel

As regards the steel bars, a 'simple' elastoplastic law was occupied. The curve is fully defined by Young's modulus Es =

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200 Gpa, the yield stress σy . The elastoplastic law for steel bars is a relationship between the applied stress σ and the corresponding strain ε. It describes the stress-strain behaviour of the material and provides a description of the plasticity of the material. The elastoplastic law is of the form:

σ = Es ε + σy + Ep (ε-εy),

where Es is the Young's modulus, σy is the yield stress, Ep is the plastic modulus, and εy is the yield strain.

This law is used to determine the stress-strain behaviour of steel bars in various applications. It is used to calculate the load-carrying capacity of the bars, as well as to predict the behaviour of the material under different loading conditions. The elastoplastic law can be used to determine the response of the material to different levels of strain, and can also be used to determine the yield point of the material.

Textile

A single textile fiber may be defined as a linear elastic material because of its behavior. The fiber strength dictates the stress at which a textile will fail when pulled in the fiber direction. There is no yielding tendency and stress is linear up to the tensile strength. The stress suddenly lowers to zero after achieving the tensile strength, symbolizing the textile's rupture.

Table 1. Steel and textile parameters

Steel				Textile			
Es	v_S	f_y	ε_y	*Et*	V_t	F_{tu}	ε_t
200 GPa	0.3 578 Mpa		0.00289	31940 MPa	0.22 623Mpa		0.0195

Concrete

The yield surface and flow potential in the CDP model are subject to the influence of five factors that determine their development and overall form. These settings should be left at their default values, since these are the CDP model's suggestion in the ABAQUS user's manual.

Finite Element Model Verification

In order to verify the FE model, Hussein (et al., 2013) compared the analytical results with the experimental result.

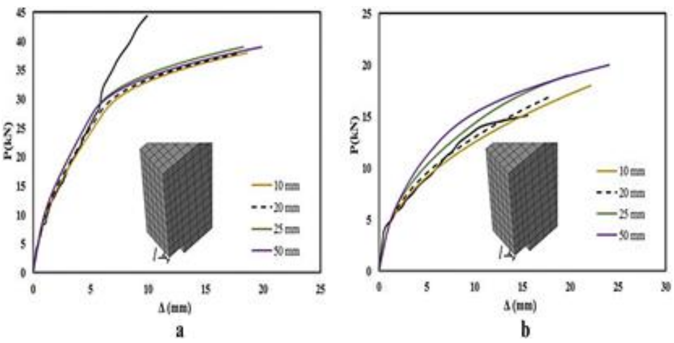

Figure 2. BF1 and BF2 beams Load-displacement curves

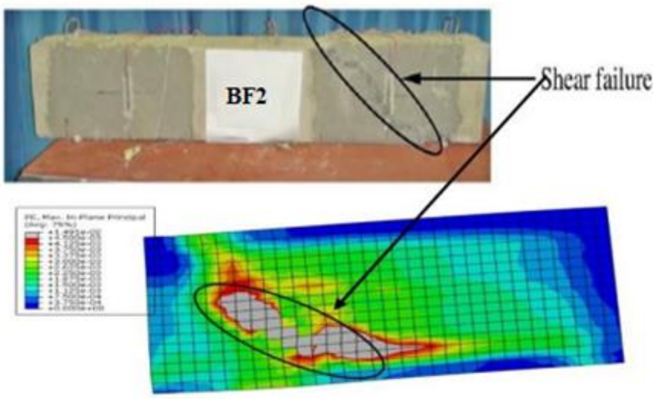

Figure 3. Strengthened beam BF2 Failure mode

Maximum deflection and softening curves of the reinforced beam and the RC beam were compared with experimental data, and the results are shown in Figure 2. When comparing the load bearing capacity of the two approaches, the deviation between the numerical result and the experimental result is between 1.3% and 1.6%. When compared to their unreinforced counterparts, the strengthened beams can support up to 86% more mass.

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III. CONCLUSION

The effectiveness of TRC for strengthening and repairing RC beams is investigated in this research. For the RC beam and the RC beam reinforced with TRC layer, the proposed model accurately predicted the load-bearing capabilities and load-deflection relationships. The statistics demonstrate that TRC produces positive consequences. Increase the stiffness and strength of the reinforced beam substantially.

Declarations

Availability of Data and Material

The data generated and analyzed during the present experimental and numerical investigation are included within the manuscript. Additional datasets, finite element input files, and supporting calculation details are available from the corresponding author upon reasonable request for academic and research purposes.

Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Authors' Contributions

Salla Arun Tejadhar Reddy conducted the experimental work, numerical modeling, data analysis, and manuscript preparation. Prashant S. Lanjewar provided guidance on research design, methodology, interpretation of results, and critical revision of the manuscript. Both authors reviewed and approved the final version of the manuscript.

Ethical Consideration

This study does not involve human participants or animals. All experimental procedures were conducted in accordance with standard laboratory practices and institutional research guidelines applicable to civil engineering experimental research.

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