

Experimental Study on Shear Strengthening of R C Beams Using Nylon Textile-Reinforced Mortar

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ABSTRACT: Reinforced concrete beams are the important structural element that transmit the load from slab, wall to columns. Due to increasing serviceability requirement and poor construction practice in the past, there is a need to strengthening of beam to resist sudden failure against shear. In this paper, the effectiveness of textile-reinforced mortars (TRMs), for increasing the shear resistance of reinforced concrete beams, is to be investigated experimentally. TRM is a combination of textile bonded to RC member using cementitious mortar. The strength of TRM depends on tensile strength of textile and bonding strength of mortar. Textiles comprise of fabric meshes made of long woven, knitted or even unwoven fiber rovings in at least two (typically orthogonal) directions. TRMs may be considered as an alternative to fiber-reinforced polymers (FRP), providing solutions to many of the problems associated with application of the latter without compromising much of the performance of strengthened members. In the present study, a new type of textile (nylon-based textile) is used as strengthening material. The variation in strength with orientation of fiber and number of layers were studied.

KEYWORDS: Textile Reinforced Mortar, Nylon Textile, Load Carrying Capacity, Shear Failure.

I. INTRODUCTION

The structural retrofitting of existing reinforced concrete structures has been so frequent in the past years because of deterioration and the need for upgrading to meet the current design requirements. One of the most common structural deficiencies is the poor shear capacity of RC beam. The common upgrading techniques for reinforced concrete members involves the use of fiber reinforced polymer (FRP) jackets, which are aimed at increasing the shear resistance in regions with inadequate transverse reinforcement. The use of FRP has gained increasing popularity in the civil engineering community, because of the favourable properties possessed by these materials, namely: extremely high strength-to-weight ratio, corrosion resistance, ease and speed of application, and minimal change in the geometry. Despite all these advantages, the FRP strengthening technique has a few disadvantages, which are attributed to the resins used to bind or impregnate the fibers. These drawbacks may include debonding of FRP from the concrete substrate, poor behaviour of epoxy resins at temperatures above the glass transition temperature, relatively high cost of epoxies, inability to apply FRP on wet surfaces or at low temperatures, lack of vapor permeability, which may cause damage to the concrete structure, incompatibility of epoxy resins and substrate materials, difficulty to conduct post-earthquake assessment of the damage suffered by the reinforced concrete behind (undamaged) FRP jackets.

In an attempt to alleviate the problems arising from the use of epoxies, a new composite material have been introduced, namely textile reinforced mortar (TRM), which combines advanced fibers in the form of textiles with open mesh configuration and inorganic matrices such as cement based mortars. In recent years it is reported that TRM is a

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promising alternative to the FRP retrofitting solution. TRM has been used for strengthening of RC members and seismic retrofitting of masonry-infilled RC frames.

Nylon textile are manufactured fibers composed of nylon. Polyamide is popularly known as nylon. Polyamides are made when a reaction takes place between diacids and diamines Nylon textile have higher strength to weight ratio compared to basalt and carbon fibers. Nylon has a compact molecular structure, resistance to corrosion, low thermal conductivity, very high durability and can be elongated to the extent as desired by the manufacturer, less resilient to the action of acids.

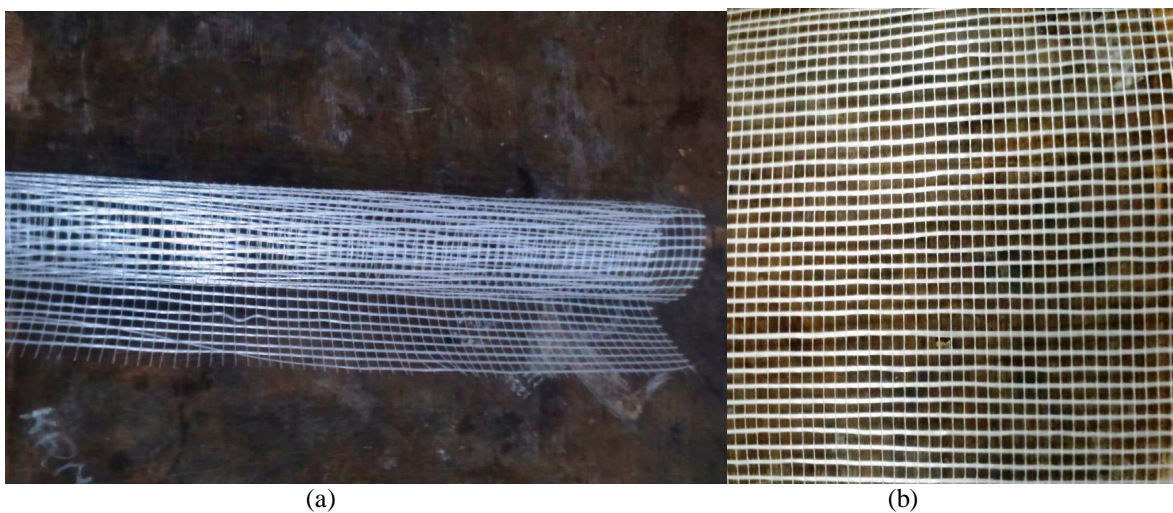


Fig. 1. Nylon Textile

II. EXPERIMENTAL WORK

The goal is to study the effectiveness of TRM in enhancing the shear capacity of RC beams. The studied parameters included variation in shear strengthening with number of TRM layers, and textile orientation in the shear span region. The test matrix is shown in Table 1. The test matrix has two control beams which were intentionally designed to be deficient in shear. These beams represent the worst case scenario of typical construction practices in the past. Furthermore, the absence of shear reinforcement within the shear-span may represent the case of corroded shear stirrups as a result of harsh environmental conditions.

SI No:	Specimen	Number of specimens	Mix	No. of layers of TRM	Orientation
1	BS1	2	M30	-	-
2	BS2	2	M30	2	45 ⁰
3	BS3	2	M30	2	0/90 ⁰
4	BS4	2	M30	4	45 ⁰
5	BS5	2	M30	4	0/90 ⁰

Table 1. Test Specimens

This study comprises of testing 10 simply supported small scale RC beams. The beams were 1000 mm long, with rectangular cross section of 150 x 200 mm. The criterion for selection of the beam dimensions was on the basis of available resources in the laboratory. Steel bars of 12 mm in diameter were used as the longitudinal main bars. Two steel

bars are used as compression reinforcement for these beams. Steel bars of 10mm diameter with two numbers as tension reinforcement are respectively used as control specimen. Steel stirrups of 8 mm in diameter are used as shear reinforcement. M30 grade concrete with a water cement ratio of 0.43. Thickness of cover concrete selected was selected 25 mm. Detailing of beam specimens were shown in figure 2.

The materials used in this study included ordinary Portland cement, fine aggregate (manufactured sand), coarse aggregate, mixing water, unidirectional Nylon textile. The cement used was 53 grade Ordinary Portland cement, which conforming to IS 12269:2013. The coarse aggregate of size 20mm was used in the study. Potable water was used for mixing and curing of specimens throughout the experimentation. Unidirectional nylon textile of thickness 0.3mm were used for the study.

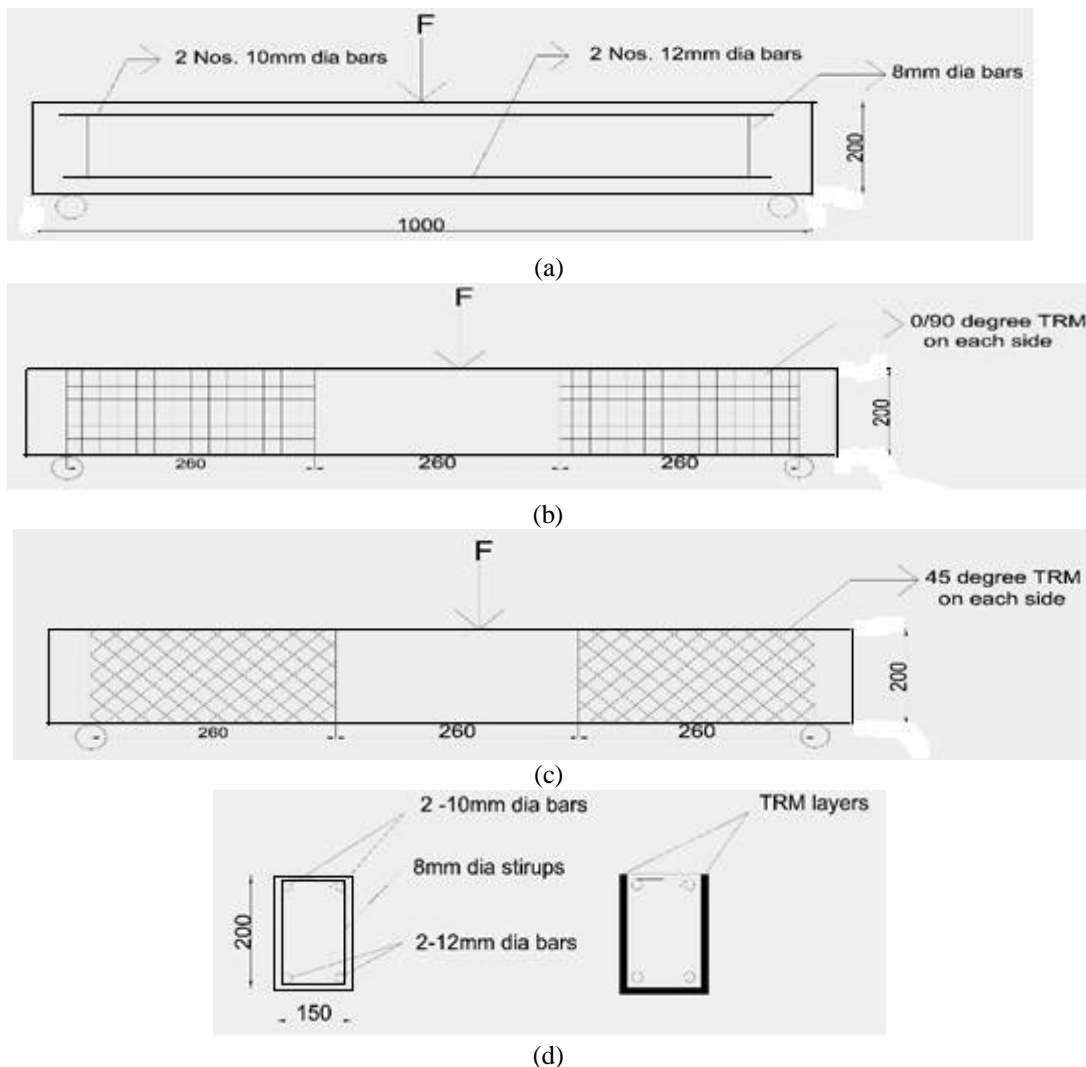


Fig. 2. Detailing of Test beams (a) Control Beam (b) Beams with 0/90° textile orientation (c) Beams with 45° textile orientation (d) Cross section of beams

III. CASTING OF SPECIMENS

Steel moulds are used for the casting of beams of size 150X200X1000mm. Reinforcements were tied as per design and placed in the mould with a cover of 25mm. Concrete was mixed and placed in the mould in layers and vibrated

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thoroughly. The top surface leveled and finished. The same procedure continued for all the 10 beams. From the next day onwards curing was started. After 28 days curing TRM application was started for the remaining 8 beams. Before the application of TRM the surface was prepared. All the four sides of shear span were roughed by using chisel. A layer of mortar of about 2 mm thickness was applied on the prepared surface using trowel (figure 3(b)). Then the textile was applied on the mortar surface until the mortar protruded out of the perforations between the rovings (figure 3(c)). The next layer of mortar was applied on the surface for covering the textile fabric. This procedure was repeated for all other beams. Each layer should be applied only after drying the previous one. Then 28 days curing was done before testing.



(a)



(b)

(c)



(d)

Fig. 3. Casting of specimen (a) Casting of RC Beam (b) Cleaning and chipping of beam surface (c) Wrapping of Nylon textile (d) Applying Mortar

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IV. TEST SETUP

The beam flexural tests under three point loading were performed in a universal testing machine with 1000 kN capacity. The load was applied at midpoint of the beam specimen, increased at a uniform rate till the ultimate failure. The specimens were arranged with simply supported conditions with an effective span of 800 mm. Deflection of the beam was measured using a dial gauge of least count .01mm at centre of the specimen. The experimental test set up is as shown below.



Fig. 4. Test set up for beam specimen

V. TEST RESULTS AND DISCUSSIONS

A summary of test results for all beams is displayed in Table 2. The two control beams (BS1/1 and BS1/2) failed in shear-compression mode, through the formation of diagonal cracks in the shear span followed by concrete crushing in compression zone as seen in Fig.5(a). The average ultimate load for the two beams was 105. Similar failure was also observed for all strengthened beams BS2 to BS3 as shown in Fig.5(b) and Fig 5(c). But in case of BS4 and BS5, the failure mode changed to flexure. The cracks generated at midspan as seen in Fig.5(d) and 5(e). Bond failure was not evident in the experiments as the induced shear stresses were not enough to mobilize the debonding failure. It concludes that TRM layers were effective in enhancing the shear capacity of the test beams as gains in ultimate shear resistance.



(a)



(b)

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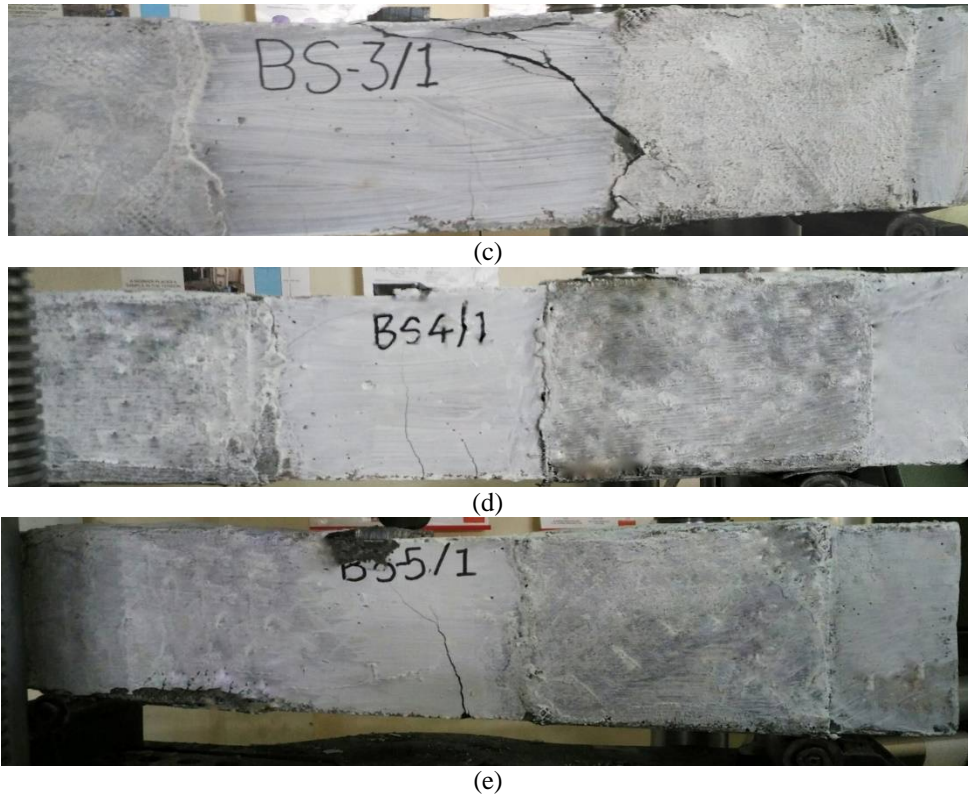


Fig. 5. Failure Pattern (a) Shear failure of control beam BS 1 (b) Shear Failure of BS 2 (c) Shear Failure of BS 3 (d) Flexural Failure of BS 4 (e) Flexural Failure of BS 5

Specimen	Ultimate Load (kN)	Max deflection	Failure mode
BS-1	105kN	5.9mm	Shear failure
BS-2	119kN	6.4mm	Shear failure
BS-3	126kN	6.9mm	Shear failure
BS-4	142kN	7.4mm	Flexural failure
BS-5	151kN	8.1mm	Flexural failure

Table 2. Ultimate load of beam specimens

The maximum loads in specimens BS2, BS3, BS4, and BS5 were 119 kN, 126 kN, 142 kN, and 151 kN, respectively. This brings about the conclusion that textile with zero degree orientation show better result than 45° orientation even though the ultimate load were almost similar. It also conclude that the shear strength increases with increase in number of layers. The load vs deflection curve of all beam specimens were shown in figure 6.

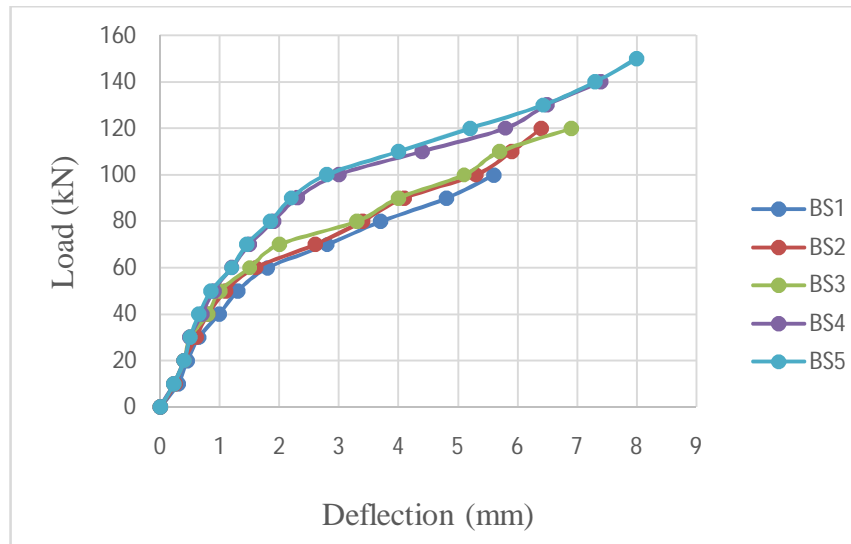


Fig. 6. Load vs Deflection graph

VI. CONCLUSION

Experimental investigations were carried out on the control and Nylon textile wrapped beam specimens. Load carrying capacity, maximum deflection and failure patterns were analysed for control and TRM wrapped beams and the following conclusions were drawn.

- Due to environmental condition or due to manmade situation, a beam may act as shear deficient. Textile reinforced mortar is a promising option for rehabilitating such type of members. Also nylon textile based cement mortar is economical and durable solution.
- In the experimental study the control beam and 2 layer TRM upgraded beam failed in shear. But when the TRM was applied in 4 layers, the beam behaves in more ductile manner and the failure mode becomes flexural failure. So it is cleared that textile reinforced mortar provides shear enhancement of reinforced concrete beams.
- Also from the study it has been found that when the number of layers of TRM increases the load carrying capacity of the beam increases.
- The orientation of the textile has some effect in the load carrying capacity. When the textile is oriented in weft direction upward, it gives more load carrying capacity than the other.
- The shear resistance of the beam increases as the number of layer increases. The nylon textile with mortar gives a substantial gain in shear capacity of 12-41%.
- Compared to the other textile like basalt textile[1]; nylon textile is more efficient in shear strengthening.

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