Enhancement of RC Beams by Textile Reinforced Concrete (TRC)

Mansi .V. Shah
PG Student
Parul University

Hardik Solanki
Assistant Professor
Parul University

Kaizad Engineer
Director Technical
Ushta Infinity Construction Co.Pvt.Ltd

Harishkumar Sheth
Proprietor
Achyuta Consultants

Abstract

This paper deals with the effectiveness of Textile Reinforced Concrete (TRC), as a means of increasing the flexural capacity and Shear capacity of Reinforced Concrete (RC) beams, is experimentally investigated. A new type of Alkali Resistant (AR) glass textile fabric was utilized as strengthening and the Polymer-modified cementitious mortar was utilized as bonding material for the Textile fabric instead of Epoxy resin, because of their advantages related to fire safety and their relatively low cost. The parameters examined in this research work include: (a) The number of the strengthening layers (one, three and five) and (b) The strengthening configuration, namely Bottom-wrapping and U-shape wrapping. In total, Eighteen Reinforced Concrete (RC) beams were casted and tested as simply supported under three-point bending till failure.

Keywords: AR-glass textile fabric, Concrete beam, Polymer modified cementitious mortar, strengthening, Textile Reinforced Concrete (TRC)

I. INTRODUCTION

Structural retrofitting of existing Reinforced Concrete (RC) structures is a continually developing need because of their deterioration like ageing, deficient concrete production, environmental induced degradation, lack of maintenance, and need more strict design requirements [9]. The most widely strengthening techniques for Reinforced Concrete members include the utilization of Fiber Reinforced Polymer (FRP) composites because of their favorable properties like, Extremely high strength to width ratio, speed of the application and corrosion resistance [6]. In spite of all these preferences, the FRP strengthening procedure has a certain disadvantages mainly associated with the use of epoxy resins like High cost, Poor performance in high temperatures, Inability to apply on wet surfaces, De-bonding of FRP from the concrete substrate etc.

One conceivable answer for the above issues would be the replacement of organic binder (typically epoxy) with inorganic binder (cement mortar). Hence the researchers introduced a new composite material, namely Textile Reinforced Concrete (TRC), which combines advanced textile fabric (with open-mesh configuration) with cementitious matrix. The use of technical textiles mainly made of AR-glass, Carbon, basalt and aramid fabric which gives high effectiveness because of they are placed in the main stress direction of the composites [10]. This permit the design of very thin-structured concrete elements. In this experimental work, TRC composites comprising of Alkali-resistant (AR) glass textile fabric were been used for the strengthening of RC beams [1].

II. DESIGN AND PROPERTIES OF MATERIAL

A. Mix Design

A Concrete mixture can be designed to provide a wide range of mechanical and durability properties to meet the design requirement of a structure. The specified design strength of concrete was 25MPa at 28 days. The specific gravity of Fine Aggregates (FA) and Coarse Aggregates (CA) was 2.61 and 2.81 respectively. Ordinary Portland Cement was used of 53grade. Coarse aggregate was found to be Absorptive to the extent of 0.5% and free surface moisture in sand was found to be 1%. According to IS 10262-2009, the mix proportioning for concrete of M25 grade shown in Table 1.

Table – 1
Mix Proportion

Material	*Weight (kg / m^3)*
Cement	*356.43*
Water	*153.26*
Fine Aggregate	*725.64*
Coarse Aggregate	*1295*

Chemical Admixture	2.14
W / C Ratio	0.43

B. Properties of Materials

1) Concrete and Steel reinforcement

Concrete Mix design with a target compressive strength of 25 MPa was used to cast the RC beam specimens. Total, 12 standard cubes (150 × 150 x 150 mm) were also cast which were tested under compression at 28 days. The average compressive strength of concrete at 28 days was 28.97 N/mm^2 .To determine the actual characteristics of steel reinforcement, three samples of steel bars for 12 mm diameter were tested under tension. The steel used is TMT500 grade. The average values for yield and tensile strengths of the bars were 496.74 N/mm^2 and 627.87 N/mm^2. After the curing period for the concrete beams at 28 days, the specimens, which were to be strengthened, were thoroughly sandblasted to remove dirt and any loose material. This was done to ensure optimum bond quality in between the concrete substrate and the TRM layers. Markings were made on the specimens to outline the TRM edges.

2) Textile Reinforced Mortar (TRM)

The mortar used as Textile Reinforced Mortar systems was BS 5F-U, manufactured by THERMAX Limited. BS 5F-U is a one component thixotropic corrosion resistance fiber reinforced polymer modified repair mortar. In order to determine the compressive strength of mortar, Total 6 cubes (100 x 100 x 100mm) were prepared and then tested under compression at 28 days. The average compressive strength of concrete at 28 days was 22.38 N/mm^2. The mortar datasheet provided by the manufacture indicates that it has a flexural strength of 7 N/mm^2 at 7 days.

3) Alkali-Resistant (AR) Glass Fabric

AR-glass based textile, increase the Structural performance of RC beams after strengthening, is shown in Fig. 1, and was used in this study. The AR-glass textile mesh used for strengthening the Reinforced Concrete beams had a grid size of 5 x 5 mm. The details of AR-glass textile mesh used are given in Table 2.

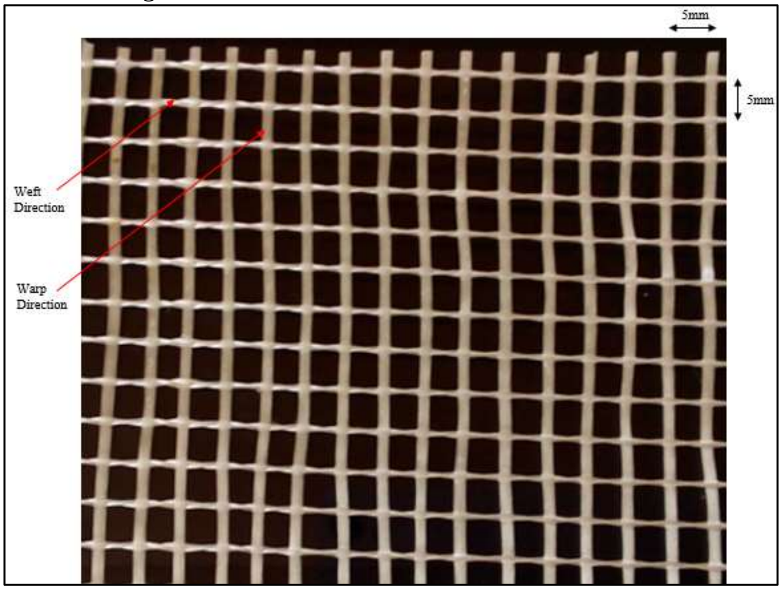


Fig. 1: AR-glass textile fabric

Table - 2
Mechanical properties of Fabric

Properties (unit)	Value
Woven STR	Leno
Elastic Modulus (MPa)	72000
Tensile Strength (MPa)	36.54
Fiber Weight (GSM)	145
Density (g /cm^3)	10
tackiness (mm)	0.49

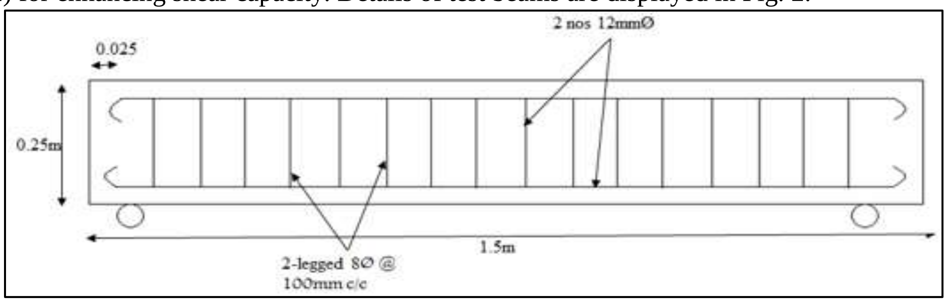
III. Experimental Program

This study comprises of testing total 18 simply supported Reinforced Concrete (RC) beams (150 × 250 × 1500 mm) in three-point bending when externally upgraded by TRC sheets. The criterion for selection of the beam dimensions was on the basis of available resources in the laboratory. The main Objective was to study the effectiveness of Textile Reinforced Concrete (TRC) in enhancing the flexural and shear capacity of RC beams. The beams were reinforced with 2-12mmØ longitudinal rebar on each face (top and bottom), at a cover of 25 mm. The shear reinforcement comprised of 2-legged 8mmØ stirrups at a spacing of 100 mm. The studied parameters included: Number of strengthening layers (1, 3 and 5) and Textile configuration (Bottom and U-shape). The test matrix is shown in Table 3.

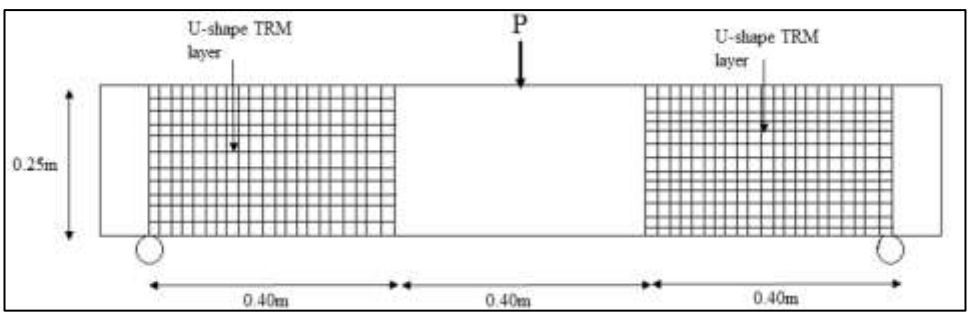
Table – 3
Test Matrix

Sr. No	*Identification Mark*	*No. of Strengthening layer*	*Shape of Strengthening layer*	*No. of Specimens*
1	CB	-	-	*3*
2	F1LB	*1*	*Bottom*	*3*
3	F3LB	*3*	*Bottom*	*3*
4	F5LB	*5*	*Bottom*	*3*
5	1UL	*1*	*U-shape*	*2*
6	3UL	*3*	*U-shape*	*2*
7	5UL	*5*	*U-shape*	*2*
Total Number of Specimens				*18*

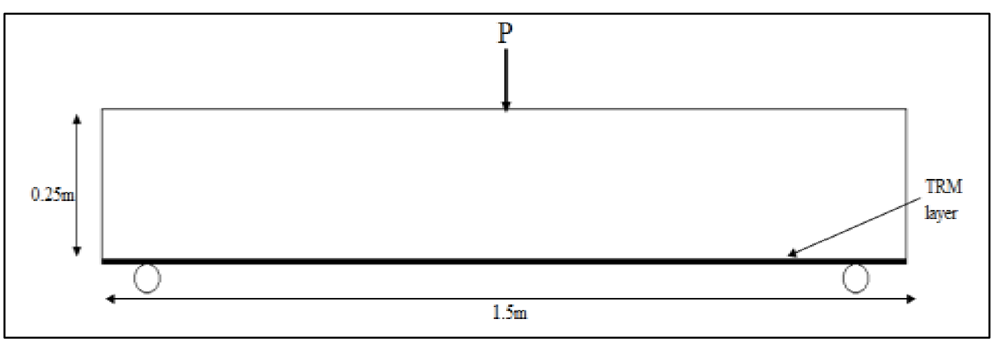
Three beams were kept unstrengthened to check the efficacy of unstrengthened beams and perform as Control Beam (CB-1, CB-2 and CB-3). While the remaining beams were strengthened with one layer, three layers and five layers of textile fabric bonded with Polymer-modified mortar. In which, Nine beams were externally upgraded by AR-glass textile sheets at bottom (F1LB, F3LB and F5LB) for enhancing their flexural capacity; and other six beam were strengthened by U-shape wrapping (1UL, 3UL and 5UL) for enhancing shear capacity. Details of test beams are displayed in Fig. 2.



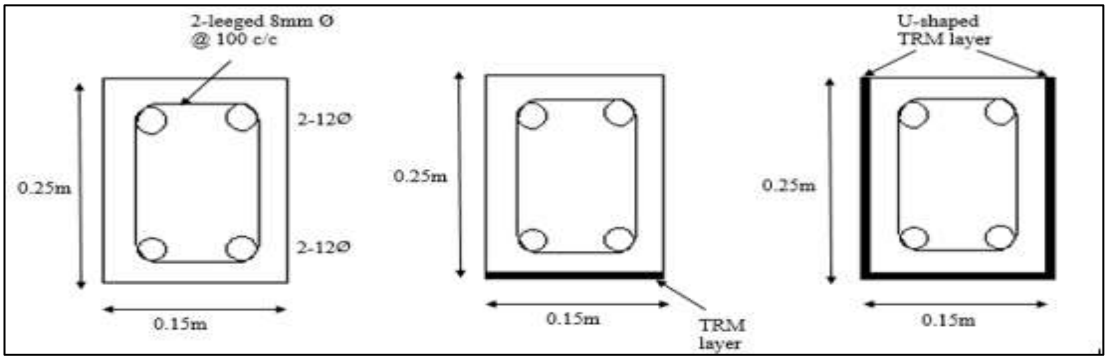
(a) Control beam



(b) Beams 1UL, 3UL and 5UL



(c) Beams F1L, F3L and F5L



(d) Section at Beam mid-Span (e) Section of F1L, F3L and F5L (f) Section of 1UL, 3UL and 5UL

Fig. 2: Details of Test beams

IV. Test Setup

All the 18 beams were tested to failure in a Three-point loading system with a clear span of 1.5m and an effective span of 1.2 m as shown in Figure 2. The load was applied using Hydraulic jack. Two Dial gauges were used to measure the displacement of the specimen near the load point. The testing of beams were carried out in Loading frame of 1000 kN load capacity. The tests were carried out using Load control, and the applied loads were monitored through a high accuracy load. The reading was taken at regular intervals of load. During loading, the specimen was visually inspected and cracks were marked. The test region was coated with white paint in order to clearly observe the evolution and propagation of cracks appeared. Pictures were taken at regular intervals to properly capture the crack pattern during testing.

V. Test Results and Discussion

A summary of test results for all strengthened RC beam with bottom and U-shape wrapping is shown in Table 4.The load v/s deflection curve of RC control beams and strengthened beams are shown in Figure 3 and 4. The average load carrying capacity of control beam was 86.43kN and final failure by Crushing. Similarly, flexural failure was observed for all Nine bottom strengthened RC beams. The maximum load carrying capacity of one, three and five layers of strengthened RC beams were 120kN, 126.46kN and 131.7kN respectively, which are increased with the increasing numbers of strengthening layers as shown in Figure 3. Debonding of textile reinforced strengthening layer occur at the bottom of the beam but the failure of beams strengthened by one and three layers of fabric in bottom face due to the rupture of the textile fabric and the final failure of beam is by crushing of concrete at the compression face in both RC strengthened beams. In addition, remaining six U-shape strengthened RC beams for shear enhancement, they should not be failed in shear. The ultimate load carrying capacity of six specimens 1UL, 3UL and 5UL was 123.1kN, 137.33kN and 141kN, respectively, the corresponding increase in their shear capacity was equal to 42.43%, 11.56% and 2.89% with increasing the number of strengthening layer as shown in Figure 4. As a result, TRM layers were generally effective in enhancing the both flexural and shear capacity of the test beams as shown in Table 4.

Table – 4
Test Matrix

Sr. No	*Identification Mark*	*Ultimate Load (kN)*	*Mid-span deflection at Ultimate Load (mm)*	*Mode of Failure*
1	CB	*86.43*	*6.81*	*CC*
2	F1LB	*120*	*12.25*	*FR, DB*
3	F3LB	*126.46*	*8.353*	*FR, DB*
4	F5LB	*131.7*	*7.697*	*FR, DB*
5	1UL	*123.1*	*11.76*	*CC*
6	3UL	*137.33*	*10.83*	*CC*
7	5UL	*141.3*	*9.89*	*CC*

CC: Concrete Crushing, FR: Textile Rupture, DB: Debonding

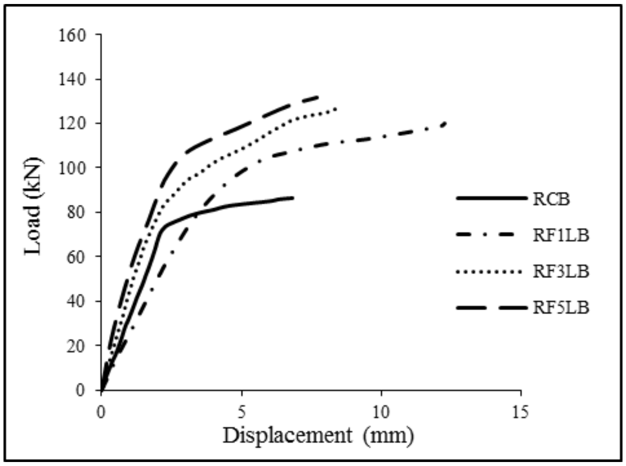


Fig. 3: Load-deflection Curve for Bottom wrapping Strengthened Beam

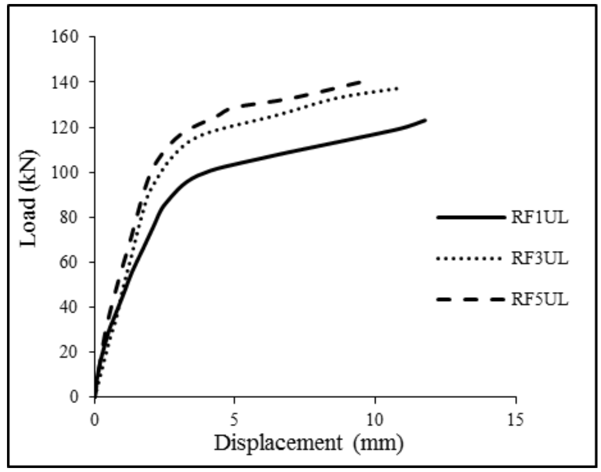


Fig. 4: Load-deflection curve of U-shape wrapping Strengthened beam

VI. CONCLUSION

This paper presents an experimental investigation on the effectiveness of Textile Reinforced Concrete (TRC) in flexure and shear strengthening material for Rectangular RC beams. It conclude that the performance of existing member can be enhanced by strengthening with Alkali-Resistant (AR) glass textile fabric. The effectiveness depends on both the strengthening configuration and the number of layers. Both of the strengthening configuration was observed by increasing the number of layers (1, 3 and 5). The ultimate load carrying capacity of one, three and five strengthened layer were increased by 38.84%, 5.38% and 4.14% in terms of bottom wrapping and 42.43%, 11.56% and 2.89% increase in terms of U-shape wrapping respectively. The results obtained from the investigations opens up possibilities of further investigations to prove the efficiency of AR-glass TRC towards structural strengthening.

REFERENCES

[1] Bruckner A., R. Ortlepp, and M. Curbach. "Textile reinforced concrete for strengthening in bending and shear." Materials and structures 39.8 (2006): 741-748.
[2] Larbi, A. Si, et al. "Shear strengthening of RC beams with textile reinforced concrete (TRC) plate." Construction and Building Materials 24.10 (2010): 1928-1936.
[3] Al-Saidy, A. H., et al. "Textile reinforced mortar for strengthening reinforced concrete beams." ECCM15 - 15TH EUROPEAN CONFERENCE ON COMPOSITE MATERIALS (2012): 24-28
[4] Larbi, A. Si, R. Contamine, and P. Hamelin. "TRC and hybrid solutions for repairing and/or strengthening reinforced concrete beams." Engineering Structures 45 (2012): 12-20.
[5] Al-Salloum, Yousef A., et al. "Experimental and numerical study for the shear strengthening of reinforced concrete beams using textile-reinforced mortar." Journal of Composites for Construction 16.1 (2012): 74-90.
[6] Elsanadedy, Hussein M., et al. "Flexural strengthening of RC beams using textile reinforced mortar–Experimental and numerical study." Composite Structures 97 (2013): 40-55.
[7] Verbruggen Svetlana, Tine Tysmans, and Jan Wastiels. "TRC or CFRP strengthening for reinforced concrete beams: an experimental study of the cracking behaviour." Engineering Structures 77 (2014): 49-56.
[8] Verbruggen Svetlana, et al. "Bending of beams externally reinforced with TRC and CFRP monitored by DIC and AE." Composite Structures 112 (2014): 113-121
[9] Tetta, Zoi C., Lampros N. Koutas, and Dionysios A. Bournas. "Textile-reinforced mortar (TRM) versus fiber-reinforced polymers (FRP) in shear strengthening of concrete beams." Composites Part B: Engineering 77 (2015): 338-348.
[10] Gopinath Smitha, et al. "Behaviour of reinforced concrete beams strengthened with basalt textile reinforced concrete." Journal of Industrial Textiles 44.6 (2015): 924-933.
[11] Raoof, Saad M., Lampros N. Koutas, and Dionysios A. Bournas. "Bond between textile-reinforced mortar (TRM) and concrete substrates: Experimental investigation." Composites Part B: Engineering 98 (2016): 350-361.
[12] IS 10262(2009), Concrete Mix Proportioning-Guidelines, First version.