

Retrofitting Of Beams with Glass Textile as Reinforcement in Polypropylene Added Mortar

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Abstract - Retrofitting the concrete infrastructure is progressively becoming more important due to their continuous deterioration due to ageing, environmental induced degradation and lack of maintenance. Using Textile Reinforced Mortar for retrofitting has gained popularity as it overcomes the disadvantages of using Fibre Reinforced Polymers. But formation of micro cracks and its rapid propagation in early stages of load carrying has reduced the preference Textile Reinforced Mortar among other methods of retrofitting. In this paper a new alternative using Polypropylene and Cement based composite material known as Glass Textile Reinforced Polypropylene Mortar (GTRPM), was used for retrofitting. It was mainly found that retrofitting with GTRPM increased the load carrying capacity of RC beams with an effectiveness ratio varying from 0.22 to .58, depending on the parameters examined.

Key Words: Fibre Reinforced Polymer, Textile Reinforced Mortar, Uniaxial Tension Test, Dog bone specimen, Two Point Loading Test, Partial U Wrapping, U Wrapping As End Anchorage.

1. INTRODUCTION

A structure is designed for a specific period and its design life varies depending on the nature of that structure. Deterioration in concrete structures is a major challenge faced worldwide by the infrastructure and bridge industries [3]. The deterioration of structures is mainly due to environmental effects , gradual loss of strength with ageing, repeated high intensity loading, variation in temperature, freeze-thaw cycles, contact with chemicals or saline water and exposure to ultra violet radiation. The most popular technique for strengthening of reinforced concrete beams is the use of external epoxy-bonded steel [2]. Even though steel bonding technique is simple, cost-effective and efficient, it has the drawback that steel will corrode and hence deterioration of bond occurs at the steel and concrete interface. To eliminate these problems, steel plates were replaced by corrosion resistant and light weight FRP composite plates. FRP systems can be used in areas with limited access. The need for retrofitting the existing concrete infrastructure is progressively becoming more important as replacing the deficient concrete structures in the near future with new is not a viable option as it would be prohibitively expensive[4]. For this reason a shift from new construction towards renovation and modernization has been witnessed in the construction sector between 2004 and 2013, with practically 50% of the total construction

output being renovation and structural rehabilitation [1]. In this paper, we propose an improved glass textile-based cement mortar composite for retrofitting beams weak in flexure.

2. EXPERIMENTAL PROGRAMME

2.1 Optimum Amount of Polypropylene

The objective was to study the amount of polypropylene that can be used with cement mortar and Glass matt to obtain a stronger material which would be called as Glass textile reinforced polypropylene mortar (GTRPM). Two variants of the material were created, one which has one layer of glass mat (GTRPM-1) and other which had two layers of glass mat (GTRPM-2).

In order to determine the maximum content of polypropylene fibre that can be added with TRM material, the specimens specified in ISO 527-2012 [5] were made by adding various percentages of polypropylene to it. The initial percentage was fixed as 2% as it is mentioned in data sheet. The percentage by weight of polypropylene was varied as shown in the Table 1. The specimens were prepared as the following

1. Mould used for making the dog bone specimen conforming to Type 3 is as shown in Figure 1.

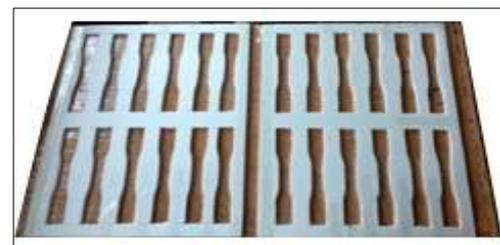


Fig -1: Mould Used

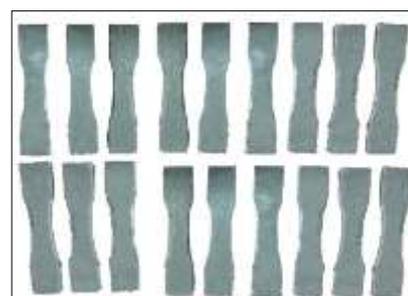


Fig -2: Specimens

2. A total of eighteen specimens were made with varying percentages of polypropylene as shown in Table 1, which belonged to GTRPM-1 category.

Table -1: Percentage variation of polypropylene

Sl. No.	% by weight of polypropylene
1	0.2
2	0.25
3	0.5
4	0.75
5	1
6	2

3. After 24 hrs the specimens were carefully demoulded and were kept cured for 28 days.

4. After curing the specimens were taken out and dried.

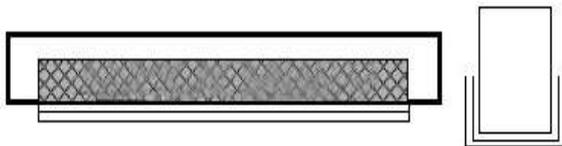


Fig -9: Beam retrofitted as partial U wrap till the neutral axis using two layer of GTRPM (GTRPM-2)

5. Ends of the specimen where wrapped with Teflon to prevent the crushing of mortar at grips (See Figure 3).

6. Each specimen was tested under uniaxial tension test (See Figure 4).

7. Tensile strength and stress strain behaviour of GTRPM were calculated.

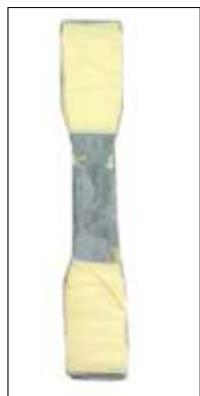


Fig -3: Specimen wrapped with Teflon



Fig -4: Test set up for tension test

2.2 Test specimens and investigated parameters

Beam specimen used for the test consists of two 10mm diameter bars at bottom and two 8mm stirrup holders. The beam size was fixed as 120mm x 180mm x 1250mm and the transverse reinforcement used consist of 6mm diameter vertical stirrups (See Figure 5).

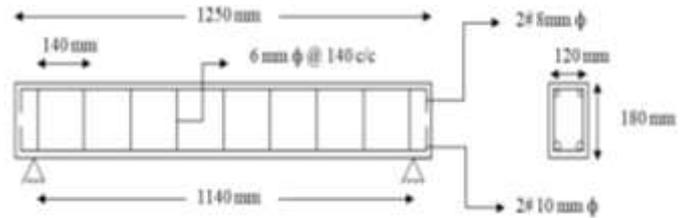


Fig -5: Reinforcement detailing of beam

The parameters varied included, Number of layers of strengthening material (1 and 2) and End-anchorage system of the external reinforcement (See figures 6 to

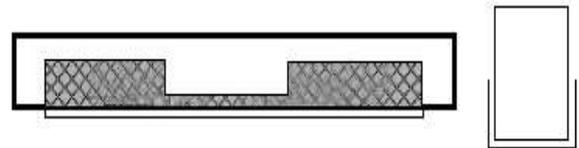


Fig -6: Beam retrofitted in bottom and in shear span as end anchorage using one layer (GTRPM-EA-1)

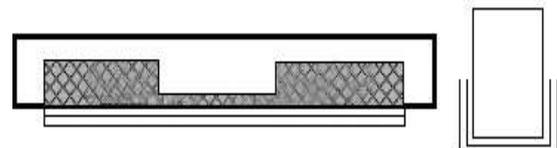


Fig -7: Beam retrofitted in bottom and in shear span as end anchorage using two layer (GTRPM-EA-2)

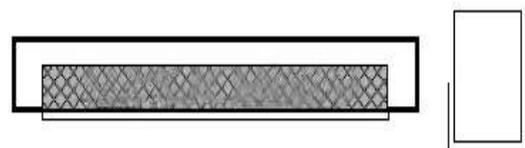


Fig -8: Beam retrofitted as partial U wrap till the neutral axis using one layer (GTRPM-1)

9).The specimens were tested in a two point load testing machine (See Figure 15). A dial gauge of least count 0.01mm was used for obtaining deflections. Deflections at mid span were noted at each load steps until failure. The ultimate load, load at first crack, load deformation behaviour and failure modes where observed.

2.3 Preparation of specimens

The retrofitting material was externally bonded to the bottom of the beams over a length of 1140 mm (see Figure 6 to Figure 9). The strengthening procedure for both

strengthening systems had the characteristics of a typical wet lay-up application and comprised the following steps:

1. Prior to strengthening, the concrete surface was prepared as follows: The surface was roughened using a grinding machine and the resulted concrete surface was cleaned from dust with compressed air (See Figure 10 and Figure 11).

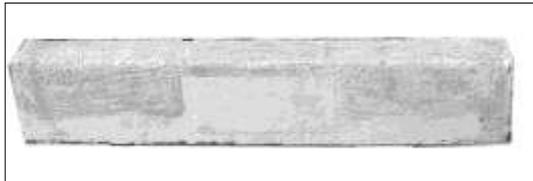


Fig -10: Surface roughed beam with U as End anchorage

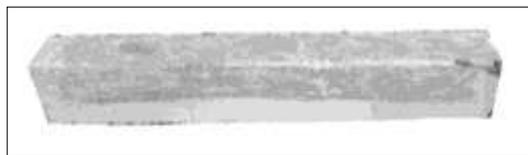


Fig -11: Surface roughed beam with Partial U wrapping

2. The procedure for application of GTRPM materials included: (a) Dampening the concrete surface with water (b) Application of a layer of polypropylene mortar with approximately 4mm thickness (See Figure 12) (c) Application of the textile into the polypropylene mortar and gently pressing with hand to ensure good impregnation with polypropylene cement mortar (See Figure 13).

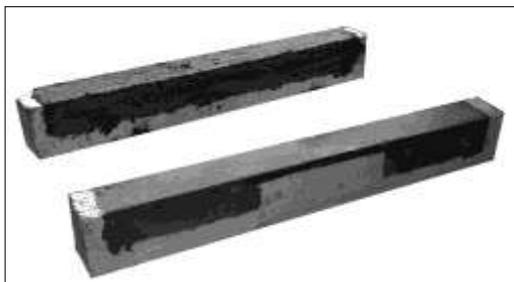


Fig -12: Beams with a layer of grout and mortar applied

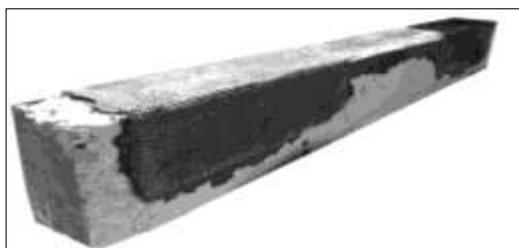


Fig -13: Beams with a layer of Glass mat placed

3. The above procedure for both strengthening systems was repeated in case of more than one textile layers were applied. For GTRPM-retrofitted beams, the final layer of textile was covered with a final layer of mortar with approximately 4 mm thickness and levelled (See Figure 14).

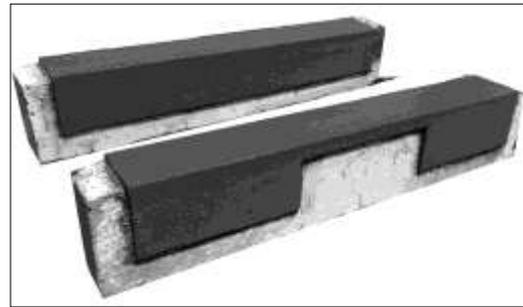


Fig -14: Beams with after finishing

2.4 Testing of specimens

All beams were subjected to two point loading as shown in Figure 11. The clear span was 1140 mm, and the selected configuration resulted in a 380 mm-long constant moment zone and a 380 mm-long shear span. The load was applied monotonically. A dial gauge was fixed at the mid-span of the beam to measure the mid-span deflection.

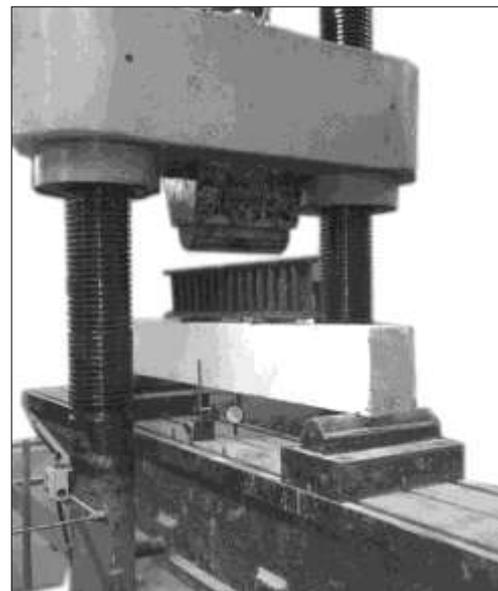


Fig -15: Testing of specimen

2.4 Observations

The main observations of all tested beams are presented in Table 2 which includes: (1) Cracking load (2) Ultimate load (3) Displacement at cracking load (4) Displacement at ultimate load (5) Observed failure mode.

Table 2: Observations

Sl. No.	Beam Code	load- kN		Displacement (mm) at	
		Cracking	Ultimate	Cracking load	Ultimate load
1	CON	64	100	1.8	3.2
2	GTRPM_1	80	127	3	6.5
3	GTRPM_2	85	98	4	16.5
4	GTRPM_EA-1	80	120	2.8	5.9
5	GTRPM_EA-2	85	100	3.5	15

3. RESULTS AND INTERPRETATION

3.1 Optimum amount of polypropylene fibre strands that can be added with cement mortar

From the tension test it was observed that the specimen with one percentage of polypropylene showed the highest increase in tensile strength. The results are as shown in Table 3.

Table 3: GTRPM Tensile properties

Specimen details		
SL No.	% by weight of polypropylene	% increase in tensile strength
1	0.2	35.58
2	0.25	44.4
3	0.5	58.5
4	0.75	88.9
5	1	99.6
6	2	60.3

The stress-strain curves of the GTRM coupon tests under tension for GTRPM-1 and GTRPM-2 specimens are presented in Chart 1 and Chart 2. Stress-strain curves for GTRPM showed a slight deviation from the behaviour of normal textile reinforced mortar. The initial phase observed in GTRM was seen more predominant in case of GTRPM

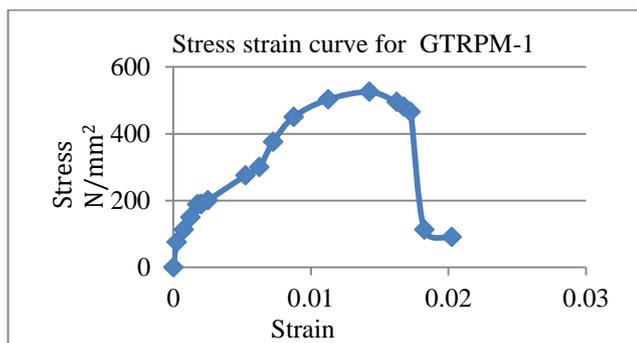


Chart 1 Stress strain curve for GTRPM-1

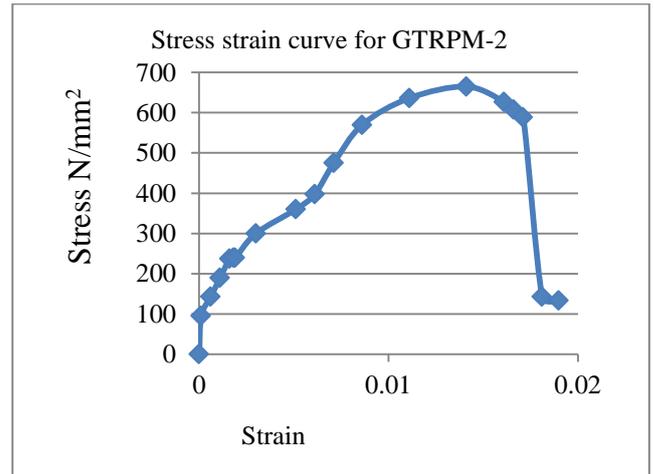


Chart 2 Stress strain curve for GTRPM-2

3.2 Load deformation curve for GTRPM retrofitted beams.

The load-deflection curves of GTRPM retrofitted beams are presented in Chart 3. The difference between the curves of the retrofitted beams and the control one is attributed to the contribution of strengthening materials to the flexural performance of the beams. The effect of strengthening was more pronounced for beams retrofitted with two layers of GTRPM. The beams retrofitted with one layer of GTRPM also showed an improved performance when compared with control specimen. It is to be noted that the beams retrofitted with end anchorage and partial U wrapping schemes showed almost the same load displacement variation.

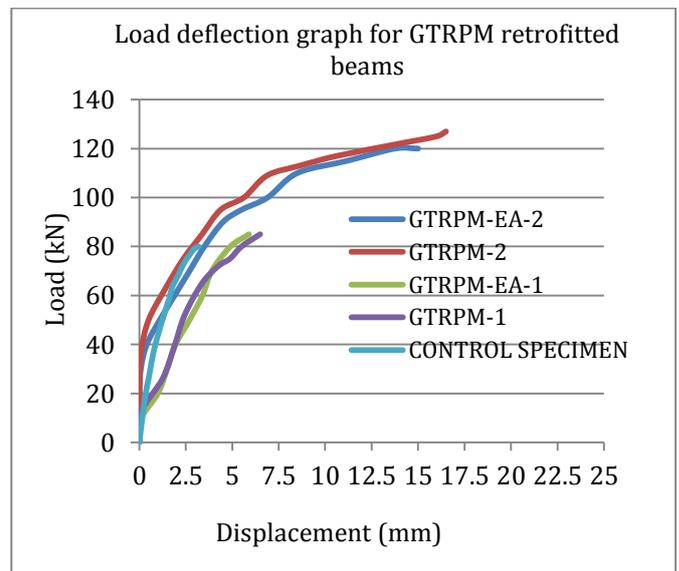


Chart 3 Load deflection graph for GTRPM retrofitted beams

3.3 Ultimate loads and failure modes

The values of maximum loads and the observed failure modes of all tested beams are presented in Table 2, supported by Chart 3. The reference beam (CON) failed in flexure after the formation of large flexural cracks at the

constant moment region. The failure was due to yielding of the tensile reinforcement followed by concrete crushing at the compression zone this type of failure mode is typical for under-reinforced beams. The yield and ultimate load was 64 kN and 79 kN, respectively, at corresponding mid-span deflection of 1.8 mm and 3.2 mm, respectively.

GTRPM-retrofitted beams, all specimens strengthened with TRM failed in flexure after displaying flexural strength considerably higher compared to the control specimen. For GTRPM-1, GTRPM-2, GTRPM-EA-1 and GTRPM-EA-2 the maximum loads were 100 kN, 127 kN, 85 kN and 120 kN, contributing 25%, 58.75%, 22.5% and 50% increase in flexural capacity. The beams strengthened with both one and two layers of GTRPM failed due to crack in mortar along with fibre rupture at the constant moment region of the beam.

Wide flexural cracks with extensive slippage of the fabric from the mortar matrix which arised due to loss of composite action within the mortar accompanied by partial rupture of the fibres, at a single crack within the maximum moment region .This type of failure mode was not brittle and was observed in specimens retrofitted with GTRPM .



Fig -16: Crack pattern of GTRPM retrofitted beam (Partial U as end anchorage)



Fig -17: Crack pattern of GTRPM retrofitted beam (Partial U)

4 CONCLUSIONS

This study was an experimental investigation on the performance of GTRM and GFRP composite in flexural strengthening of RC beams. The parameters examined were (a) Number of GTRPM layers and (b) End anchorage system. The obtained results revealed the following conclusions:

1. The effectiveness of GTRPM system in increasing the loading carrying capacity of retrofitted beams were from 22.5 % to 58.75 %.
2. GTRPM effectiveness was sensitive to the number of layers. It was found that the effectiveness factor

increased for partial U wrapping scheme from 0.25 to 0.58 when the number of GTRPM layers increased from 1 to 2.

3. Providing end-anchorage with U-jackets to GTRPM-retrofitted beams showed same enhancement in the flexural capacity compared to partial U wrap.

REFERENCES

1. Lampros N. Koutas , Zoi C. Tetta, and Dionysios A. Bournas (2015), "Textile-reinforced mortar (TRM) versus fiber-reinforced polymers (FRP) in shear strengthening of concrete beams" Composites Part B, volume 77 ,page 338-348.
2. Misra R.K, Anurag Dixit, and Harlalsingh Mali(2014), "Finite element shear modeling of woven fabric textile composite" Composites Part B Volume 59 page 540-661.
3. Saad M. Raoof ,Lampros N. Koutas and Dionysios A. Bournas (2016), "Bond between textile-reinforced mortar (TRM) and concrete substrates: Experimental investigation" Composites Part B ,Volume 98 , page 350-361.
4. Saad M. Raoof , Lampros N. Koutas and Dionysios A. Bournas (2017), "Textile-reinforced mortar (TRM) versus fibre-reinforced polymers (FRP) in flexural strengthening of RC beams" Construction and Building Materials volume 151 page 279-291.
5. ACI 549-13, Design and construction guide of externally bonded FRCM Systems for concrete and masonry repair and strengthening, American concrete institute, Farmington 2013.
6. Thanasis C. Triantafilloua, Dionysios A. Bournasb and Zoi C. Tetta (2018), "On the design of shear strengthened RC members through the use of textile reinforced mortar overlays", Composites Part B, Volume 147 ,page 178-196.
7. Torang Sitorus , Johannes Tarigan and Fadel Muhammad Patra (2018), "Flexural strength using Steel Plate, Carbon Fiber Reinforced Polymer and Glass Fiber Reinforced Polymer on reinforced concrete beam in building technology", Earth and Environmental Science.
8. G.M. Chen, J.F. Chen and J.G. Teng (2012), "On the finite element modelling of RC beams shear-strengthened with FRP", Construction and Building Materials ,volume 32, page 12-16.
9. M.N.S. Hadi (2003), "Retrofitting of shear failed reinforced concrete beams" Composite Structures volume 62 pages 1-6.