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Numerical method for determine the flexural capacity of beam strengthened by Fibre Reinforced Polymer and Textile Reinfrced Mortar material laminates

Poojan shah[1], Prof. Nihil Sorathia [2], Harishkumar sheth[3]

[1]*Civil Engineering & Parul University,*
[2]*Civil Engineering & Parul University,*

Abstract: Characterization study is required to determine the mechanical characteristics of a particular material which is essential in understanding its efficacy and usefulness as a strengthening ma Detailed Parametric study for a material needs so much time and cost. For example, to perform parametric study of any cementitious based material shall start with casting and then curing of the specimens for 28 days. More variations in parameters increase the number of same can be tested only after 28 days to examine their efficiency. Therefore detailed parametric studies are always time consuming and costly task. Therefore, objective of this study is to develop analytical models which can depict accurate behavior of material the specimens and the some suitable approach is required to be decided for development of analytical model. In this project, macro-mechanical approach shall be used for the same. Detailed literature review shall be carried out to understand this approach. The aim of the study is to develop analytical models for fibre reinforced polymers and textile reinforced mortar. Thorough literature study shall be carried out to understand the behavior of these materials under different parametric conditions. After completing analytical simulation by using any suitable programming language, the accuracy of the models shall be checked by referring the outcome of experimental research study carried out for the same material.

Keywords— Mechanical characterization, Textile Reinforced Mortar(TRM), Fibre Reinforced polymer(FRP), Characteristic behaviour

I. INTRODUCTION

At early starting of 21st century**,** The Construction Industries required tremendous repairing, rehabilitation and strengthening of structures. The reinforced concrete (RC) structures are needed structural repairing due to their deterioration (ageing, environmental induced degradation, and lack of maintenance) and need for upgrading to meet current design requirements.

One very suggestive advantage offered by composites is that their properties can be layer based. Further, each layer can be alternating selection of fibre materials, having a mix of fibres, changing their orientation, using matrix material with appropriate properties,. Numerical models developed thus far help us calculate fairly accurately mechanical properties of each laminate. The mechanical behaviour of laminate is presented in this project on a macro-mechanical scale in which the individual components of the lamina such as the fibre and matrix are not considered individually but the entire lamina at its response in the laminate.. Each laminate in this stack-up may have different properties. The first step for predicting the response of a laminate involves developing stress-strain relations for composite materials.

II. METHOD0LOGY AND MATERIAL PROPERTIES

A. *Four-Point Bending Test*

One specimen was used as control beam, which were designed to be under reinforced. So as to determine the effectiveness of TRM and FRP composites in increasing the flexural capacity. While the remaining six beams were casted with one, three and five layers of three beams of textile reinforced mortar and other three beams are Fibre reinforced mortar. In which, six beams were externally strengthened by AR-glass textile laminate at bottom for enhancing their flexural capacity; Details of test beam are displayed in Figure 1.

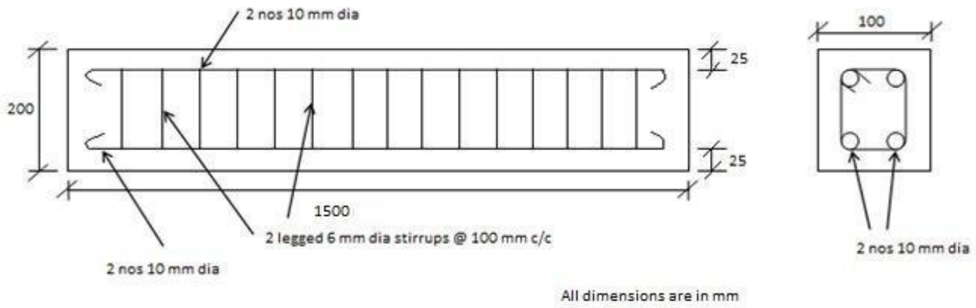

Figure 1: Details of Specimens

B. Material Properties

1. Cement

The cement used in this experimental work is class B50 Grade. All properties of cement are tested by referring IS12269-1987 specification for class M40 grade. Modulus of elasticity and poission ratio is 19700 and 0.19 respectively

Material's parameters	B50	The parameters of CDP model	
		β	38°
Concrete elasticity		m	1
E[GPa]	19.7	$f=f_{b0}/f_c$	1.12
ν	0.19	γ	0.666
Concrete compression hardening		Concrete compression damage	
Stress [MPa]	Crushing strain [-]	DamageC [-]	Crushing strain [-]
15.0	0.0	0.0	0.0
20.197804	0.0000747307	0.0	0.0000747307
30.000609	0.0000988479	0.0	0.0000988479
40.303781	0.000154123	0.0	0.000154123
50.007692	0.000761538	0.0	0.000761538
40.236090	0.002557559	0.195402	0.002557559
20.236090	0.005675431	0.596382	0.005675431
5.257557	0.011733119	0.894865	0.011733119
Concrete tension stiffening		Concrete tension damage	
Stress [MPa]	Cracking strain [-]	DamageT [-]	Cracking strain [-]
1.99893	0.0	0.0	0.0
2.842	0.00003333	0.0	0.00003333
1.86981	0.000160427	0.406411	0.000160427
0.862723	0.000279763	0.69638	0.000279763
0.226254	0.000684593	0.920389	0.000684593
0.056576	0.00108673	0.980093	0.00108673

Table 1: The material parameters of CDP model for concrete class B50[14]

2. Steel

Generally steel is used as reinforcement in beams. So that we are Fe415 grade of steel using as a longitudinal reinforcement and stirrups. The diameter of reinforcement and stirrups are taken 10mm and 6mm respectively. The modulus of Elasticity and poissions ratio of steel is 200000 and 0.3.

3. AR-Glass Fibre

fabric is also defined as elastic-plastic material. Modulus of elasticity and poisson's ratio of fabric defined are 50000 MPa and 0.2 respectively. Modulus of rigidity in all three directions is taken as 20833.33 MPa

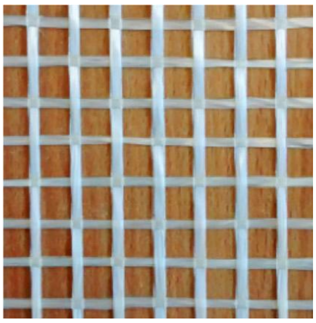

Figure2. Fabric Type Fibre

4. Epoxy

In material property of epoxy, its elastic property is defined in terms of traction. In elastic traction property, three ratios $E=K_{nn}$, $G1=K_{ss}$ and $G2=K_{tt}$ are required to be given. The modulus of elasticity (E) and modulus of rigidities (G_1 and G_2) for epoxy used as adhesive are 10000 MPa and 7407 MPa respectively by considering poisson's ratio as 0.35. It is assumed that in elastic range, stiffness of epoxy in all the three directions (K_{nn}- normal direction, K_{ss}-shear direction-1 and K_{tt}-shear direction-2) are equal to its modulus of elasticity. Therefore, the values of three ratios $E=K_{nn}$, $G_1=K_{ss}$ and $G_2=K_{tt}$ are given as 1, 0.74 and 0.74.

III. NUMERICAL MODELLING

Numerical modelling gives exibility to carry out parametric studies on the structure which would otherwise experimentally very expensive. In this study, numerical simulation of RC beam strengthened with epoxy is carried out in software ABAQUS by developing appropriate material and geometrical models.
Main steps of finite element analysis which software generally follows are as under:

1. Creating the geometry of parts.
2. Creating defining the materials to be used such as concrete, steel, etc.
3. Assigning the material properties.
4. Assigning the defined material section to the parts.
5. Creating analysis steps to carry out analysis.
6. Applying the required loads and boundary conditions.
7. Creating instances of the parts created and assembling them to replicate the model.
8. Meshing the assembled model using suitable element types.
9. Submitting the input file for analysis.
10. Visualization of the analysis results.

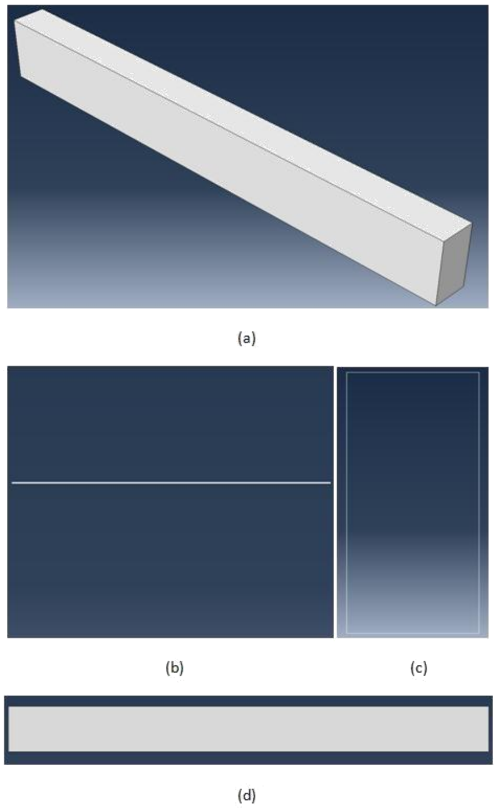

Fig.3: (a) Concrete beam part, (b) Longitudinal reinforcement part, (c) Stirrup part, (d) Strengthening layer (cement mortar) part

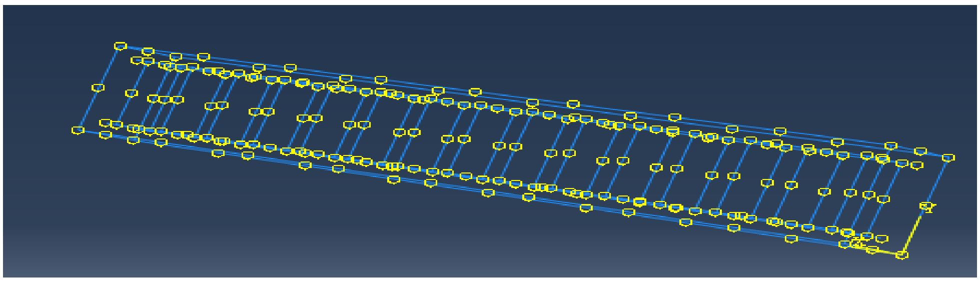

Figure4: Reinforcement embedded in concrete

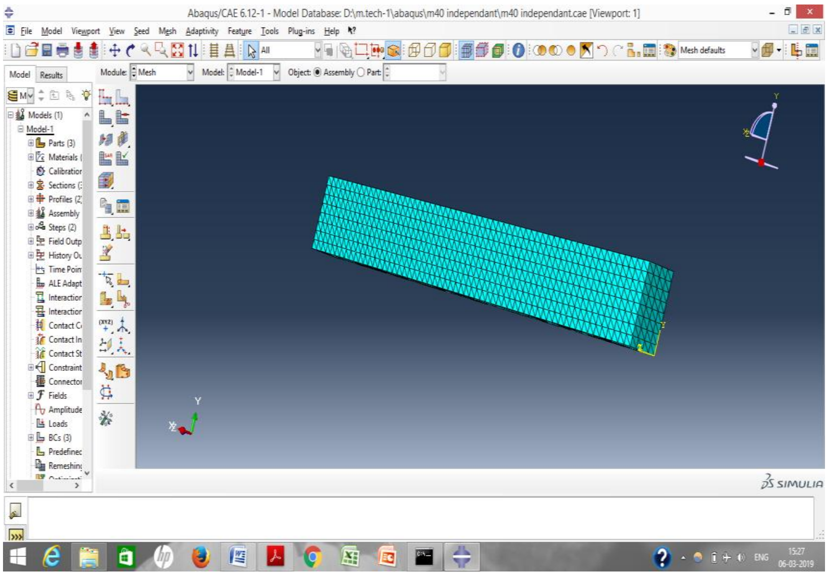

Figure 5: Meshed assembly of strengthened RC Beam

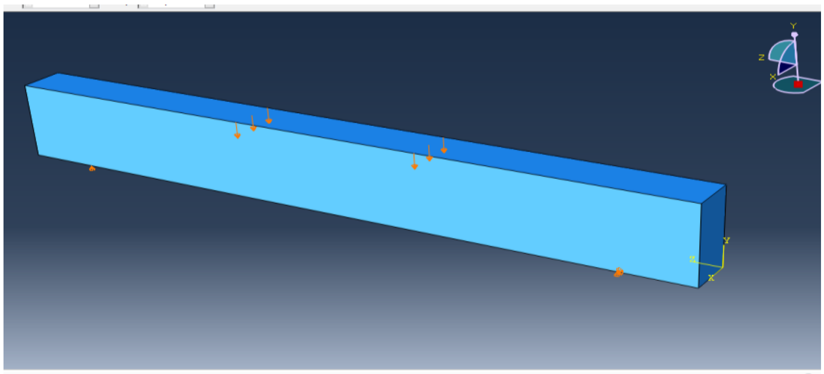

Figure 6: Strengthened RC Beam loaded under four point flexure condition

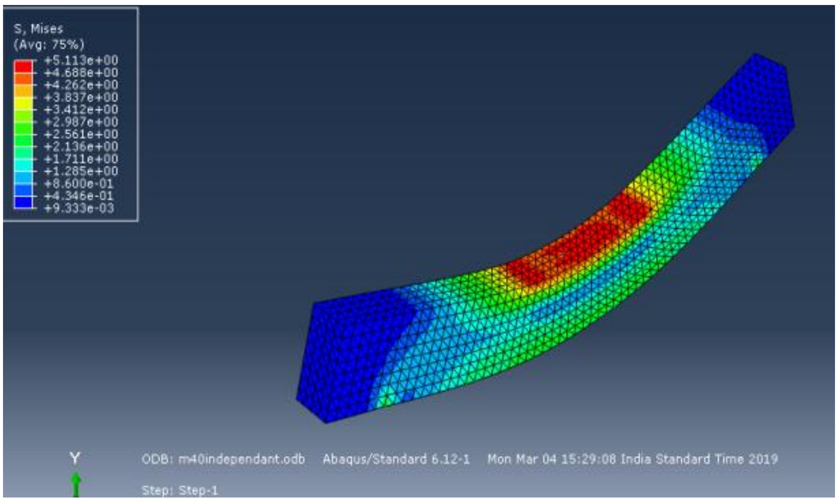

Figure 7: Deflaction of Beam Element

IV. RESULTS

In case of control beam peak state, numerical models are showing stiffer behaviour than experimental result. As the number of layer increases, the stiffness of the structure increases and flexural capacity also increases. For all the TRM and FRP strengthened beams, the FRP strengthened beam ultimate load carrying capacity were only slightly higher than TRM. Table 4 enlist the Comparison details. As seen in Table 2;

TABLE 2. Numerical simulation

No. of Layers	Loads (KN)		(%) Difference
	FRP	TRM	
CB	85.99		-
1	122.406	117.99	3.74
3	136.70	126.23	8.29
5	140.52	131.61	6.77

The comparision of the respective layers are as follows:

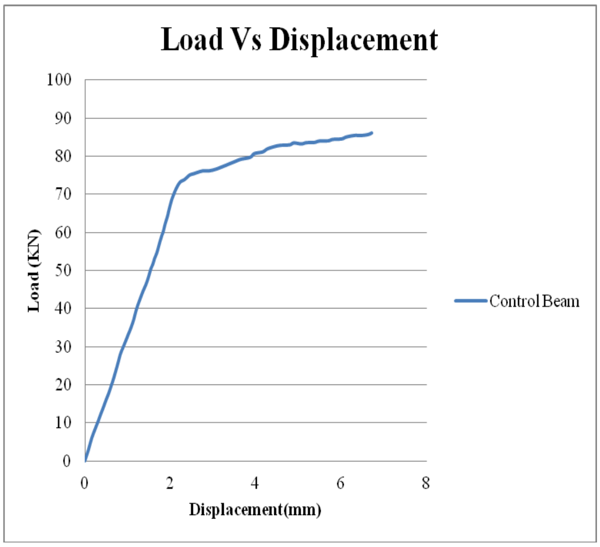

Figure6.1. Control Beam

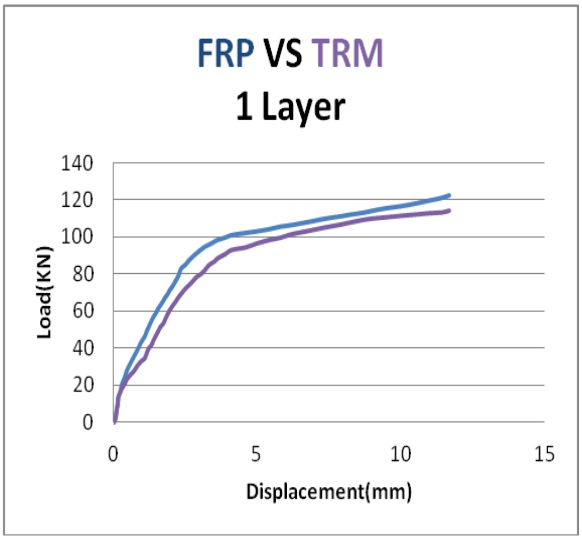

Figure 9. 1st Layer of FRP and TRM

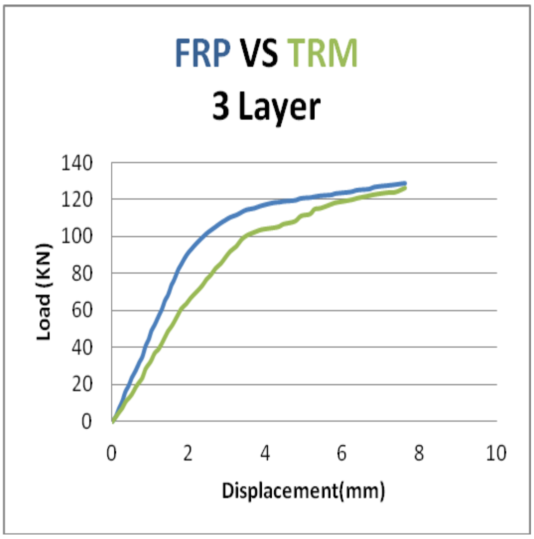

Figure 10. 3rd Layer of FRP and TRM

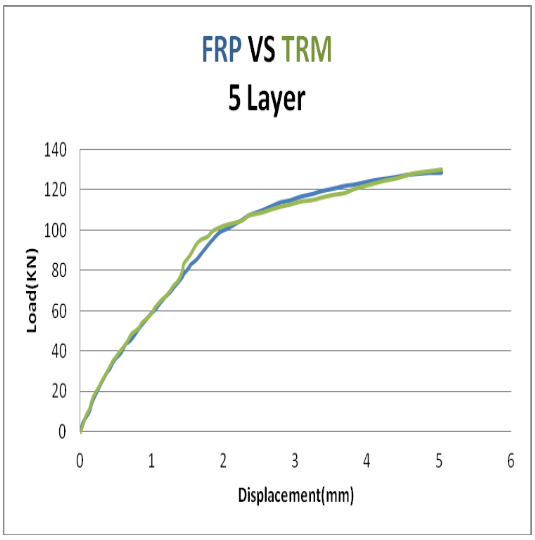

Figure 11. 5th Layer of FRP and TRM

CONCLUSIONS

- Under both loading rates, epoxy bonded strengthened beams exhibit better load carrying capacity than cementicious matrix bonded beams. Numerical models are developed for both Cementicious matrix bonded and epoxy bonded beams. Models are compared with control beam results. For Cementicious matrix bonded beams, models with finer mesh size are in good agreement with the numerical result outcome. For epoxy bonded beams, model with coarser mesh size is in good accordance with the data. FRP is more capable to resist the Flexural capacity other than TRM. Increases the number of layer, it will increases the strength.

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