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Analytical Study on Behaviour of RC Beam Column Joint Retrofitted with Various Thicknesses of CFRP and GFRP Sheets.

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Abstract: Many existing structures located in seismic regions are not adequate because of current seismic design codes[3]. In addition, a number of major earthquakes during recent years have underscored the importance of mitigation to reduce seismic risk. Seismic retrofitting of existing structure is one of the most effective methods of reducing this risk[6,7]. However, the seismic performance of the structure may not be improved by retrofitting or rehabilitation unless selecting the appropriate technique. Therefore, the requirements of rehabilitation of various retrofit techniques must be taken before selecting retrofit schemes. In the present study, a beam column joint from an existing G+3 storey office building is considered for analytical study. The CFRP and GFRP sheets of varying thicknesses in beam column joint were modeled and compared with the model without FRP. The most effective and economical retrofit material is identified. The analytical study for the model has been done by using ANSYS software and the results are discussed.
Key words : Beam Column Joint, CFRP, GFRP, Seismic Retrofitting, ANSYS.

1.0 Introduction

A large number of existing buildings in India are severely damaged during earthquake forces and the number of such deficient buildings is growing rapidly[1]. Retrofitting of any existing building is an important mission and requires more skill. Retrofitting of RC building is mainly difficult due to complex performance of the RC composite material[2-4]. The behaviour of the buildings during earthquake not only depends on the member size and amount of reinforcement, but to a greater amount on the placing and detailing of the reinforcement. There are three main sources of deficiencies in a building, which have to be taken into consideration by the retrofitting Engineer.

- Inadequate design and detailing.
- Degradation of material with time and use.
- Damage due to earthquake or other catastrophe.

The three sources, suggest a retrofit scheme to make up for deficiencies and demonstrate that the retrofitted structure will able to safety resist the future earthquake forces expected during the lifetime of the structure.

2.0 Methodology

2.1 Types of FRP Sheets

Four types of fibers are normally used for retrofitting of beam column joints.

- Glass fiber reinforced polymer sheets
- Carbon fiber reinforced polymer sheets
- Basalt fiber reinforced polymer sheets
- Aramid fiber reinforced polymer sheets

2.2 Glass Fiber Material

Fiber glass reinforced plastics use textile grade glass fibers. These textile fibers are different from other forms of glass fibers used to deliberately trap air, for insulating application. Fiber mats are web-form non- oven mats of glass fibers[6]. Mats are manufactured in cut dimensions with chopped fibers, are in continuous mats using continuous fibers. Chopped fiber glass is used in processes where lengths of glass threads are cut between the ranges between 3 and 26 mm.

Fig 1 Testing of beam column joint using GFRP sheets.

2.3 Carbon Fiber Material

Carbon fibers are made when poly-acrylo-nitrile (PAN) fibers, pitch resins and rayon are carbonized by means of thermal pyrolysis and oxidation at high temperatures[3]. Carbon fibers are manufactured in diameters ranging between 9 and 17 □m. This fibers are wound into larger number of threads for transportation and production processes. Further production process including weaving and braiding into carbon fabrics, cloths and mats rather than glass that can then be used in actual reinforcements.

Fig 2 Testing of beam column joint using CFRP sheets.

Table 1 Properties of FRP Sheets

Properties	CFRP	GFRP
Elastic Modulus (KN/mm^2)	240	73
Tensile Strength (N/mm^2)	4900	3400
Fiber Weight (g/m^2)	200	350
Density (g/cm^3)	1.7	2.6
Thickness (mm)	0.017, 0.117, 0.217	0.067, 0.077, 0.087
Ultimate Strain (%)	1.55	4.5

2.4 ANSYS Software

A beam column joint is modeled by using ANSYS. The simple linear static analysis is performed for the following cases of study

Case 1: Model without FRP.
Case 2: Model with CFRP.
Case 3: Model with GFRP.

Coarse meshing has been preferred for the beam column joint.

2.4.1 Building The Model

Element type for various structural elements are discussed below in Table 2.

Table 2 Ansys Element Type

Element Type	ANSYS Element
Concrete	SOLID 65
FRP composite	SOLID 46
Steel Reinforcement	LINK 8

2.4.2 Defining Material Properties

The material properties are assigned in ANSYS analysis are discussed below in Table 3.

Table 3 Material Properties Assigned in ANSYS

Material properties	**CFRP**	**GFRP**
Elastic Modulus (MPa)	240×10^3	73×10^3
Poisson Ratio	0.3	0.28
Ultimate tensile strength (MPa)	4900	3400
Bulk modulus (MPa)	20000	92308
Shear modulus (MPa)	92308	17578

2.4.3 Loading

. In the analysis, the concentrated load of 10 KN is applied at the free end of Cantilever Beam. The end of the column is fixed and top of the column is made free for analysis.

2.4.4 Solution

The following are the results obtained from ANSYS software.

1. Deformation
2. Equivalent Von Mises stress
3. Normal Stress
4. Normal elastic strain

3.0 Results and Discussions

3.1 Model without FRP

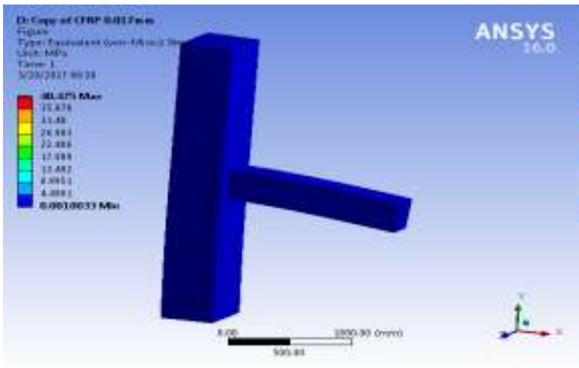


Fig3 Typical view of Equivalent Von Mises Stress

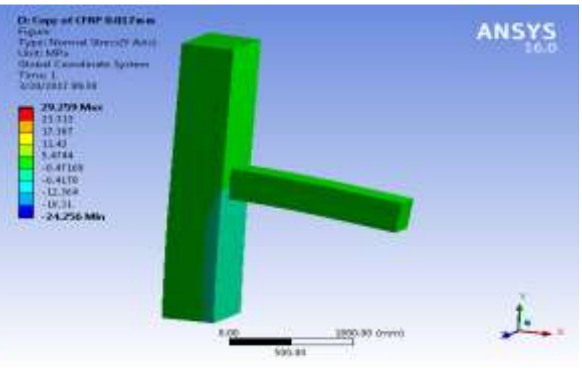


Fig 4 Typical view of Normal Stress in Y Axis

Table 4 Deformation, Stress and Strain Results of Model Without Wrapped with FRP

LOAD = 10KN

Properties	Results
Total deformation (mm)	0.96
Equivalent (von-mises) stress (MPa)	40.48
Normal stress in Y axis (MPa)	29.26
Normal elastic strain	0.00032

3.2 CFRP Model 1

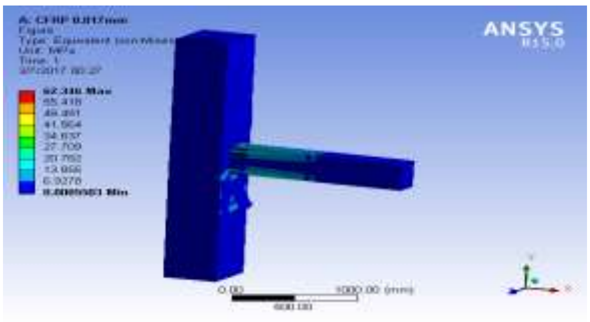


Fig 5 Typical view of Equivalent Von Mises Stress

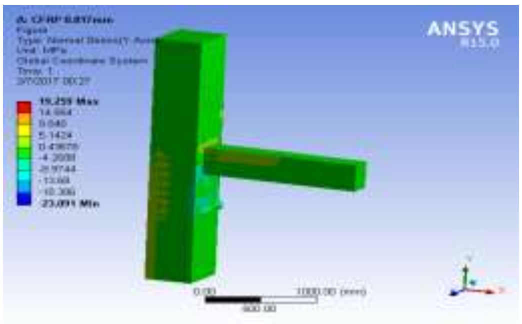


Fig 6 Typical view of Normal Stress in Y Axis

3.3 CFRP Model 2

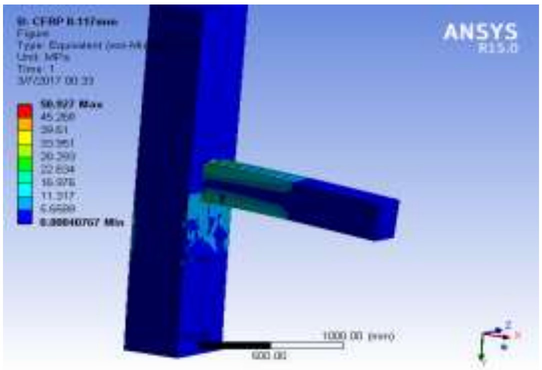


Fig 7 Typical view of Equivalent Von MisesStress

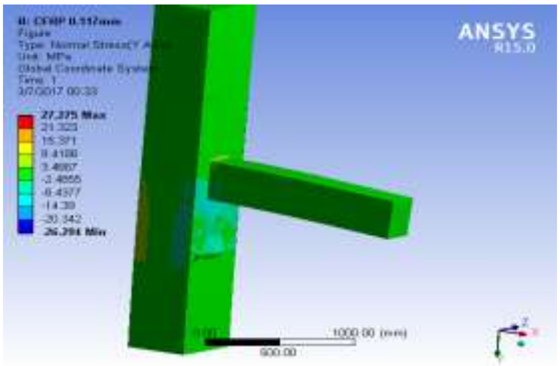


Fig 8 Typical view of Normal Stress in Y Axis

3.4 CFRP Model 3

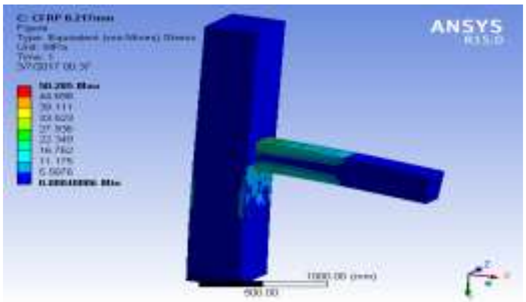


Fig 9 Typical view of Equivalent Von MisesStress

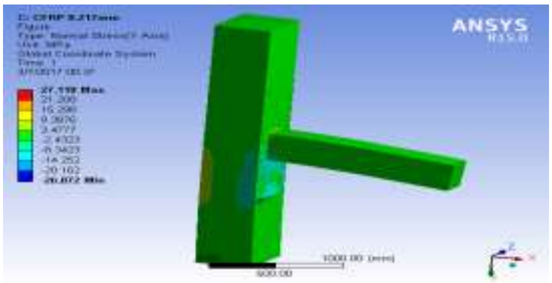


Fig 10 Typical view of Normal Stress in Y Axis

Table 5 Deformation and Stress Results of Model Wrapped with CFRP Laminates

LOAD = 10KN

Name of CFRP	Thickness (mm)	Total deformation (mm)	Equivalent (von-mises) stress (MPa)	Normal stress in Y Axis (MPa)
Model 1	0.017	8.03	62.35	19.26
Model 2	0.117	1.42	50.93	27.28
Model 3	0.217	0.94	50.30	27.12

3.5 GFRP Model 1

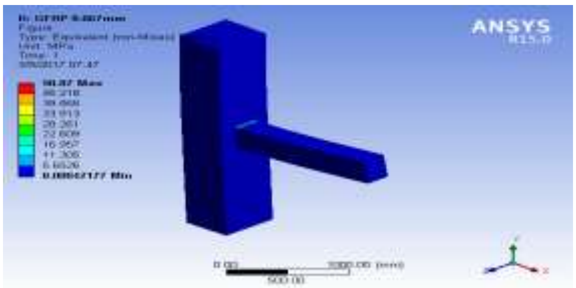


Fig 11 Typical view of Equivalent Von MisesStress

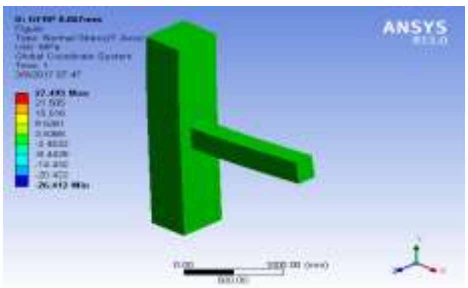
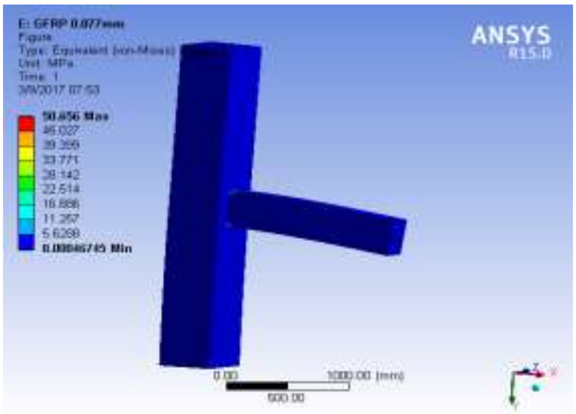


Fig 12 Typical view of Normal Stress in Y Axis.

3.6 GFRP Model 2



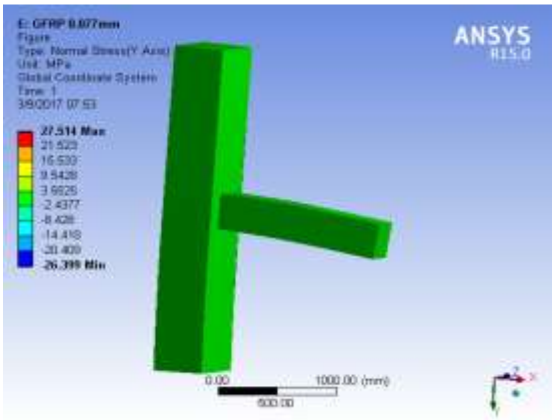
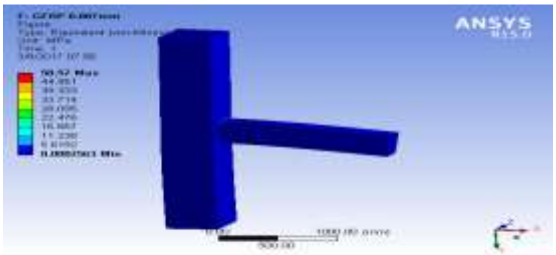


Fig 13 Typical view of Equivalent Von MisesStress Fig 14 Typical view of Normal Stress in Y Axis

3.7 GFRP Model 3



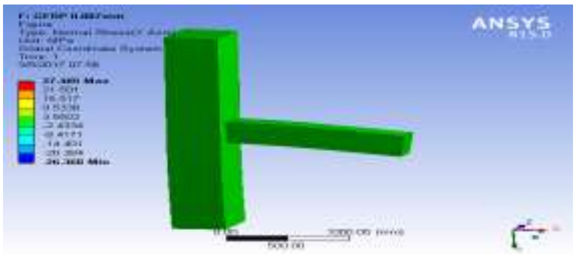


Fig 15 Typical view of Equivalent Von MisesStress Fig 16 Typical view of Normal Stress in Y Axis

Table 6 Deformation and Stress Results of Model Wrapped with GFRP Laminates.

LOAD = 10KN

Name of GFRP	**Thickness (mm)**	**Total deformation (mm)**	**Equival-ent (von-mises) stress (MPa)**	**Normal stress in Y Axis (MPa)**
Model 1	0.067	0.96	50.87	27.50
Model 2	0.077	0.96	50.65	27.51
Model 3	0.087	0.96	50.57	27.49

Table 7 Normal Elastic Strain Results for CFRP and GFRP

Name bf FRP	**Normal Elastic Strain**
CFRP Model 1	0.00013
CFRP Model 2	0.00014
CFRP Model 3	0.00014
GFRP Model 1	0.00015
GFRP Model 2	0.00016
GFRP Model 3	0.00015

Table 8 comparison of Results of CFRP and GFRP Model with the Model Without Wrapped with FRP

Model name	% Increase in Equivalent (von-mises) stress	% Increase in Normal Stress in Y axis
CFRP model 1	54.035	51.92
CFRP model 2	25.82	7.274
CFRP model 3	24.24	7.895
GFRP model 1	25.68	6.416
GFRP model 2	25.15	6.342
GFRP model 3	24.94	6.454

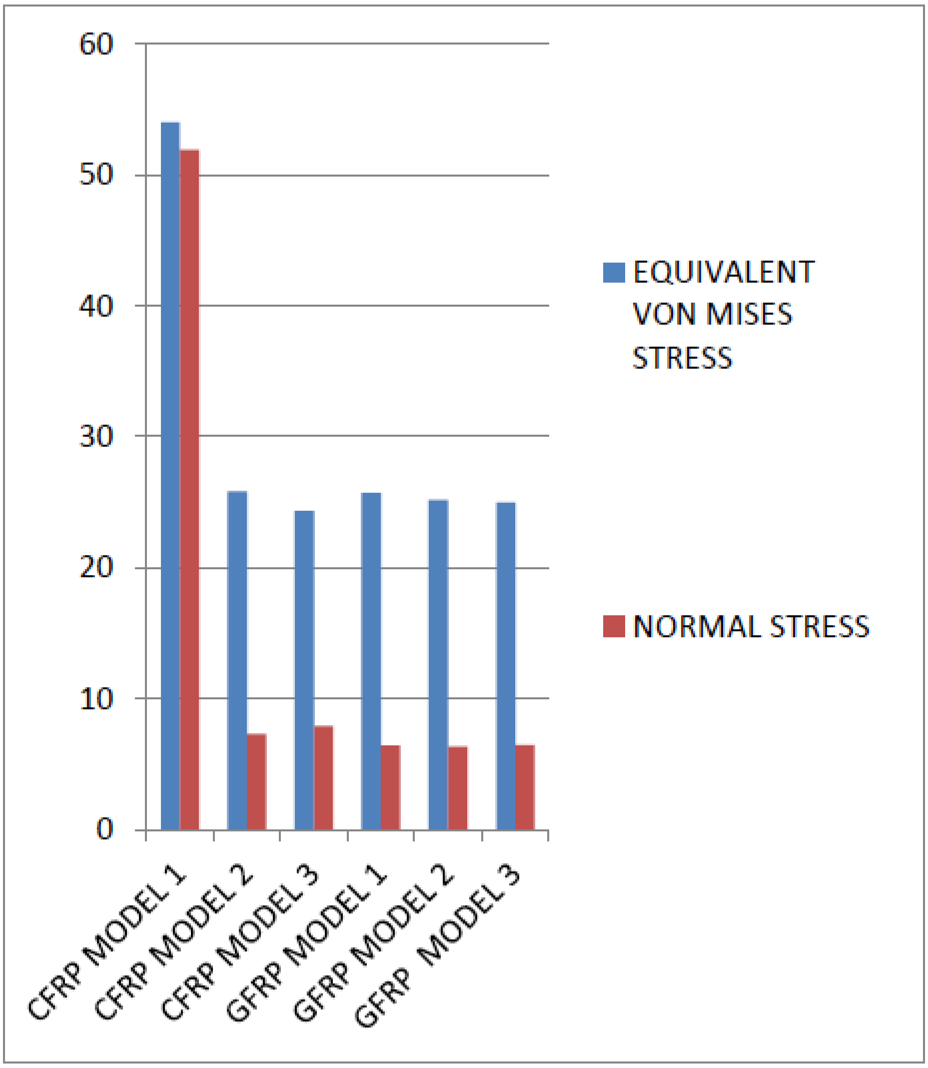


Fig 17 Percentage Increase in Stresses of CFRP and GFRP Model

4.0 Conclusion

From the study it is concluded that many existing structures that were built according to past design codes and standards are often found vulnerable to earthquake damage due to inadequate detailing, under estimated earthquake loads or material deterioration by time etc., the high cost of new construction and historical importance of older buildings has led building owners to renovate rather than replace the existing structures. Most retrofitting techniques will result in increase in stiffness and slightly increase in mass which causes in a return a shorter period. Shortening in period of vibration often results an increase in strength and stiffness of retrofitted structure. Based on the ANSYS modelling and analysis carried out on the beam column joint model the following conclusions are drawn.

1. The Equivalent Von-Mises stress for 10 KN Load for model wrapped with CFRP of three various thicknesses (0.017, 0.117, 0.217) were found to be increased by 54.035%, 25.82% and 24.29% respectively.
2. The Equivalent Von-Mises stress for 10 KN Load for model wrapped with GFRP of three various thicknesses (0.067, 0.077, 0.087) were found to be increased by 25.68%, 25.15% and 24.94% respectively.
3. The Normal Stress for 10 KN Load for model wrapped with CFRP of three various thicknesses (0.017, 0.117, 0.217) were found to be increased by 51.2%, 7.274% and 7.895% respectively.
4. The Normal stress in Y axis for 10 KN Load for model wrapped with GFRP of three various thicknesses (0.067, 0.077, 0.087) were found to be increased by 6.416%,6.342% and 6.454% respectively.

Thus it is concluded that, the model retrofitted with CFRP of 0.017 mm thickness is more effective in taking concentrated load than other model analysed above.

5.0 References

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