An Analytical Study of Performance of Retrofitted Column.

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Abstract:

RC columns often need strengthening to increase their capacity to sustain the applied load. This research investigates the effect of elevated temperature on behavior of reinforced concrete (RC) circular columns strengthened with different fiber reinforced polymer (FRP) systems. For this purpose, 5 column specimens were prepared. The test matrix of models comprised: 1 unstrengthened or control columns, 2 columns strengthened which were wrapped with a single layer & double layer of CFRP sheet having a thickness of 1mm & 2mm respectively, and 2 specimens strengthened which were wrapped with a single layer & double layer of GFRP sheet having a thickness of 1.3mm & 2.6mm respectively. In addition to control specimens at room temperature(i.e. 26 ^{0}C), some other columns were subjected to high temperature regimes of 100 ^{0}C, 200 ^{0}C, 300 ^{0}C, 400 ^{0}C & 500 ^{0}C.Behavior of the both unstrengthened & strengthened columns were analytically investigated on all of the five specimens divided into one un-strengthened specimen and four strengthened ones. A finite element model was developed to study the behavior of these columns in finite element (F.E) package ANSYS 14.0.The research demonstrated that at elevated temperature CFRP sheets were more resistance & performed better than GFRP sheets.

Keywords: RC columns; Strengthening; Retrofitting; FRP; GFRP;CFRP;F.E analysis; ANSYS ;Epoxy resins

1. INTRODUCTION

Strengthening of reinforced concrete (RC) columns is required for several reasons such as increasing their lifetime, column degradation due to lack of maintenance, and the need to carry more loads than their designed values. Several strengthening measures have been developed by researchers and practicing engineers for RC columns such as by providing anyone of the following methods reinforced concrete jacket or steel jackets or encasing the column with steel sheels & filling the gap with non shrink grout in order to provide passive confinement to core concrete. One of the most recently used techniques involves wrapping of RC columns by fiber reinforced polymer (FRP) composites to provide confinement for strength and ductility enhancement. FRP composites present an attractive option due to several reasons such as their high strength-to-weight and stiffness-to-weight ratios, large deformation capacity, minimal change in the geometry, corrosion resistance to environmental degradation, and speed of application. Use of FRP jackets to strengthen RC columns has been studied by several investigators [16]. The application of externally bonded FRP composites in structures, yet, has been mired due to uncertainties concerning their performance in fire or elevated temperature environments. FRP composites are vulnerable to ignition of their polymer matrix. Furthermore, strength and stiffness of polymer matrices get significantly reduced if heated above their glass transition temperature (Tg). Hence, if left uninsulated, FRP composites may ignite with increased flame spread and toxic smoke evolution, and they may quickly lose bond and/or mechanical properties [17, 18].Therefore, the behavior of FRP-strengthened RC columns exposed to fire or elevated temperature environments is of big concern. As yet, research in this area is limited, and more work is needed.

1.1 Literature Review

1. **Majid Jarrah** [2] In this study, the effects of fiber type (i.e., carbon and glass fibers) and intumescent paint on the tensile performance of fiber reinforced polymer (FRP) sheets at elevated temperatures are investigated. For this purpose, a series of tensile tests were conducted on the glass and carbon fibre reinforced polymer (GFRP and CFRP) sheets, with and without intumescent fire retardant paint, at different elevated temperatures. The studied temperatures ranged from 26 °C to 600 °C. Scanning electron microscopy was also used to examine the effects of elevated temperatures on FRP sheets and the fire protecting mechanism of the intumescent paint.
2. **Hussein Elsanadedy** [5] This research investigates the effect of elevated temperature on behavior of reinforced concrete (RC) circular columns strengthened with different fiber reinforced polymer (FRP) systems. For this purpose, 32 column specimens were prepared. The test matrix comprised: 14 unstrengthened columns, 14 columns strengthened with a single layer of CFRP sheet, and 4 specimens strengthened with a single layer of GFRP sheet. Out of the 14 CFRP-wrapped specimens, 4 columns were thermally insulated with commercially available fire-protection mortar. In addition to control specimens at room temperature, some other columns were subjected to high temperature regimes of 100 ^{0}C, 200 ^{0}C, 300 ^{0}C, 400 ^{0}C, 500 ^{0}C, and 800 ^{0}C for a period of 3 h. After cooling down, the columns were tested under axial compression until failure. It was indicated that exposure to elevated temperature adversely affected the residual strength, stiffness, and axial/lateral stress–strain response of unstrengthened columns.
3. **Yousef** [6] This paper examines the effect of different elevated temperature environments on performance of reinforced concrete (RC) circular columns strengthened with different techniques. For this purpose, 50 RC circular column specimens were prepared. The test matrix was divided into five groups, of which the first group was composed of 14 unstrengthened columns. The second group consisted of 14 columns strengthened with one layer of continuous carbon fiber reinforced polymer (CFRP) sheet. The third group was composed of 14 columns strengthened with one layer of 5 CFRP strips combined with near surface mounted (NSM) steel bars. Out of the 14 columns in the second or third groups, 4 specimens from each RC columns group were insulated using cement-based, fire protection mortar. The fourth group involved 4 columns strengthened with one layer of continuous glass fiber reinforced polymer (GFRP) sheet combined with steel bars.

4. **Hamza M.** [11]This paper presents a finite element model to simulate and investigate the behavior of adding steel jacket to a preloaded and non-damaged reinforced concrete column. Depending on the loading state of the non-strengthened reinforced concrete column and the purpose of adding the steel jacket, two possible cases have been studied. In the first case, which is suitable to investigate the reinforced concrete column with design errors, the steel jacket has been added to the unloaded reinforced concrete column; while the second case is suitable for adding steel jacket to the pre-loaded non-damaged reinforced concrete column. The finite element model was carried out using the ABAQUS/standard v. 6.13 software. The results obtained by the proposed finite element model showed fairly good agreement with the existing experimental and analytical results.

1.1 Objective of the analysis

The following are the objective of this analysis

1) To obtain the deformation of CFRP retrofitted column & GFRP retrofitted column by varying the thickness of both CFRP & GFRP sheets at elevated temperature.
2) Also, to obtain the stress, strain and shear-stress value generated in the retrofitted column at different elevated temperature.

2. MATERIAL USED

Material used in reinforced concrete column is of grade M30 is used.[14]and types of concrete used is Portland cement concrete (conventional concrete). Reinforcement consider is HYSD steel bars whose tensile strength is equal or greater than 415 N/mm2 and the dia. of bar is not less than 8mm for stirrup & 16mm for main bars. [14]

Both CFRP and GFRP sheets considered in this study were uni-directional. A two component, resin based epoxy was used as the adhesive. Table 1 enlists the properties for both CFRP and GFRP sheets. The properties of the epoxy adhesive as provided by the manufacture are also depicted in Table 1.

Table 1: Material Properties

S.NO.	MATERIAL	MECHANICAL PROPERTIES
1.	Concrete	Density = 2400kg/m3
		Compressive strength = 30 MPa
		Young's modulus = 30x10^3MPa
		Poisons ratio = 0.2
2.	Steel	Density = 7850 kg/m3
		Tensile yield stress= 415 MPa

		Young's modulus = 2×10^5 N/mm2
		Poisons ratio = 0.3
3.	CFRP	Density = 1800 kg/m3
		Young's modulus =$77.3\text{x}10^3$MPa
		Ultimate tensile strength = 846MPa
4.	GFRP	Density = 1440 kg/m3
		Young's modulus =$20.9\text{x}10^3$ MPa
		Ultimate tensile strength =460 MPa
5.	Epoxy resins	Tensile strength =71.6 MPa
		Young's modulus =$1.8\text{x}10^3$ MPa

Geometrical Details of Retrofitted column as Per Codes:

Details of the Tested Models:

Geometrical Details of Control COLUMN (model 1)

- Height of column 3.0 m.
- Section of column 230 mmX230 mm.
- Grade of concrete is M25
- Size & grade of steel bar is 16mm & Fe500.
- Size & grade of stirrups is 8mm & Fe500.
- Spacing between stirrups @150mm c/c

Geometrical Details of CFRP COLUMN (model 2)

- Height of column 3.0 m.
- Section of column 230 mmX230 mm.
- Grade of concrete is M25
- Size & grade of steel bar is 16mm & Fe500.
- Size & grade of stirrups is 8mm & Fe500.
- Spacing between stirrups @150mm c/c
- Thickness of CFRP layer =1mm
- Adhesive = Epoxy Resins

Geometrical Details of CFRP COLUMN (model 3)

- Height of column 3.0 m.
- Section of column 230 mmX230 mm.
- Grade of concrete is M25
- Size & grade of steel bar is 16mm & Fe500.

- Size & grade of stirrups is 8mm & Fe500.
- Spacing between stirrups @150mm c/c
- Thickness of CFRP layer =2mm
- Adhesive = Epoxy Resins

Geometrical Details of GFRP COLUMN (model 4)

- Height of column 3.0 m.
- Section of column 230 mmX230 mm.
- Grade of concrete is M25
- Size & grade of steel bar is 16mm & Fe500.
- Size & grade of stirrups is 8mm & Fe500.
- Spacing between stirrups @150mm c/c
- Thickness of CFRP layer =1.3mm
- Adhesive = Epoxy Resins

Geometrical Details of GFRP COLUMN (model 5)

- Height of column 3.0 m.
- Section of column 230 mmX230 mm.
- Grade of concrete is M25
- Size & grade of steel bar is 16mm & Fe500.
- Size & grade of stirrups is 8mm & Fe500.
- Spacing between stirrups @150mm c/c
- Thickness of CFRP layer =2.6mm
- Adhesive = Epoxy Resins

Analytical Load Details:

Table 2: Load consideration on column

S.NO.	LOADS	VALUES
1.	Dead Load	3 KN/m^2
2.	Live Load	3 KN/m^2
3.	Finishing Load	1 KN/m^2

Total applying loads on column is considered as per IS:875(Part -1) [19] for dead load and IS:875(Part-2) [19] for imposed load.

3. Methodology

In designing and analyzing the performance of conventional concrete and Sulphur concrete slab, it is especially important that an effective modeling technique be involved because of the complexity of the real structural behavior and the difficulties of full-scale measurement. In the analysis of all kind of structure, a number of assumptions should be made in order to reduce the size of the actual problem, in this part, the assumption taken are material behavior, element behavior, structural behavior. The analysis of the models is done on ANSYS Workbench ver. 14.0 by using this software there is an inbuilt material data library by which we change its mechanical properties. Concrete, steel is taken by ANSYS library then modified it as per the requirement and create geometry of the required model to analyze and apply dense tetra meshing for finite element analysis (FEA) of models. After this apply loads, supports boundary condition and temperature is applied then add parameters to check the results of each model.

4. Results:

4.1 Analytical Results Displaying Deflection

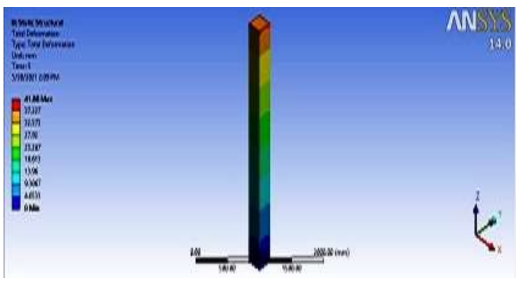

Fig. 1 CONTROL COLUMN

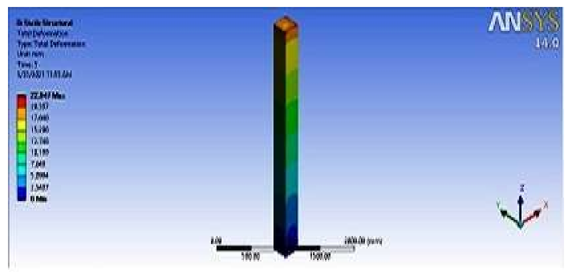

Fig. 2 CFRP 1mm thick layer

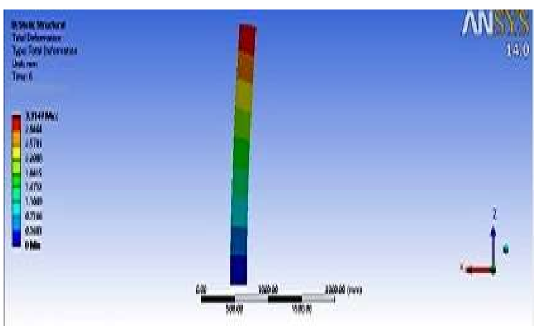

Fig. 3 GFRP 1.3mm thick layer

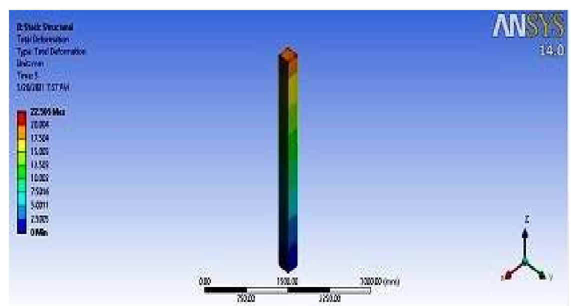

Fig. 4 CFRP 2 mm thick layer

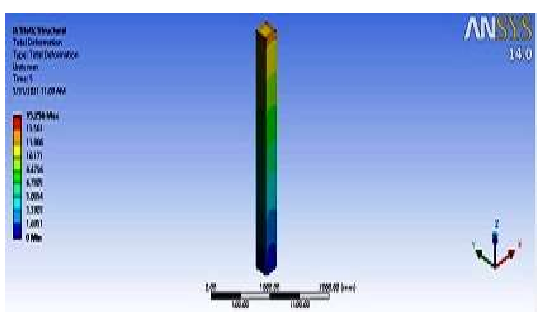

Fig. 5 GFRP 2.6 mm thick layer

4.2 Analytical Results Displaying Strain

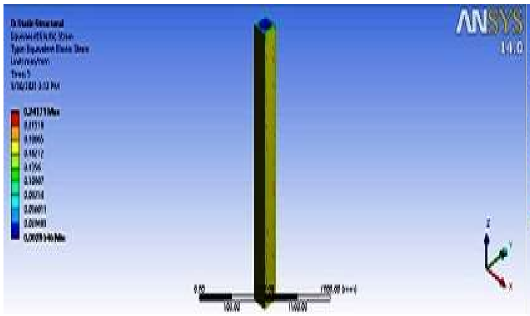

Fig.6 CONTROL COLUMN

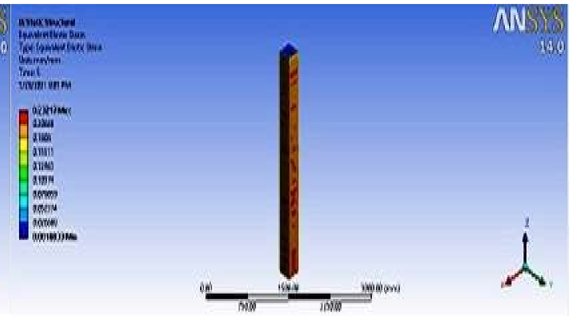

Fig. 7 CFRP 1mm thick layer

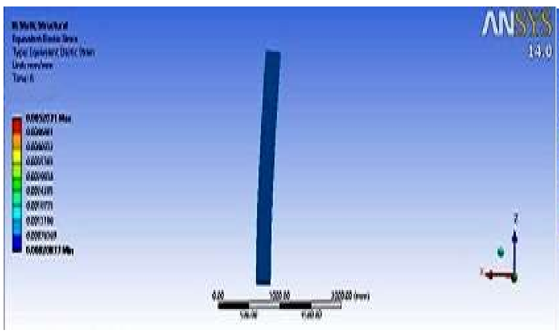

Fig. 8 GFRP 1.3mm thick layer

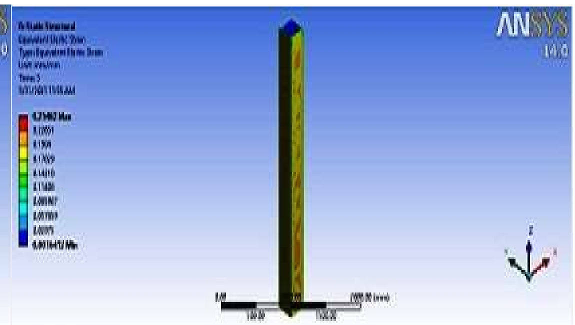

Fig. 9 CFRP 2 mm thick layer

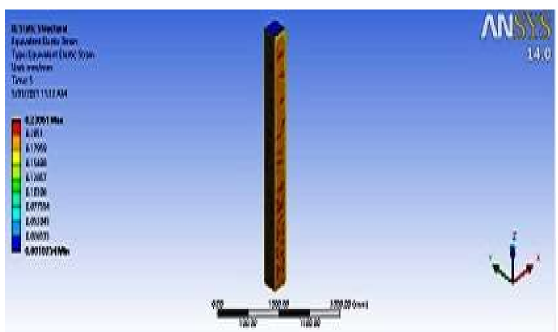

Fig. 10 GFRP 2.6 mm thick layer

4.3 Analytical Results Displaying Stress

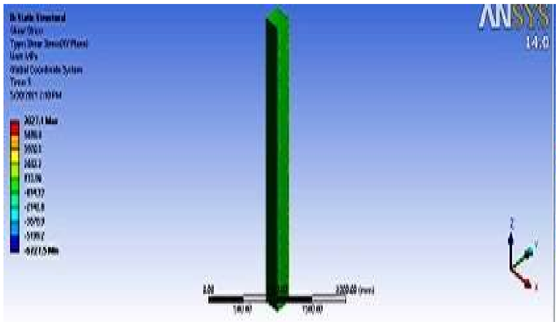

Fig. 11 CONTROL COLUMN

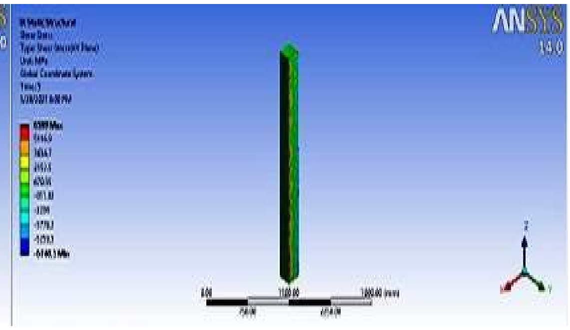

Fig. 12 CFRP 1mm thick layer

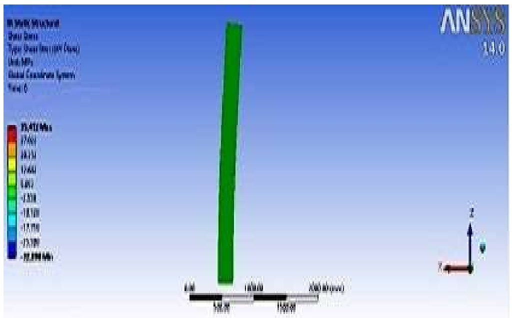

Fig. 13 GFRP 1.3mm thick layer

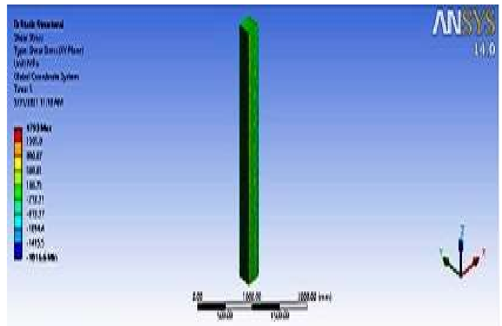

Fig. 14 CFRP 2 mm thick layer

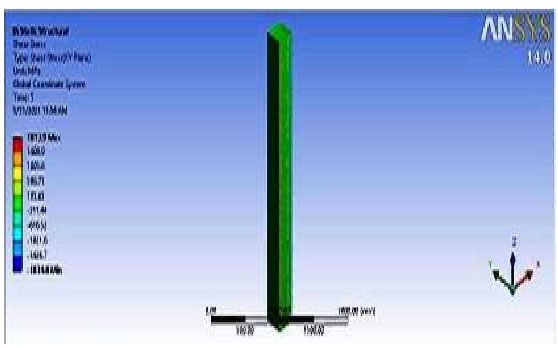

Fig. 15 GFRP 2.6 mm thick layer

Table 3

Represent the value of deflection, strain & stress of control column and retrofitted columns of with CFRP (1mm,2mm) thick sheets & GFRP (1mm,2mm) thick sheets at different temperature (26,100,200,300,400,500 ^{0}C).

MODEL	**Temperature (^{0}C)**	**Deflection (mm)**	**Strain (MPa)**	**Shear stress (MPa)**
Control column	26	3.3147	0.032	81.41
	100	4.8313	0.072	1153.9
	200	14.01	0.095	2622.2

		70		
	300	23.3050	0.148	4090.5
	400	32.5930	0.201	5558.8
	500	41.8800	0.254	7027.1
CFRP 1mm thick layer	26	1.0536	0.0052	48
	100	1.5441	0.047	790.7
	200	6.8939	0.058	2000.9
	300	12.8459	0.130	2755.6
	400	19.2965	0.170	3795.2
	500	25.1474	0.220	4749.7
GFRP 1.3mm thick layer	26	1.5675	0.009	60
	100	2.2964	0.058	1083.8
	200	9.5688	0.090	2462.6
	300	12.8459	0.141	3841.4
	400	19.2965	0.191	5220.2
	500	25.1474	0.241	6599.0
CFRP 2mm thick layer	26	1.5675	0.0025	28.81
	100	0.9809	0.027	345.36
	200	4.4003	0.048	1156.81
	300	7.7529	0.115	2138.64
	400	11.5040	0.150	3206.49
	500	15.2560	0.198	3928.73
GFRP 2.6mm thick layer	26	2.0645	0.0038	45.78
	100	1.4721	0.034	765.6
	200	6.7283	0.071	1607.78

	300	11.98 70	0.134	2507.35
	400	17.24 60	0.182	3834.26
	500	22.50 50	0.225	3928.73

- Control column displayed reasonable deflection upto 100 ^{0}C,but at elevated temperature above 100 ^{0}C the deflection observed was beyond the permissible limit.
- CFRP confinement improves ultimate load carrying capacity & reduces deflection.
- At temperature between 100 to 500 ^{0}C load carrying of confined columns were significantly enhanced with increasing the thickness of CFRP sheets & GFRP sheets, as its enhancement ratio was about 86% and 33.51% respectively.
- At temperatures ranging from 200 to 500 ^{0}C, both GFRP(1.3mm thick) & CFRP(1mm) sheets 2-5% variation in equivalent elastic strain was observed .
- At temperatures ranging from 100 to 500 ^{0}C, both GFRP(2.6mm thick) & CFRP(2mm) sheets negligible variation in equivalent elastic strain was observed .
- The Shear stress of confined columns were significantly reduced with increasing the thickness of CFRP sheet & GFRP sheet, as its decreased by was about 6.01% and 1.05% respectively.

CONCLUSION

From the above results, it is concluded that there is a benefit of using CFRP (1mm, 2mm) thick sheets rather than GFRP (1.3mm, 2.6mm) thick sheets for retrofitting at elevated temperature. It's seems in analysis 2mm thick CFRP sheets performed best by reducing the deflection upto 24.88% than rest of the other at elevated temperature ranging 100-500 ^{0}C. FRP composites were found effective in enhancing the axial load capacity of exposed columns provided that the temperature at the FRP level does not exceed the decomposition limit of the epoxy resin. The degradation in strength and stiffness was higher in GFRP-strengthened columns compared with CFRP-strengthened columns when exposed to the same temperature level.

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