IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

COMPARATIVE STUDY ON THE SEISMIC PERFORMANCE ASSESSMENT OF AN EXISTING BUILDING WITH AND WITHOUT RETROFIT STRATEGIES

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***Abstract*:** Civil engineering is the field of exploring the limits of buildings structures and for discovering technologies to make the buildings go higher, last longer and consist of lighter materials. Retrofitting technique is used to increase the strength and ductility of building also helps in up gradation of lateral strength. In this project work behaviour and performance of lateral load resisting system i.e. structure with FRP laminates with various methods is observed. CFRP sheet are used in this project work. CFRP have been used in different industries like automotive, aerospace and building structures. They also been using in other applications because of their low weight and stiffness. In this present work a G+4 storey building is situated in Aurangabad. On that building various NDT tests are carried out and results are collected. Then that building modelled in ETABS software to find out axial force, shear force and bending moment. This model are analysed for Static structural behaviour. On the basis of NDT test results, select the critical column for retrofitting. That column modelled in ANSYS software and CFRP sheet is attached to that column with various methods. And then analysis is done in ANSYS with forces which are finding out in ETABS model analysis. Based on this parametric study, logical and meaningful conclusion is made for future study considering the safety and economy of the buildings.

***Index Terms* - Retrofitting, CFRP, NDT, ETABS, ANSYS.**

I. INTRODUCTION

Seismic protection of buildings is an important concept to improve the performance of any structure under earthquakes. Earthquakes of various magnitudes have in India, causing extensive damage to life and property. In the world, India is one of the most earthquake prone countries and has experienced several major or moderate earthquakes during the last 15 years. About 50-60% of the total area of the country is comes under the various seismic activities. Many existing buildings are not design as per seismic strength requirement. The seismic retrofitting of an existing building can consider due to some reasons like: building not designed to code, subsequent updating of code and design practice, subsequent upgrading of seismic zone, modification of existing structure, change in function of the building, etc. Seismic retrofit is primarily applied to provide public safety. The deterioration of the structures takes place due to weathering action, fire, natural disasters like earthquake, flood, tsunami, cyclones, and defects in construction. Post the technical evaluation of such structures, the decision is taken either repair or replaces a component of structure. This has to be taken into consideration with economy, construction feasibility and as per latest trends and techniques. The selection of materials and techniques which is used for retrofitting depends on various factors like requirement and availability of financial resources and materials for the repair of damaged structures. Use of standard repair materials, proper technology, accurate workmanship and quality control are the main things for successful repair, strengthening and restoration of damaged structures.

II. SIGNIFICANCE OF RETROFITTING

Seismic retrofitting is very important for existing structures to make them more resistant to seismic activity, ground motion or soil failure due to earthquakes. Seismic retrofitting is important concept for the better understanding of seismic demand on structure. The retrofit techniques are considered for other natural hazards such as cyclones, tornadoes and thunderstorms.

III. MAJOR CAUSES FOR DETERIORATION OF STRUCTURES

Concrete provides excellent corrosion protection to reinforcement. The high alkaline environment in concrete forms a protective oxide film on steel bars. When concrete is not well compacted and dense, it is undergoes into carbonation, capacity loss to protect reinforcement. The deterioration of typical concrete structure starts from the time it is exposed to the nature, high humidity, high temperature & variation in temperature. Some factors such as temperature variations, pollution, wind, rains, floods etc. contribute towards deterioration. Various causes which create conducive conditions to accelerate/propagate rate of corrosion are as under:

1. Inadequate cover to reinforcement.
2. Use of inadequate grade of concrete for the purpose.
3. Use of rusted steel.
4. Workmanship/workability/compaction, thus leaving concrete porous.
5. Poor unsuitable ingredients (both coarse & fine aggregate).
6. Use of high W/C ratio resulting in fine hairline cracks in concrete during drying.
7. Use of water containing high incidence of salts/sulphates.
8. Wave action (alternate wetting and drying processes).
9. Presence of harmful gases in the air.
10. Contact with acids/fumes.
11. Exposures to relatively high humidity (>70%).

Advantages of retrofitting

1. When retrofitting approach is adopted, retrofitting building can still be operated.
2. Retrofitting will take relatively less construction cost with similar structural performance achievement.
3. Retrofitting will involve relatively less resources, either human resources or natural resources.
4. Retrofitting will not significantly change the building configuration and shape. It is preferable when the retrofitted building has historical values.
5. Retrofitting the building will produce less debris than reconstructing the building.

Disadvantages of retrofitting

1. The skill of the worker must comply with the adopted retrofitting approaches.
2. Limited access of the construction site, since the building could be still in function.

IV. NDT (NON-DESTRUCTIVE TESTS)

Commonly adopted NDT methods

1. Rebound Hammer Test
2. Ultrasonic Pulse Velocity Test
3. Rebar Locater Test (Cover meter test)
4. Corrosion Analysis Test
5. Resistivity Meter Test
6. Impact Echo/Pulse Echo Test
7. Ground Penetrating Radar Test

V. AIM AND OBJECTIVES OF RETROFITTING OF STRUCTURE

1. To increase the lateral strength of the structure by increasing stiffness of the structural member.
2. The aim is to increase the ductility of the structural member.
3. To maintain the economy of the retrofitting technique.
4. Conduct analytical investigation of building to find out axial force, shear force on particular member using ETABS.
5. Conduct analytical investigation to compare the structural member without CFRP wrapping, full CFRP wrapping and strip CFRP wrapping by using ANSYS.
6. Carry a parametric study of parameters such as total deformation, equivalent stress and equivalent strain.
7. Provide a logical and meaningful conclusion for future study considering the safety and economy of the building.

VI. STAGES OF WORK

1. A G+4 on-going / under construction structure which is situated in Aurangabad. It is used as a case study for this project work. NDT tests were done on all the structural members because cubes are failed after 28 days testing. NDT tests like rebound hammer test and ultrasonic pulse velocity test are carried out. All the NDT reports, structural drawings are available.
2. Before ETABS modelling, it is required to draw centre line plan in AutoCAD. So, in ETABS it is easy to model the building.
3. Before applying retrofitting methods need to prepared ETABS model of above case study to find out the column, beam reactions like axial force, and shear force and bending moment.
4. Then last stage is prepared ANSYS model of critical column and beam of above case study. Then apply CFRP wrapping in various iterations till to get economical and safer solution.

VII. INPUT DATA FOR THE MODEL

Table 1: Input data for the Model

Geometrical Data		
1	Size of Plan	25.175 m x 11 m
2	Height of Storey	3 m
3	No. of Storeys	G+4
Materials		
4	Grade of Columns	M25
5	Grade of Steel	Fe500
6	Density of Concrete	25 KN/m^3
7	Density of brick	20 KN/m^3
Element Sizes in mm		

8	Columns (Line Element)	150 X 300, 230 X 600, 300 X 600
9	Beams (Line Elements)	150 X 380, 230 X 380, 230 X 450, 230 X 530, 300 X 530, 300 X 450
10	Slabs (Membrane)	125 mm and 150 mm thick
11	CFRP thickness	2 mm
Seismic Parameter		
12	Seismic Zone Factor	0.10 (Zone II)
13	Response Reduction Factor	5.0
14	Importance Factor	1.0
15	Response Spectra	IS 1893
16	Soil Type	Type 2 (Medium)
Load Patterns		
18	Live load on floors	3 KN/m^2
19	Live load on terrace floor	1.5 KN/m^2
20	Dead load on all floors	2 KN/m^2
21	Wall load	11.73 KN/m
22	Parapet wall load	4.6 KN/m

VIII. NDT RESULTS

1. Ultrasonic Pulse Velocity Test

i. Method used: Non Destructive Test (N.D.T.) Ultrasonic Pulse Velocity test as per IS: 516 (Part 5 / Sec 1): 2018
ii. Date of performance: 02/09/2022

Table 2: Ultrasonic pulse velocity test

Sr. No.	Location	Method	Ultrasonic pulse velocity in km / sec	Remark
Ground Floor				
1	C1	Direct Probe	3.36	Doubtful
2	C4	Direct Probe	3.15	Doubtful
3	C5	Direct Probe	3.90	Good
4	C6	Direct Probe	2.76	Doubtful
5	C7	Direct Probe	3.36	Doubtful
6	C10	Direct Probe	4.1	Good
7	C8	Direct Probe	3.13	Doubtful
8	C9	Direct Probe	3.18	Doubtful
9	C15	Direct Probe	3.03	Doubtful
10	C12	Direct Probe	3.36	Doubtful
11	C11	Direct Probe	3.15	Doubtful
12	C13	Direct Probe	3.13	Doubtful
13	C14	Direct Probe	3.90	Good
14	C16	Direct Probe	4.10	Good
15	C17	Direct Probe	3.40	Doubtful
16	C21	Direct Probe	2.79	Doubtful
17	C19	Direct Probe	3.90	Good
18	C18	Direct Probe	3.90	Good
19	C20	Direct Probe	3.18	Doubtful
20	C22	Direct Probe	3.60	Doubtful
21	C23	Direct Probe	4.10	Good

Table 3: Velocity criterion for concrete quality grading

Sr. No.	Average value of pulse velocity by cross probing Km/sec	Concrete quality grading
1	Above 4.40	Excellent
2	3.75 to 4.40	Good
3	3.00 to 3.75	Doubtful
4	Below 3.00	Poor
In case of doubtful quality it may be necessary to carry out further tests.		

2. Rebound Hammer Test

i. Method used: Non Destructive Test (N.D.T.) Rebound hammer test as per IS: 516 (Part 5 / Sec 4): 2020

ii. Date of performance: 02/09/2022

Table 4: Rebound hammer test

Sr. No.	Location on site		Position	Rebound hammer test	
				Observed Q - values	Range of observed concrete strength (fck) N/mm^2
Ground Floor					
1	C1	T	H	12.1	BELOW M-10 GRADE
2		B	H	14.6	BELOW M-10 GRADE
3	C4	T	H	18.6	BELOW M-10 GRADE
4		M	H	23.4	10 to 11
5	C5	M	H	34.0	21 to 22
6		B	H	33.8	20 to 21
7	C6	T	H	29.9	16 to 17
8		M	H	23.4	10 to 11
9	C7	T	H	26.4	13 to 14
10		B	H	27.7	14 to 15
11	C10	T	H	37.7	24 to 25
12		B	H	32.9	19 to 20
13	C9	M	H	26.2	13 to 14
14		B	H	36.1	23 to 24
15	C8	T	H	19.5	BELOW M-10 GRADE
16		B	H	32.0	19 to 20
17	C12	M	H	34.5	21 to 22
18		B	H	27.9	14 to 15
19	C11	T	H	20.5	BELOW M-10 GRADE
20		B	H	28.6	15 to 16
21	C13	T	H	15.0	BELOW M-10 GRADE
22		B	H	25.1	12 to 13
23	C14	B	H	30.6	17 to 18
24		M	H	36.1	23 to 24
25	C15	T	H	20.6	BELOW M-10 GRADE
26		B	H	32.8	19 to 20
27	C16	M	H	33.3	20 to 21
28		B	H	30.4	17 to 18
29	C19	T	H	18.0	BELOW M-10 GRADE
30		B	H	25.5	12 to 13
31	C18	M	H	26.8	13 to 14
32		B	H	32.6	19 to 20
33		M	H	27.7	14 to 15
34	C17	M	H	33.7	20 to 21
35		T	H	30.4	17 to 18
36	C20	T	H	19.6	BELOW M-10 GRADE
37		B	H	27.8	14 to 15
38	C21	M	H	28.0	15 to 16
39		B	H	35.8	22 to 23
40	C22	M	H	36.7	23 to 24
41		T	H	24.1	11 to 12
42	C23	M	H	30.4	17 to 18
43		B	H	37.5	24 to 25

IX. COLUMN BEAM LAYOUT PLAN

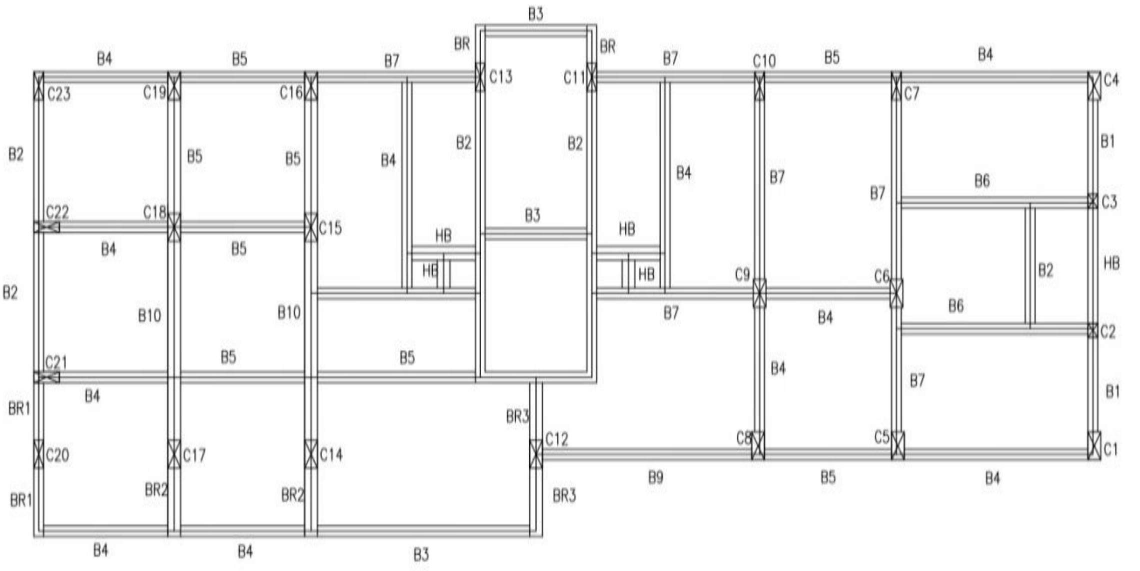


Fig 1: Column beam naming plan in AutoCAD
(Source: AutoCAD 2017)

X. ETABS MODEL

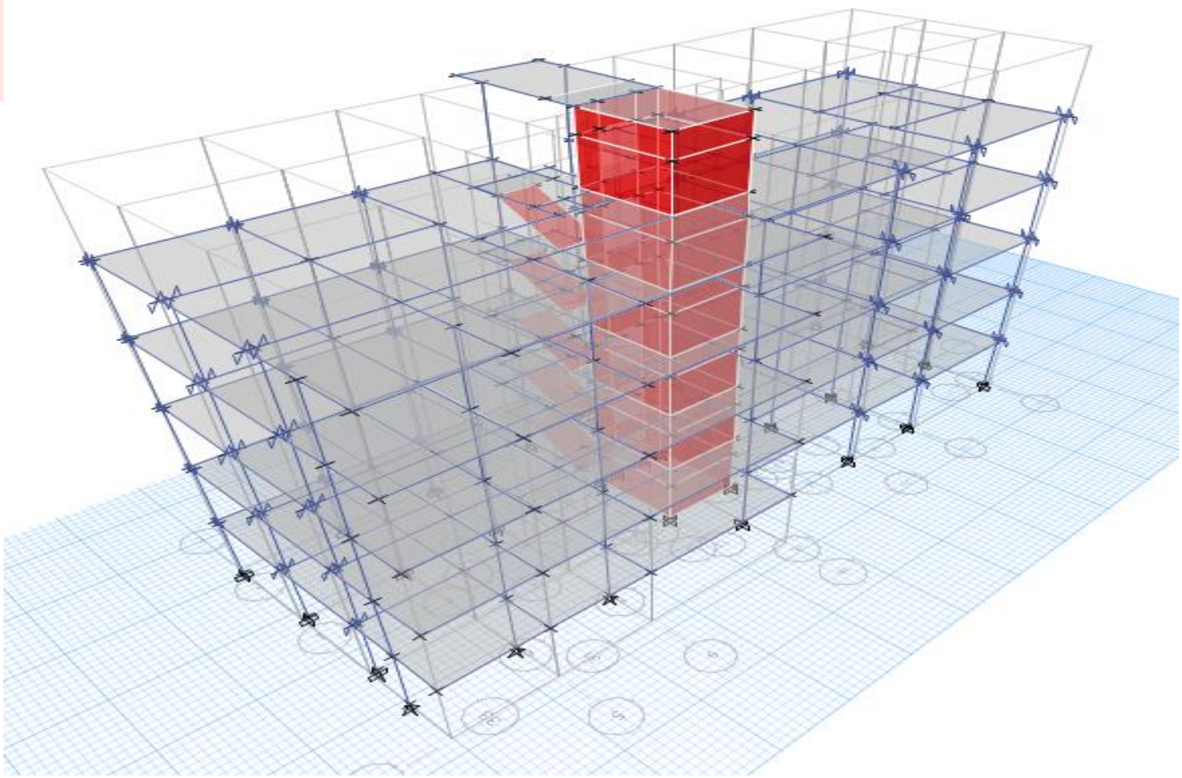


Fig 2: 3D view of ETABS model
(Source: ETABS 2018)

XI. ANSYS MODEL

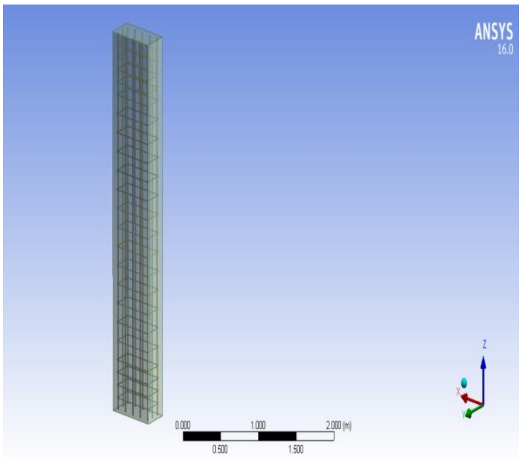


Fig 3: Without wrapping
(Source: ANSYS 2016)

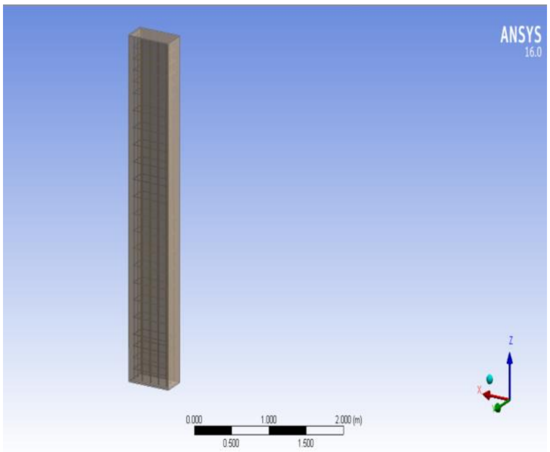


Fig 4: Full wrapping
(Source: ANSYS 2016)

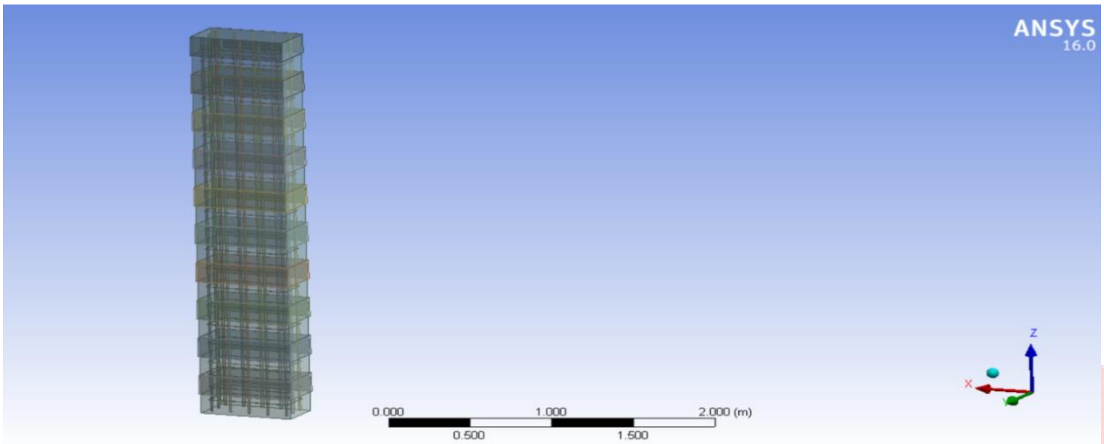


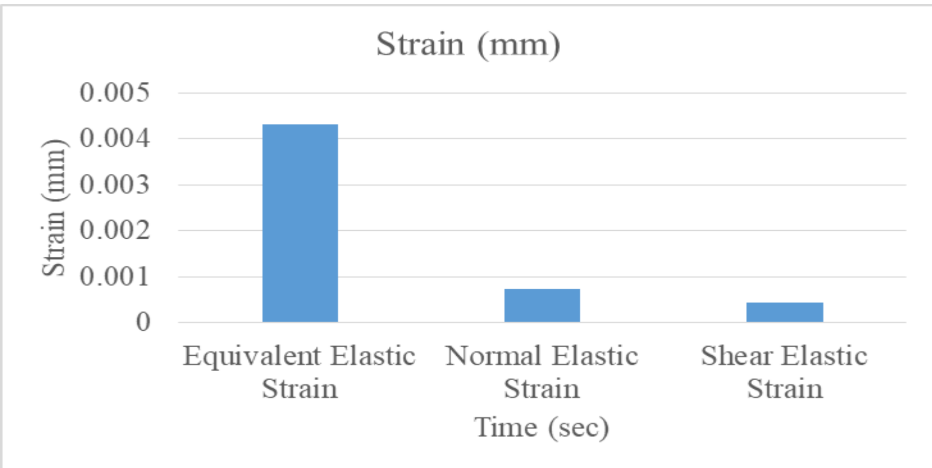
Fig 5: Strip wrapping
(Source: ANSYS 2016)

XII. RESULT AND DISCUSSION

12.1Column without wrapping

Table 5: Values of equivalent, normal and shear elastic strain

Without wrapping		
Equivalent Elastic Strain	Normal Elastic Strain	Shear Elastic Strain
0.0043095	0.00073238	0.00043961

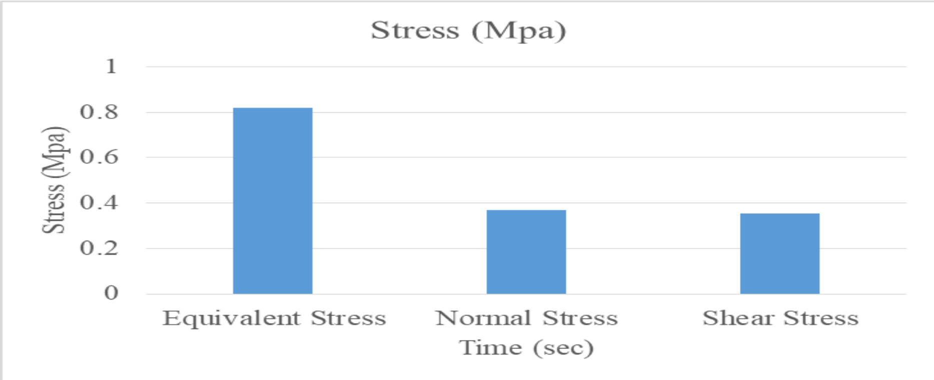


Graph 1: Equivalent, normal and shear elastic strain

Table 6: Values of equivalent, normal and shear stresses

Without wrapping

Equivalent Stress	Normal Stress	Shear Stress
0.8188	0.36901	0.35392

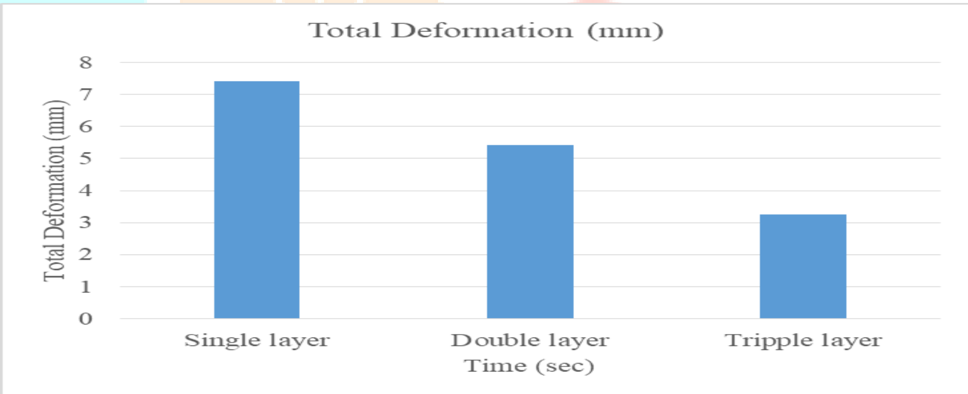


Graph 2: Equivalent, normal and shear stress

12.2Column full wrapping with single layer, double layer and triple layer

Table 7: Total deformation of column with full wrapping

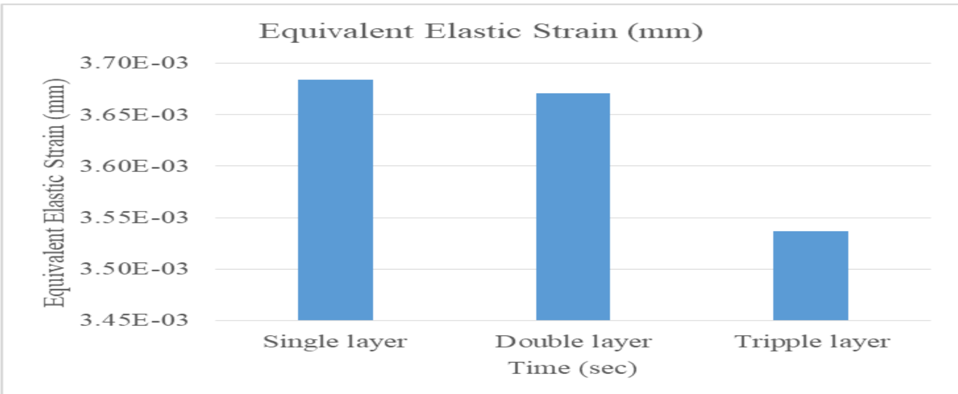
Total Deformation (mm)		
Single layer	Double layer	Triple layer
7.4018	5.4091	3.2604



Graph 3: Total deformation in single, double and triple layer

Table 8: Equivalent elastic strain of column with full wrapping

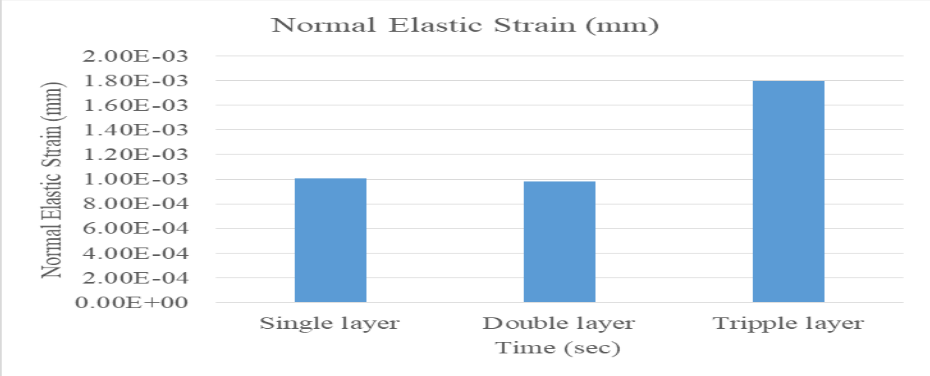
Equivalent Elastic Strain (mm)		
Single layer	Double layer	Triple layer
3.68E-03	3.67E-03	3.54E-03



Graph 4: Equivalent elastic strain in single, double and triple layer

Table 9: Normal elastic strain of column with full wrapping

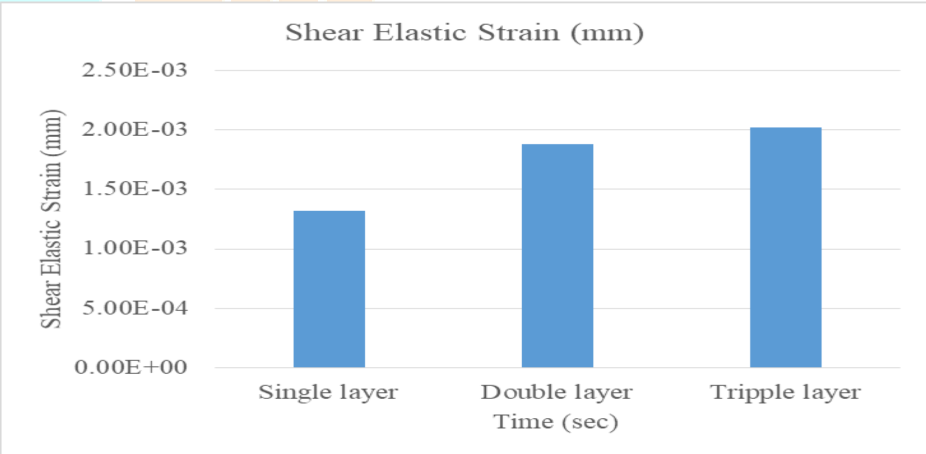
Normal Elastic Strain (mm)		
Single layer	Double layer	Triple layer
1.01E-03	9.83E-04	1.80E-03



Graph 5: Normal elastic strain in single, double and triple layer

Table 10: Shear elastic strain of column with full wrapping

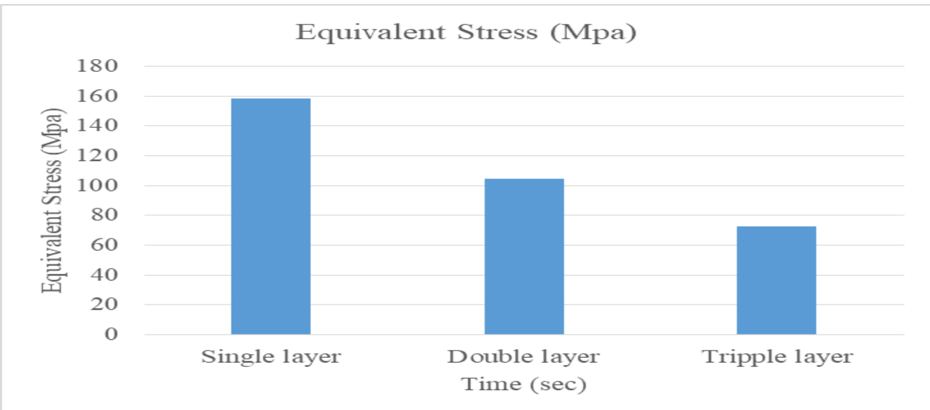
Shear Elastic Strain (mm)		
Single layer	Double layer	Triple layer
1.32E-03	1.88E-03	2.02E-03



Graph 6: Shear elastic strain in single, double and triple layer

Table 11: Equivalent stress of column with full wrapping

Equivalent Stress (MPa)		
Single layer	Double layer	Triple layer
158.66	104.57	72.532

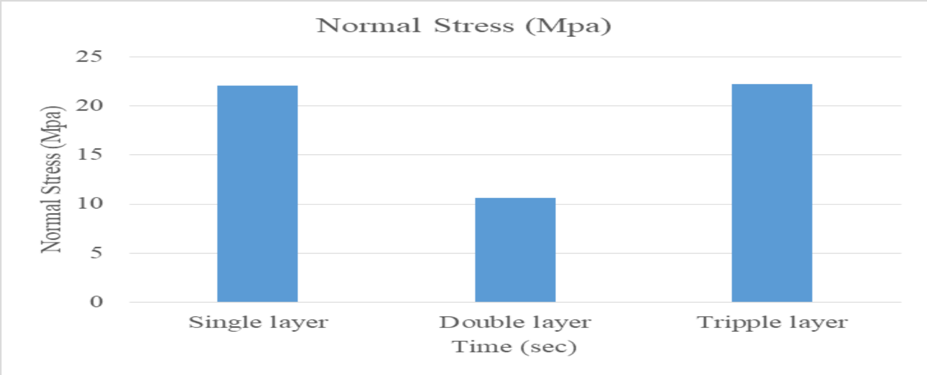


Graph 7: Equivalent stress in single, double and triple layer

Table 12: Normal stress of column with full wrapping

Normal Stress (MPa)

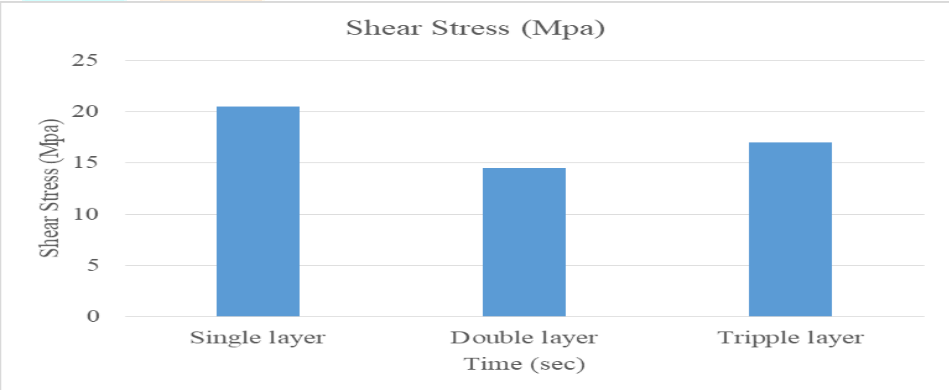
Single layer	Double layer	Triple layer
22.098	10.631	22.213



Graph 8: Normal stress in single, double and triple layer

Table 13: Shear stress of column with full wrapping

Shear Stress (MPa)		
Single layer	Double layer	Triple layer
20.518	14.493	17.044

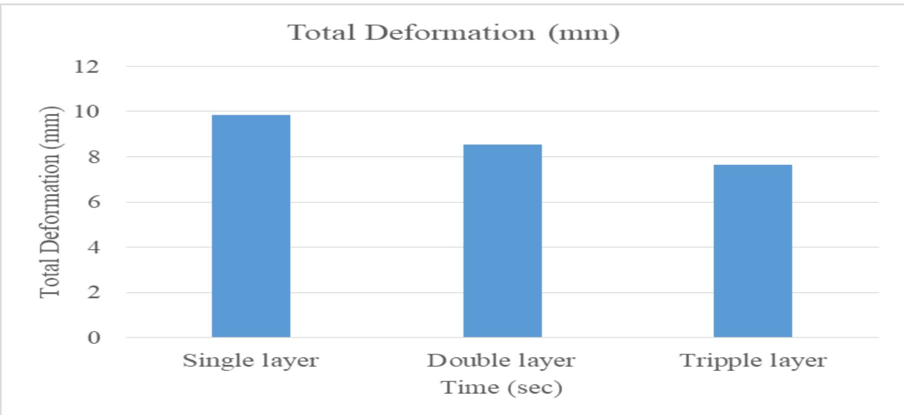


Graph 9: Shear stress in single, double and triple layer

12.3Column strip wrapping with single layer, double layer and triple layer

Table 14: Total deformation of column with strip wrapping

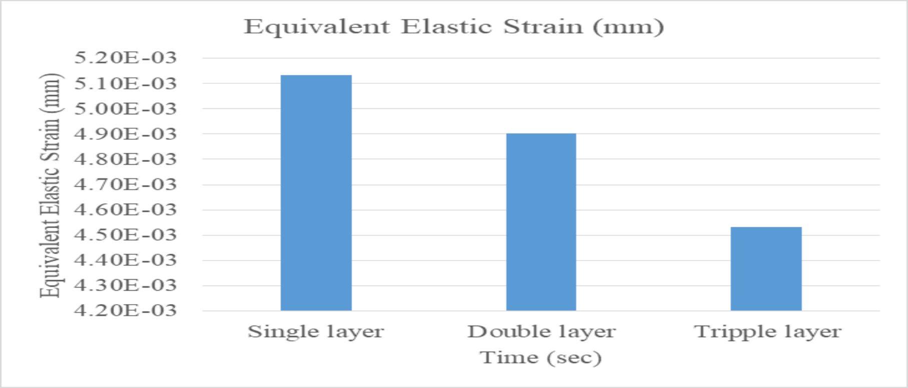
Total Deformation (mm)		
Single layer	Double layer	Triple layer
9.8607	8.559	7.6422



Graph 10: Total deformation in single, double and triple layer

Table 15: Equivalent elastic strain of column with strip wrapping

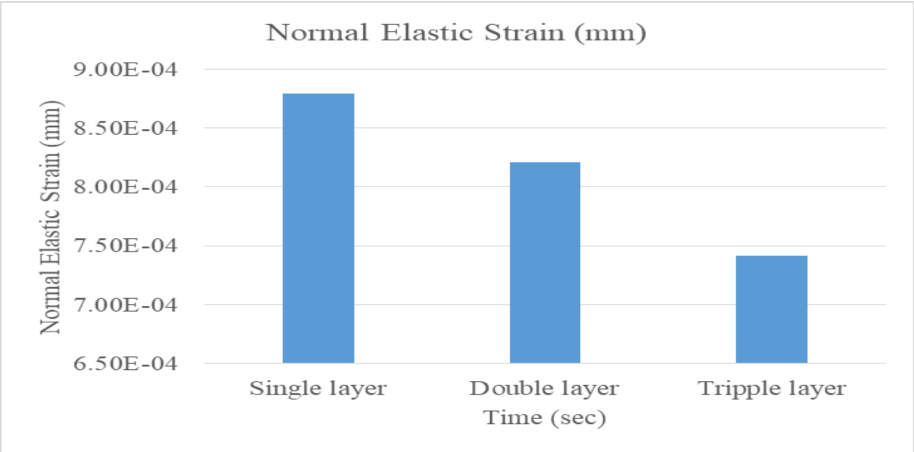
Equivalent Elastic Strain (mm)		
Single layer	Double layer	Triple layer
5.13E-03	4.90E-03	4.53E-03



Graph 11: Equivalent elastic strain in single, double and triple layer

Table 16: Normal elastic strain of column with strip wrapping

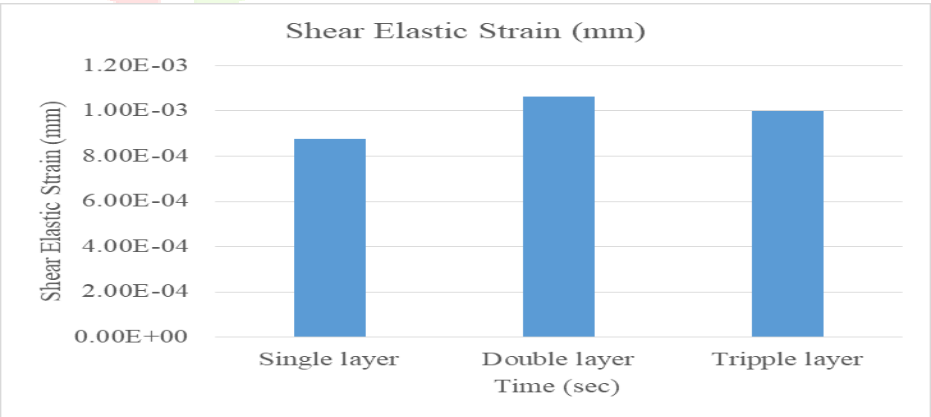
Normal Elastic Strain (mm)		
Single layer	Double layer	Triple layer
8.80E-04	8.21E-04	7.41E-04



Graph 12: Normal elastic strain in single, double and triple layer

Table 17: Shear elastic strain of column with strip wrapping

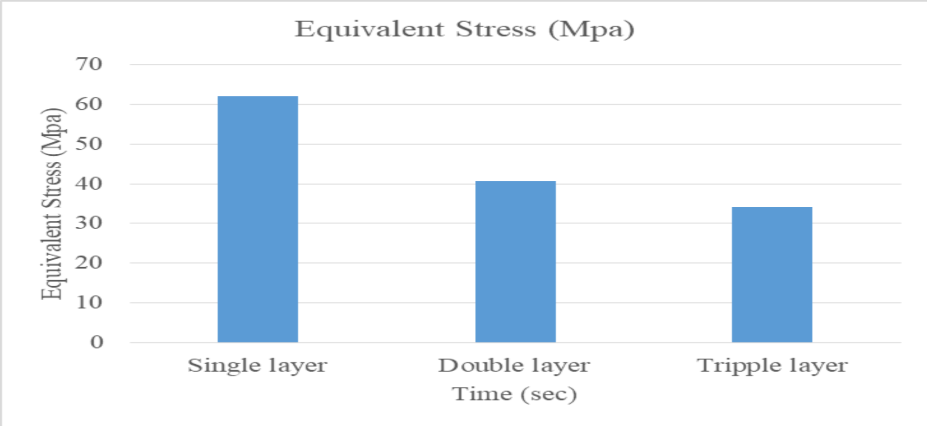
Shear Elastic Strain (mm)		
Single layer	Double layer	Triple layer
8.75E-04	1.06E-03	1.00E-03



Graph 13: Shear elastic strain in single, double and triple layer

Table 18: Equivalent stress of column with strip wrapping

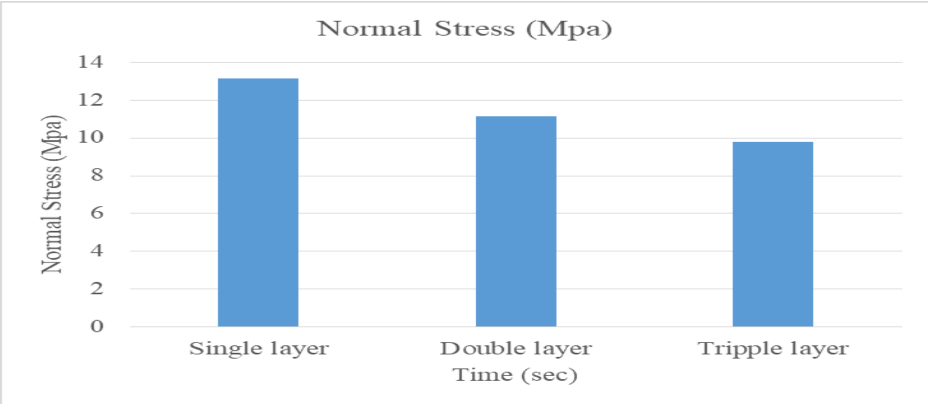
Equivalent Stress (MPa)		
Single layer	Double layer	Triple layer
62.082	40.59	34.093



Graph 14: Equivalent stress in single, double and triple layer

Table 19: Normal stress of column with strip wrapping

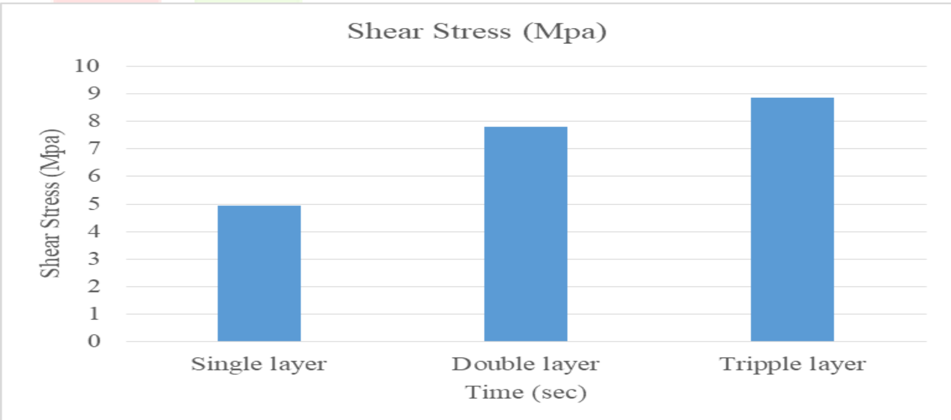
Normal Stress (MPa)		
Single layer	Double layer	Triple layer
13.134	11.137	9.7914



Graph 15: Normal stress in single, double and triple layer

Table 20: Shear stress of column with strip wrapping

Shear Stress (MPa)		
Single layer	Double layer	Triple layer
4.9341	7.795	8.8546



Graph 16: Shear stress in single, double and triple layer

XIII. CONCLUSION

1. CFRP material is used for the retrofitting of the column and in that various methods used such as full wrapping and strip wrapping. Also in that single layer, double layer and triple layer wrapping of CFRP sheet used in each condition.
2. It is observed that minimum deformation in full wrapping is in triple layer which is 3.2604 mm and minimum deformation in strip wrapping is also in triple layer which is 7.6422 mm.
3. It is observed that minimum equivalent elastic strain in full wrapping is in triple layer which is 0.00354 mm and minimum equivalent elastic strain in strip wrapping is also in triple layer which is 0.00453 mm.

4. It is observed that minimum normal elastic strain in full wrapping is in double layer which is 0.000983 mm and minimum normal elastic strain in strip wrapping is in triple layer which is 0.000741 mm.
5. It is observed that minimum shear elastic strain in full wrapping is in single layer which is 0.00132 mm and minimum shear elastic strain in strip wrapping is also in single layer which is 0.000875 mm.
6. It is observed that minimum equivalent stress in full wrapping is in triple layer which is 72.532 MPa and minimum equivalent stress in strip wrapping is also in triple layer which is 34.093 MPa.
7. It is observed that minimum normal stress in full wrapping is in double layer which is 10.631 MPa and minimum normal stress in strip wrapping is in triple layer which is 9.7914 MPa.
8. It is observed that minimum shear stress in full wrapping is in double layer which is 14.493 MPa and minimum equivalent stress in strip wrapping is in single layer which is 4.9341 MPa.
9. In full wrapping condition, it is observe that results are satisfied in double layer wrapping and triple layer wrapping. But by considering the economy factor it is observed that CFRP material is costly. So for this full wrapping condition, use CFRP sheet of 2 mm thickness in double layer. So both conditions like strength and economy are satisfied.
10. In strip wrapping condition, it is observe that results are satisfied in double layer wrapping and triple layer wrapping. But by considering the economy factor it is observed that CFRP material is costly. So for this strip wrapping condition, use CFRP sheet of 2 mm thickness and 150 mm width in double layer. So both conditions like strength and economy are satisfied.
11. Now comparing both conditions full wrapping and strip wrapping, it is observed that full wrapping is always gives better strength than strip wrapping. But the economy is the main factor taken for final conclusion.
12. So considering the strength and economy of the retrofitting of structure final conclusion is made.
13. So the final conclusion is, use CFRP sheet with strip wrapping in triple layer with 2 mm thickness and 150 mm width than CFRP sheet with full wrapping in double layer or triple layer.
14. CFRP sheet with strip wrapping in triple layer gives better strength to the column and it is also economical to adopt.
15. From the finite element analysis using ANSYS, it is confirmed that the building retrofitted using CFRP sheet with strip wrapping in triple layer stand efficiently against deformation.

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