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Retrofitting of Existing RC Columns by Reinforced Concrete Jacketing Using ANSYS and ETABS

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Abstract: ***Retrofitting is a technique to improve the structural capacities including the strength, stiffness, ductility, stability of a building that is found to be deficient. It can effectively improve the performance of a building. In this paper, an RC building of G+3 will be analyzed and design in E-tabs software. Then the number of floors will increased to 3 numbers above the top floor of existing building so that the building becomes G+6 floors and again it is increased by 2 numbers above the top floor of existing building then it becomes G+8 floors. Because of increment of floors the load on the building will be increased so the existing columns may fail in design the failure of columns may be maximum in bottom storey, so how many number of columns fail the same will rectified by Reinforced Concrete jacketing technique, because of jacketing the column strength will increased and the jacketing will be design to carry the increased load by using IS code (IS 15988:2013) and the jacketing will be done in ANSYS software. In the software each failed column will be modeled and the increased area of reinforced column can able to take an increased load so the building can raised to the above mentioned floors. Hence columns can be strengthened to carry the increased load safely.***

Keywords: Concrete Jacketing, Retrofitting, ANSYS Software, Strengthing

1. Introduction

Retrofitting is technical interventions in structural system of a building that improve the resistance to earthquake by optimizing the strength, ductility and earthquake loads. Strength of the building is generated from the structural dimensions, materials, shape, and number of structural elements, etc. Ductility of the building is generated from good detailing, materials used, degree of seismic resistant, etc. Earthquake load is generated from the site seismicity, mass of the structures, important of buildings, degree of seismic resistant, etc. Due to the variety of structural condition of building, it is hard to develop typical rules for retrofitting. Each building has different approaches depending on the structural deficiencies. Hence, engineers are needed to prepare and design the retrofitting approaches. In the design of retrofitting approach, the engineer must comply with the building codes. The results generated by the adopted retrofitting techniques must fulfil the minimum requirements on the buildings codes, such as deformation, detailing, strength, etc.

1.1. Purpose of Jacketing of Columns

There are two main purpose of jacketing of columns. (i) To increase in shear capacity of columns (strong column-weak beam design) (ii) To improve the column's flexural strength. After carrying out the detailed analysis of the existing building, deficient members are identified. A list of provided and required reinforcements is tabulated and highlighted. All these members require strengthening in order to increase their ductile strength. Hence, retrofitting of these members is carried out using Jacketing. It also increases the load carrying capacity, strength and increases the seismic resistance of the building without any demolition. It increases the ductile behaviour and lateral load capability of the building Strength and stiffness of the building is also improved.

1.2. Description of software used

ETABS is an engineering software product that caters to multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure. Basic or advanced systems under static or dynamic conditions may be evaluated using ETABS. The building is modeled and analyzed using ETABS. Then the failure columns are strengthen by providing jacketing in ANSYS software. After creating the column model the load is applied on both with and without jacketing column and compare the over stress between both original column and jacketing column. Using ANSYS, able to use various different material models to simulate the behavior of most typical engineering materials including metals, rubbers, polymers, composites, reinforced concrete, crushable and resilient foams, and geotechnical materials such as soils and rock Designed as general-purpose simulation tool, ANSYS can be used to study more than just structural (stress/displacement) problems. ANSYS offers a wide range of capabilities for simulation of linear and non linear applications.

1.3. Plan and elevation of building

Figure 1: Plan of the building

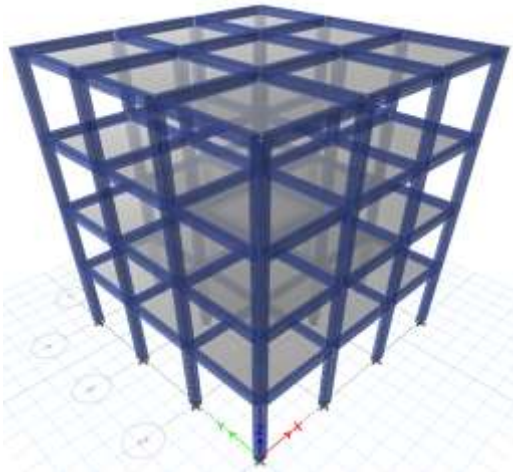

Figure 2: Elevation of the building

The number of columns failed in G+6 and G+8 buildings are tabulated as below,

Table 1: Failure of columns in G+6th floor building

Sl. No.	*Column name*	*Vertical load (P_u) in KN*	*Moment (M_u) in KN/m*
1	C6	1229.75	0.0609
2	C7	1229.75	0.0609
3	C10	1229.75	0.0609
4	C11	1229.75	0.0609

Table 2: Failure of columns in G+8th floor building

Sl. No.	*Column name*	*Vertical load (P_u) in KN*	*Moment (M_u) in KN/m*
1	C2	1237.20	2.889
2	C3	1237.20	2.889
3	C5	1272.21	3.627
4	C6	1624.04	0.0807
5	C7	1624.04	0.0807
6	C8	1272.21	3.627
7	C9	1272.21	3.627
8	C10	1624.04	0.0807
9	C11	1624.04	0.0807
10	C12	1272.21	3.627
11	C14	1237.20	2.889
12	C15	1237.20	2.889

1.4. Reinforced concrete jacketing of columns

The column jacketing is carried out as per recommendations of Indian standard code IS 15988 (2013): Seismic Evaluation and Strengthening of Existing Reinforced Concrete Buildings – Guidelines published By Bureau of Indian Standards [4]. Reinforced concrete jacketing improves column flexural strength and ductility. Closely spaced transverse reinforcement provided in the jacket improves the shear strength and ductility of the column.

1.5. Design of RC Column Jacketing using IS 15988: 2013

One design example for column no 6 in G+6 is given here:
Column No- 6
Height of column= 3000 mm; Width (b) =230 mm
Depth (D) =300 mm;Cover=40 mm
Therefore, d=300-40= 260mm;
Reinforcement provided= 6,12Ø=678.58 mm²
fy = 415 MPa; fck=30 MPa.
Pu = 1229.75 kN ; Mu = 0.0609 kN/m
Since, Pu = 0.4 × fck × Ac + 0.67 × fy × Asc

According to the provisions provided in to §8.5.1.2 (a) of IS 15988: 2013, Concrete strength shall be at least 5 MPa greater than the strength of the existing concrete. Thus, taking value of fck = 35 N/mm2 and assuming
Asc = 0.8% Ac
1229.75 x 10³ = 0.4 × 35×Ac + 0.67 × 415 × (0.8 %Ac) ;
Therefore, Ac = 75796.33 mm²
According to §8.5.1.1 (e) of IS 15988:2013,A'c =1.5Ac;
Thus, A'c =1.5x75796.33=113694.49 mm²
Assuming the cross sectional details as: B = 330mm;
D = 113694.49/330 = 344.52 mm
Jacketing details of cross section:
B = (330-230)/2 = 50 mm;
D = (344.52-300)/2 = 22.26 mm

However, According to the code specified above, Minimum jacket thickness shall be 100 mm as per §8.5.1.2 (c) of IS 15988:2013

Thus, New size of the column:
B = 230+100 +100 = 430mm,
D =300 +100 +100 = 500mm

New concrete area=430 × 500 = 215000mm² > Ac = 75796.33 mm²
Area of steel, As = 0.8% × 430 × 500 = 1720 mm²
But according to §8.5.1.1 (e) IS 15988:2013, A's = (4/3) As
A's= (4/3) x 1720 =2293.33 mm²
Assuming 12mm Ø bars,

Thus, number of bars, N = 2293.33 × 4/ (π x 12²) = 20.27 bars, Say 22 bars

Therefore, 22 no. -12mm Ø bars is for whole sections.

So, providing 16 NO. -12mm Ø bars for jacketed section. And jacketed section will be 430mm x 500 mm.

Table 3: Detailing of RC Jacket for 6 storey building

Sl No	*Column name*	*P_u in KN*	*Jacket*	*Jacketed C/S (mm²)*	*Lateral ties*
1	C6	1229.75	16-12Ø	430x500	8mmØ@150mmc/c
2	C7	1229.75	16-12Ø	430x500	8mmØ@150mmc/c
3	C10	1229.75	16-12Ø	430x500	8mmØ@150mmc/c
4	C11	1229.75	16-12Ø	430x500	8mmØ@150mmc/c

Similar design procedure is followed for G+8 building.

Table 4: Detailing of RC Jacket for 8 storey building

Sl No	*Column name*	*P_u in KN*	*Jacket*	*Jacketed C/S (mm²)*	*Lateral ties*
1	C2	1237.20	16-12Ø	16-12Ø	8mmØ@150mm c/c
2	C3	1237.20	16-12Ø	16-12Ø	8mmØ@150mm c/c
3	C5	1272.21	16-12Ø	16-12Ø	8mmØ@150mm c/c
4	C6	1624.04	16-12Ø	16-12Ø	8mmØ@150mm c/c
5	C7	1624.04	16-12Ø	16-12Ø	8mmØ@150mm c/c
6	C8	1272.21	16-12Ø	16-12Ø	8mmØ@150mm c/c
7	C9	1272.21	16-12Ø	16-12Ø	8mmØ@150mm c/c
8	C10	1624.04	16-12Ø	16-12Ø	8mmØ@150mm c/c
9	C11	1624.04	16-12Ø	16-12Ø	8mmØ@150mm c/c
10	C12	1272.21	16-12Ø	16-12Ø	8mmØ@150mm c/c
11	C14	1237.2	16-12Ø	16-12Ø	8mmØ@150mm c/c
12	C15	1237.2	16-12Ø	16-12Ø	8mmØ@150mm c/c

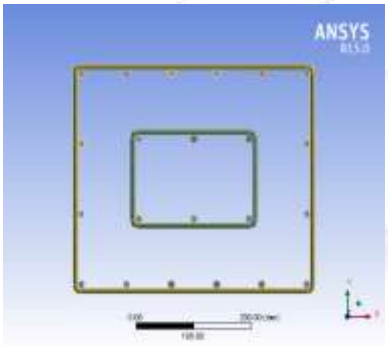

Figure 3: Column after jacketing

2. Material Properties

2.1. Steel

Table 5: Steel Properties

Sl No.	*Properties*	*Values*
1	Density	7849.05 Kg/m³
2	Modules Of Elasticity	200000 mpa
3	Poissons Ratio	0.3
4	Co-Efficient Of Thermal Expanction	0.0000117 1/c
5	Tensile Yield Strength	415 mpa
6	Tensile Ultimate Strength	485 a

2.2. Concrete

Table 6: Concrete Properties

Sl No.	*Properties*	*Values*
1	Density	2548.53 Kg/m³
2	Modules Of Elasticity	27386.13 mpa
3	Poissons Ratio	0.2
4	Co-Efficient Of Thermal Expanction	0.00000551/c
5	Shear Modules	11410.89
6	Compressive Strength	30 Mpa

3. Details of the Specimens

Table 7: dimension of specimens

Sl No.	*Section*	*Material*	*Dimension*
1	Beam	M20	300x230
2	Column	M30	300x200
3	Slab	M20	150

3.1. Finite element modelling

The cad modeling of column is carried out using finite element software i.e, ANSYS 15 work bench. The type of analysis carried out in ANSYS is linear static analysis. First we have to model a concrete control column specimen and with this we can generate the model of concrete jacketed column. The sizes of column used for modeling are 230X300X3000mm. After calculating the jacketing area as per the guidance of Indian standard code IS 15988:2013. The new jacketed dimension of the column is 500X430X3000mm. The minimum thickness of the jacketing is 100mm. The longitudinal reinforcement provided are 22 number of 12mm Ø bars and the lateral ties of 8mm Ø bars at a spacing of 150mm c/c. The 3-D modeling of column is carried out by generating the volumes in active coordinate system.

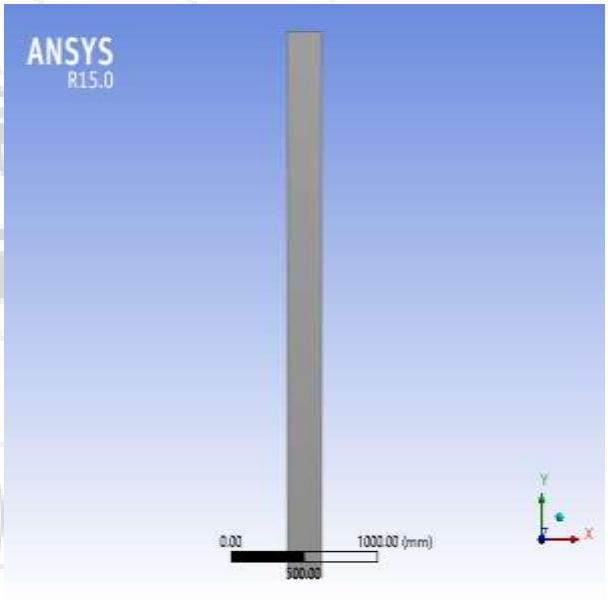

Figure 4: Model of column

3.1.1. Meshing

To obtain good results from the concrete solid element, the use of a rectangular mesh is recommended and tri-angular meshing is used for stirrups. The overall mesh of the volume is shown in Figure 5.

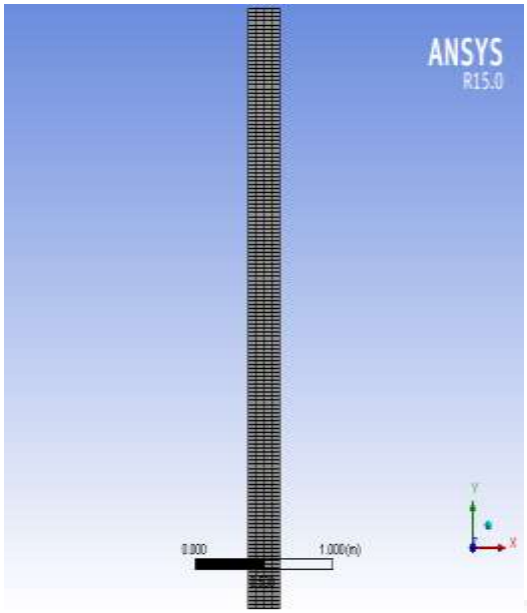

Figure 5. Meshing of column

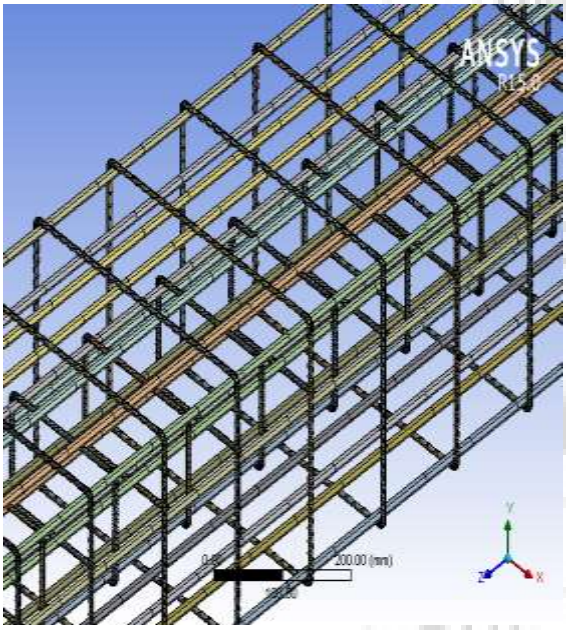

Figure 6. Meshing in with jacketing column reinforcement

3.1.2. Loading and Boundary Conditions

The hinged support is provided at the top end of the column and fixed support is provided at the bottom end of the column. The force is applied along Z-axis of the model. The force applied in the model is obtained from E-TABS by modeling a G+3 building in E-TABS and the numbers of floors are increased to G+6 & G+8 in E-TABS software.

4. Analysis of the model

The finite element model for this linear analysis is a simple column under compressive loading. For the purposes of this model, the linear static analysis is utilized. The Solution Controls command dictates the use of a linear or nonlinear solution for the finite element model. Here in this project the analysis is carried out for linear and small displacement. Analysis Is Carried By Modeling Both G+6 And G+8 Building, With And Without Jacketing Column In ANSYS Software.

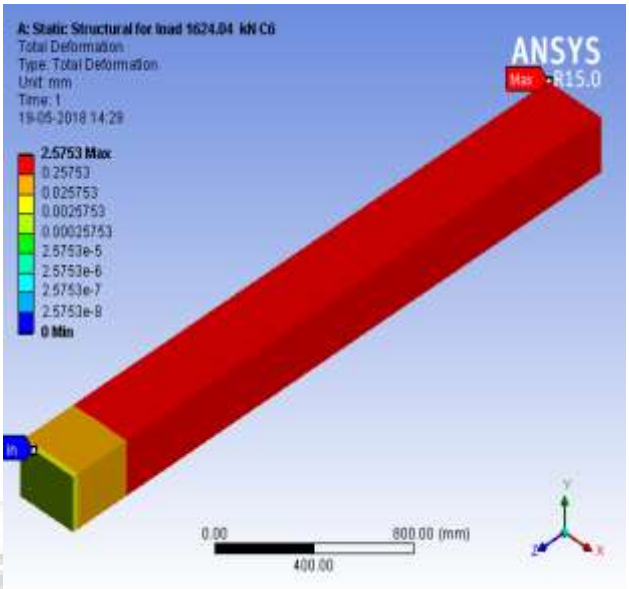

Figure 7: Column undergo total deformation in G+8th floor without jacketing.

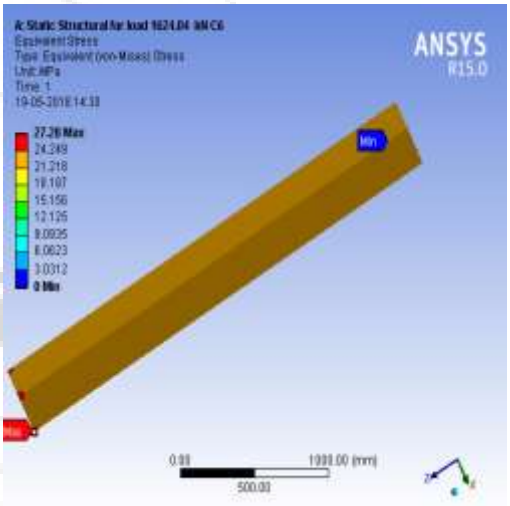

Figure 8: Stress in the column in G+8th floor without jacketing

The jacketing is designed for the failure column as per the guidance of Indian standard IS code 15988:2013. The new dimension of the jacketed column is 430X500 and the reinforcement provided in the column is 16 bars of 12mm dia for the jacketed area and the lateral ties of 8mm dia at 150mm c/c is provided. Then the failure load is applied on the jacketed column and analyse the column. After applying the load on the column, the stress in the jacketed column will be within the limit.

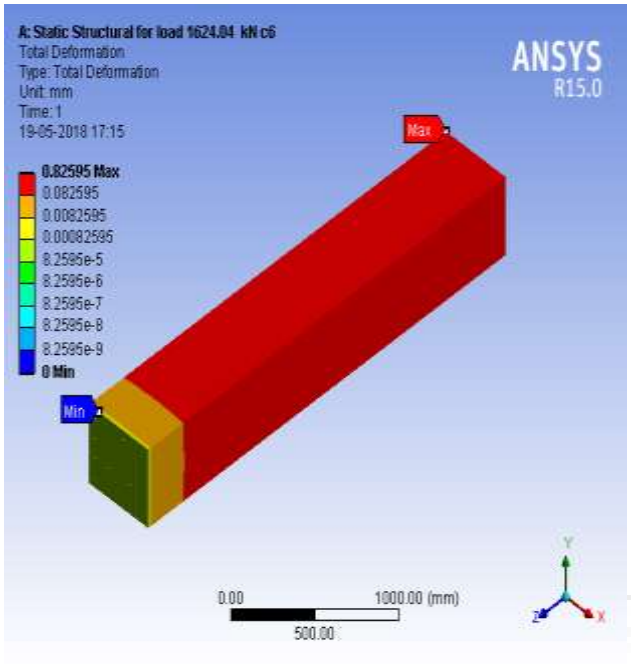

Figure 9: Deformation in G+8th floor column after jacketing

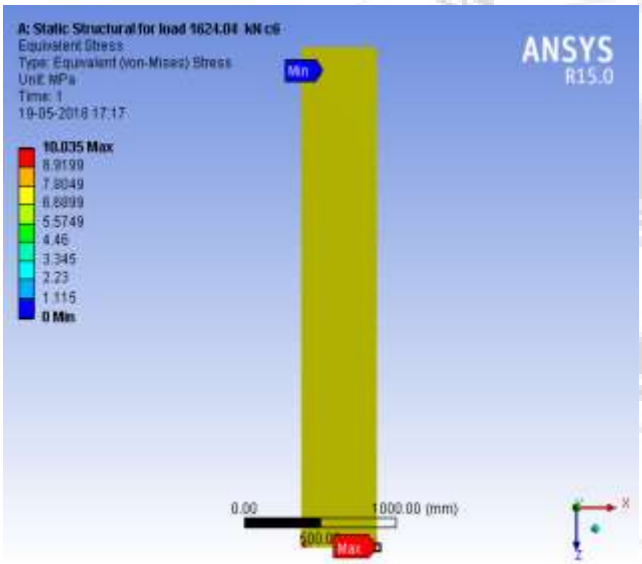

Figure 10: Stress in G+8th floor column after jacketing

4.1. Increment of load in columns

The load acting on the columns are gradually increased after providing the jacketing to get the increased load carrying capacity of the column. After stresses in the column and also deformation of the columns are note downed. The stresses and deformation in both G+6 and G+8 building are given below.

Table 8: Increment of load in G+6 building columns

Sl No.	*Column name*	*P_u before jacketing*	*P_u after jacketing*
1	C6	1229.75	1900
2	C7	1229.75	1900
3	C10	1229.75	1900
4	C11	1229.75	1900

Table 9: Load increased in columns of G+8 building after jacketing

Sl No.	*Column name*	*P_u before jacketing*	*P_u after jacketing*
1	C2	1237.20	1920
2	C3	1237.20	1920
3	C5	1272.21	1980
4	C6	1624.04	2524.04
5	C7	1624.04	2524.04
6	C8	1272.21	1980
7	C9	1272.21	1980
8	C10	1624.04	2524.04
9	C11	1624.04	2524.04
10	C12	1272.21	1980
11	C14	1237.20	1920
12	C15	1237.20	1920

5. Results and Graphs

The stress and strain values in the failure columns in both G+6 and G+8 building without jacketing is tabulated below with respect to the corresponding loads,

Table 10: Stress and strain values of column without jacketing

Sl No.	*Load in KN (P_u)*	*Stress in mm*	*Strain*
1	1229.75	20.657	1.95
2	1237.20	20.473	1.9619
3	1272.21	21.37	2.0174
4	1624.04	27.28	2.5753

The stress and strain values in the failure columns in both G+6 and G+8 building with jacketing is tabulated below with respect to the corresponding loads,

Table 11: Stress and strain values of column with jacketing

Sl No.	*Load in KN (P_u)*	*Stress in mm*	*Strain*
1	1229.75	7.6	0.625
2	1237.20	7.644	0.6292
3	1272.21	7.860	0.647
4	1624.04	10.035	0.8259

.After jacketing the failure columns the stress in the columns will reduced within the limiting stress of the column and the column remains safe without undergoing any failure. The jacketing for all failure columns are designed as per the guidance of Indian standard code IS 15988:2013. The stress v/s strain and also load v/s deflection curve for columns with respect to their corresponding loading in G+6 and G+8 building failure without and with jacketing columns are given below,

The stress v/s strain graph for without jacketing columns,

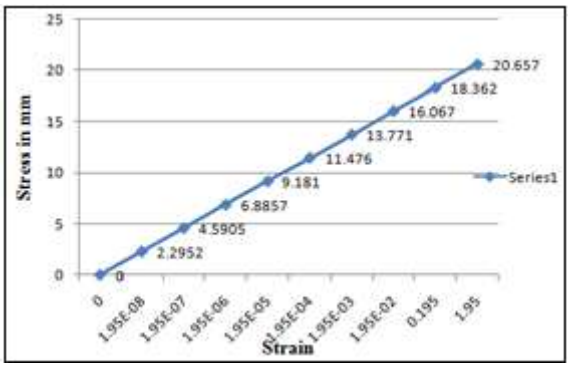

Figure 11: Stress v/s strain graph for a loading of 1229.75 KN

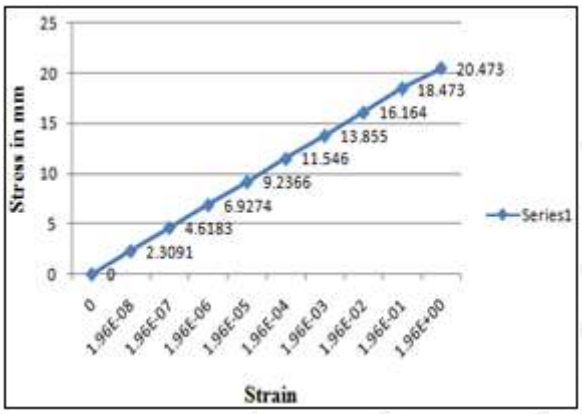

Figure 12: Stress v/s strain graph for a loading of 1237.2 KN

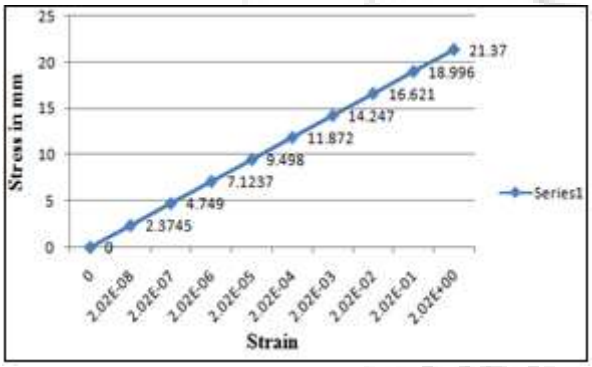

Figure 13: Stress v/s strain graph for a loading of 1272.21 KN

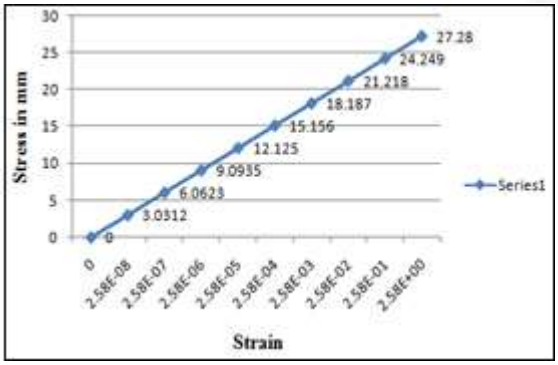

Figure 14: Stress v/s strain graph for a loading of 1624.04 KN

Load v/s Deflection graph for without jacketing columns

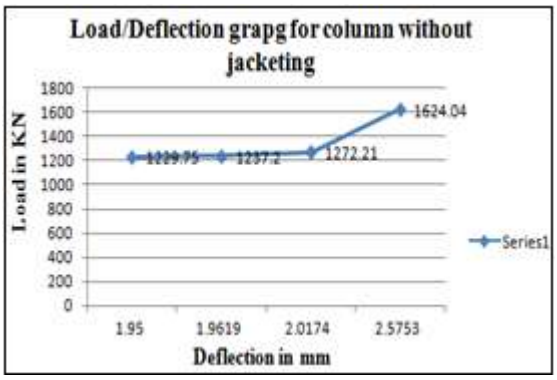

Figure 15: Load v/s Deflection graph

The stress v/s strain graph for with jacketing columns,

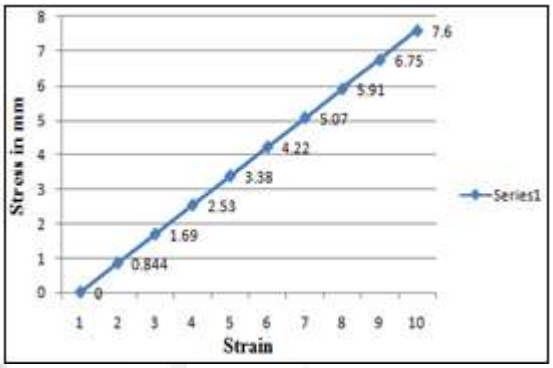

Figure 16: Stress v/s strain graph for a loading of 1229.75 KN

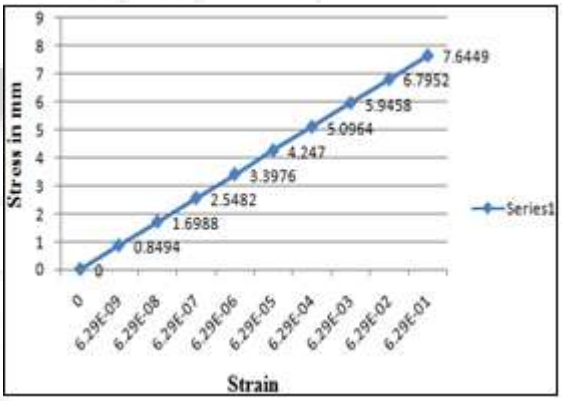

Figure 17: Stress v/s strain graph for a loading of 1237.2 KN

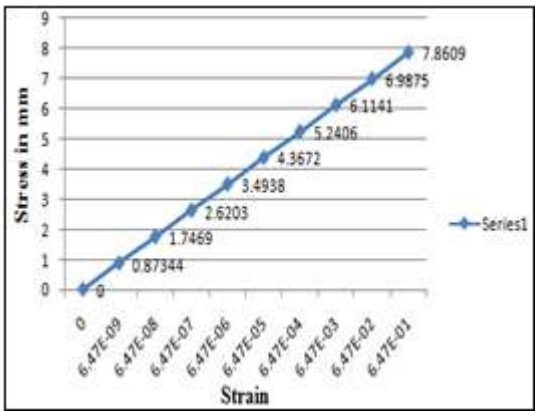

Figure 18: Stress v/s strain graph for a loading of 1272.21 KN

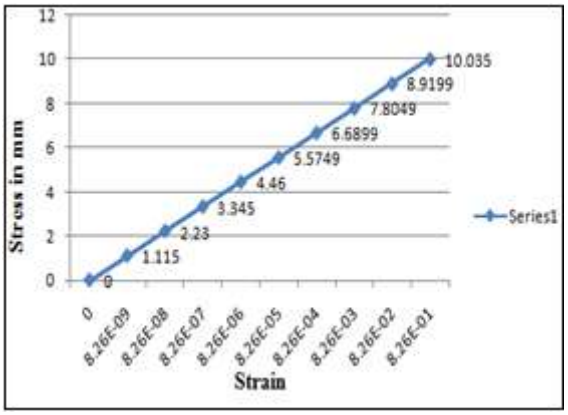

Figure 19: Stress v/s strain graph for a loading of 1624.04 KN

Load v/s Deflection graph for with jacketing columns

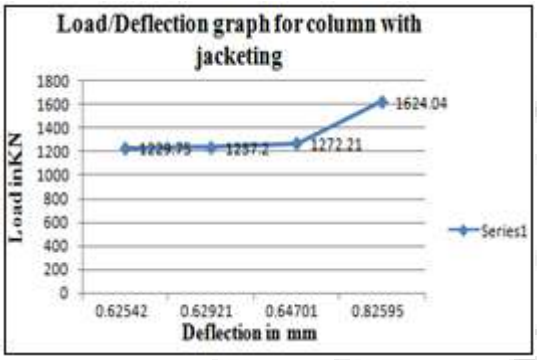

Figure 20: Load v/s Deflection graph

6. Conclusion

- Strengthening techniques can be adopted as a feasible solution for enhancing the compression capacity of concrete member.
- Confinement of concrete was achieved by jacketing the specimen with concrete. The compressive behavior of the specimens was enhanced due to the confinement pressure exerted by the strengthening material.
- The cracking behavior of the specimen was enhanced due to the presence of concrete jacket, the crack initiations were reduced due its high tensile capacity.
- The deflection of the column decreases as the cross section of the column increases.
- 5. Deflection also got decreased as the thickness of jacketing increased.
- 6. The ultimate load carrying capacity also got increased for jacketed column than column without jacketing.
- RC retrofitting technique are significant improvements in Moment resisting capacity, shear strength capacity in Beam and Axial load carrying capacity in column.

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