Finite Element Analysis of Jacketed Reinforced Concrete Column Subjected to Uni-Axial Load

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ABSTRACT

One strategy for the jacketing of reinforced concrete column is to target the improvement of local vulnerabilities in columns related to inadequate strength (compressive & Flexural) or poor ductility. Theoretical analysis have been carried out in the present study for different column sections of jacket thickness of 75mm and 100mm for jacketed RC columns subjected to uni-axial compressive loading. The uni-axial load carrying capacity along the major axes has been carried out under balanced section condition. Linear static finite element analysis has been carried out for the jacketed RC columns to compare the confined concrete strength (fcc) of finite element analysis with that of theoretical analysis, to plot the variation of stresses at the central core concrete and at the interface of old and new concrete. The displacements at core with respect to both major and minor axis are also plotted. Considerations have been given for variations in the properties of different types concretes used in the jacket and the original column. In order to find out the increase in the confined capacity of jacketed columns due to strengthening with respect to original column, theoretical analysis has been carried out.

Keywords: Uni-axial load, NISA Display IV, Jacketing, confined compressive strength.

1. INTRODUCTION

Reinforced concrete is concrete in which reinforcement bars ("rebars"), reinforcement grids, plates or fibers have been incorporated to strengthen the concrete in tension. Concrete is strong in compression, but weak in tension, thus adding reinforcement increases the strength in tension. A reinforced concrete section where the concrete resists the compression and steel resists the tension can be made into almost any shape and size for the construction industry.

Columns are critical elements, whose failure can cause the collapse of a structure. Therefore, their repairing and strengthening are frequent in order to guarantee or increase their ultimate load. Structural strengthening may be required due to many different situations. (1)Additional strength may be needed to allow for higher loads to be placed on the structure. This is often required when the use of the structure changes and a higher load carrying capacity is needed. (2) Strengthening may be needed to allow the structure to resist loads that were not anticipated in the original design.

(3) Multi storied buildings are often constructed with provision for vertical extension in future. Before carrying out vertical extension, it is sometimes noticed that the existing structure may not be adequate to take the additional vertical and/ or lateral loads on account of the additional storeys. The need to rehabilitate a structure may arise at anytime from the beginning of the construction phase until the end of the service life. During the construction phase, it may occur because of (1) Design errors, (2) Insufficient concrete production, (3) Bad execution processes during the service life, (4) It may arise on account of an earthquake, (5) An accident, such as collisions, fire, explosions, (6) Situations involving changes in the structure functionality.

Main reasons of structural strengthening are: (1) Increase of dead and live loading, (2) Material aging and corrosion, (3) Mechanical damage, (4) Reduction of strain limits, (5) Decrease of stress in steel reinforcement, (6) Decrease of crack width, (7) Modification of structure static scheme, (8) Construction failures. The model is taken as confined model [1][3] and it is tied using the lateral ties [2]. The behavior of analytical model[4] ie load capacity under un-axial eccentric loading is calculated as per [5][7]. The FEM analysis is done to check the stresses and displacement [6].

2. METHODOLOGIES

To study the variation of stresses at the central core concrete, at the interface of old and new concrete and at the column surface and lateral displacement along the length of the column, first theoretically calculate the axial compression and uni-axial moment and convert it to the pressure and apply that load on the FEM model and execute it. Then plot the variation of stresses and displacement. Then also compare the increases in the confined capacity of jacketed columns with respect to the original column.

3. THEORETICAL ANALYSIS OF JACKETED RC UNI-AXIALLY LOADED COLUMNS

The theoretical analysis of jacketed RC column subjected to uni-axial loading has been done. The grade of the original column concrete considered is 25MPa and that of jacket concrete is 30MPa, the stirrup spacing of 200mm. Details of the sections considered and reinforcement provided are given in the tables 1 and 2 respectively. Stirrup spacing has been calculated as per IS456-2000.

Table 1: Details of the original and jacketed RC columns

Original column Dimension (mm)	Jacketed column Dimension	% of steel		Stirrup spacing (mm)
		In Original column	In Jacketed column	
450X450	650X650	2% of gross area of original column	1% of gross area of Jacketed column	200
	600X600			

Table 2: Reinforcement details of original and jacketed column

Original column dimension (mm)	Jacketed column dimension (mm)	Longitudinal steel provided	
		Original column	Jacketed column
450X450	650X650	8#20	16#25
			12#25
			12#12
	600X600		8#16
			4#16+8#12
			12#12

Theoretical Original To Jacketed P_u And M_u Comparison

Analysis of the strength of a given column section basically implies determination of its design strength component P_u and M_u with the objective of assessing the safety of the column section subjected to specified factored load. The design strength of an eccentrically loaded column depends on the eccentricity of loading. For uni-axial eccentricity (e), the design strength has two components: an axial compression component (P_u) and a corresponding uni-axial moment component (M_u). The obtained P_u and M_u of original column is compared with a jacketed column and is listed in the below table.

Table 3: confined concrete strength of columns having same spacing of inner and outer stirrups in longitudinal direction and having fci=25MPa and fco=30MPa

Original column dimension (mm)	Jacketed column dimension (mm)	confined concrete strength
450*450	650*650	40.7
	600*600	

4. FINITE ELEMENT METHOD

The columns are modeled as one end free and other end hinged. In this study axial load along with uni-axial moment has been applied on the column by converting it as equivalent pressure. The details of the material properties and loads are tabulated in the table 4. Modeling of RC jacketed using NISA software is has shown in figure 1 and plan view of normal stress distribution in jacketed RC column at free end (top), at center and at bottom is has shown in figure 2 to 5.

The accuracy of the structural analysis using numerical methods depends on the representation of the behavior of material under different state of stresses and loading conditions.

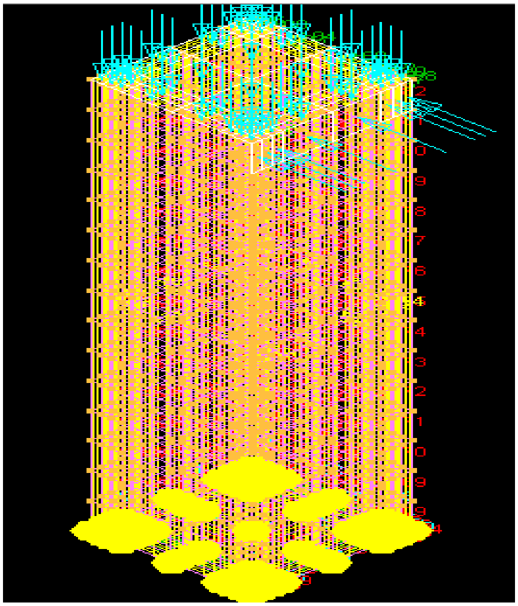
Table 4: Comparison of axial compression and uniaxial moment component of original and jacketed column

Original column dimension (mm)	Jacketed column dimension (mm)	Longitudinal steel provided		axial compression component		Uniaxial moment component	
		Original column	Jacketed column	Original column (kN-m)	Jacketed column ((kN-m))	Original column (kN-m)	Jacketed column ((kN-m))
450*450	650*650	8#20	16#25	652.10	2320.20	221.70	1140.54
			12#25		2797.51		1042.11
			12#12		3054.82		739.57
	600*600		8#16		2605.61		648.91
			4#16+8#12		2617.29		668.93
			12#12		2642.66		641.19

The details of the properties employed for finite element modeling are given in table 5.

Table-5 Geometrical and material properties

Original column dimensions(mm)	450X450
Column height (m)	3
Jacket thickness (mm)	75, 100
Original and jacketed column concrete	
Modulus of Elasticity(MPa)	25000 & 27386
Poisson's ratio	0.15
Longitudinal Reinforcement and stirrups	
Modulus of Elasticity(MPa)	200000
Poisson's ratio	0.3



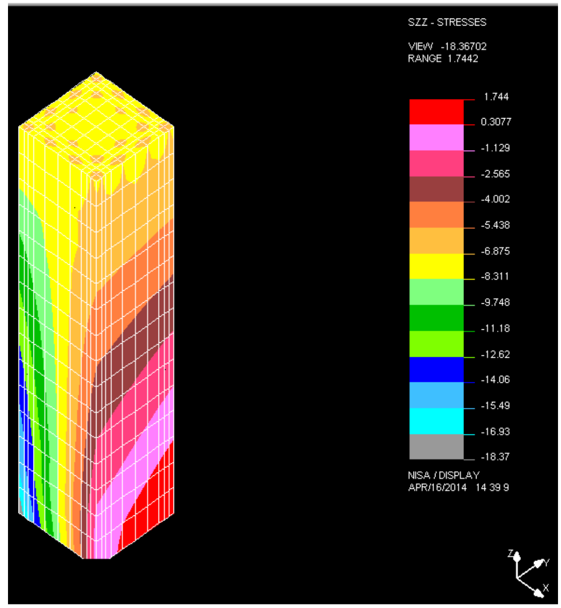
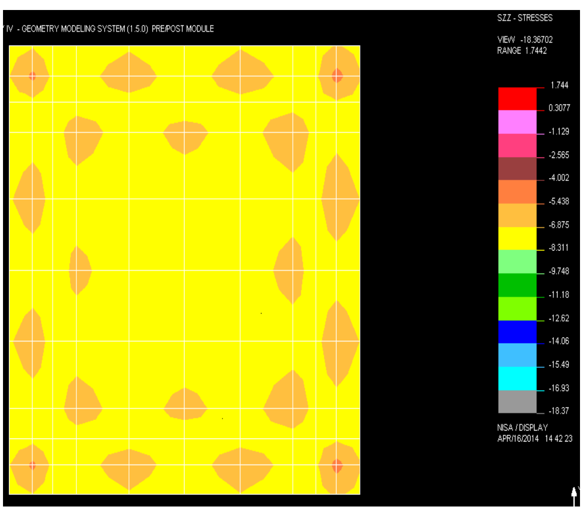


Fig-1: Modeling of jacketed RC column

Fig- 2 :Isometric view of normal stress distribution in the jacketed RC colum



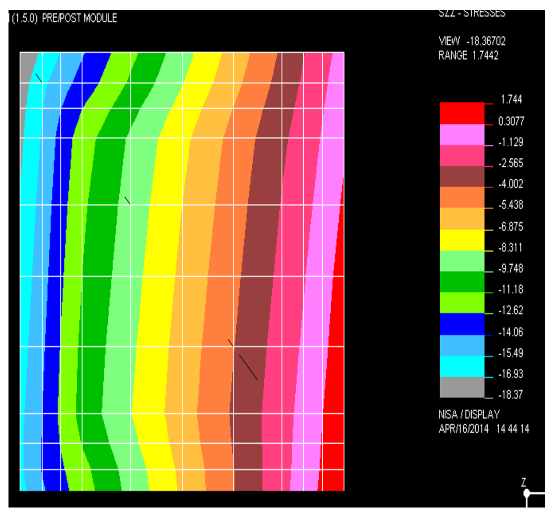
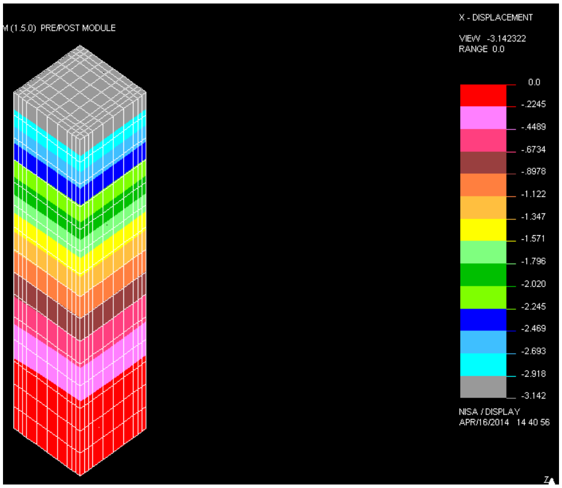


Fig-3 :plan view of normal stress distribution in the jacketed RC column (at free end)

Fig- 4: plan view of normal stress distribution in the jacketed RC column(at bottom)



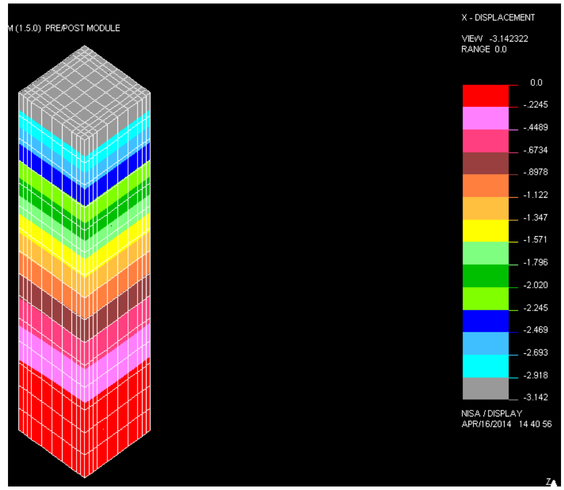


Fig- 5:Isometric view of displacement(Y- axis) in the jacketed RC column

Fig- 6:Isometric view of displacement(X- axis) in the jacketed RC column

5. RESULTS AND DISCUSSION

Table-6 : Comparison of confined concrete strength of theoretical & finite element analysis

	Jacketed column dimension (mm)	Theoretical	FEM
450X450	650X650	40.7	16.98
			18.71
			16.90
	600X600		18.97
			16.22
			19.11

Due to confinement of core concrete by both inner and outer sets of stirrups, its original strength gets increased. In order to validate the theoretical results, the same has been compared with that of the finite element analysis results. The theoretical and finite element results obtained for the different column sections and two different jacket thicknesses are as shown in the tables 5, has been taken up for the comparison. The theoretical results obtained from the analysis of jacketed column of different thickness and varying concrete strength have been considered. It can be observed from the table 5 that the results of theoretical and finite element analysis are approximately matching with some percentage of errors.

Variation Of The Normal Stresses In Jacketed Rc Columns

In order to know the behaviour of jacketed RC columns under the applied pressure in NISA the normal stress SZZ has been extracted at the point . The stress at the new concrete, and at the interface of the old and new concrete and stress at core center (x-axis).

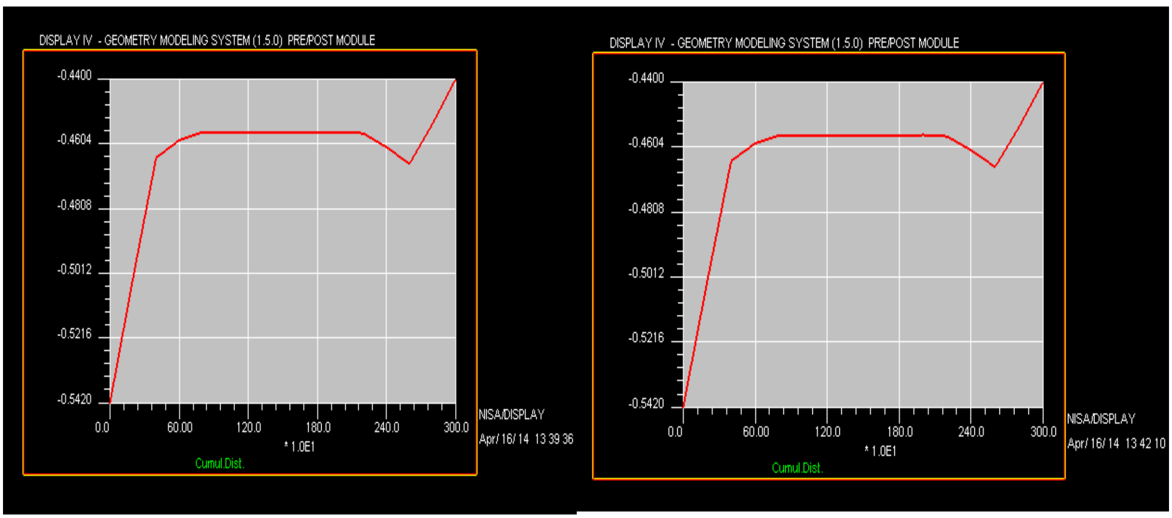


Fig-8 : shows the variation of normal stressess in the central core of column, interface of the jacket & original column and at the new concrete.

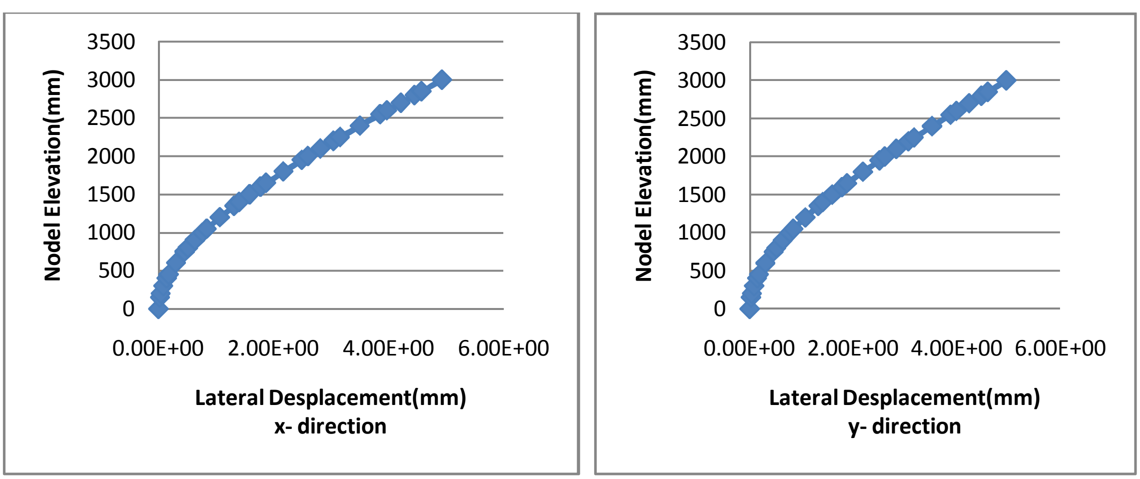


Fig- 9: The lateral displacment along a longitudinal axis of the column for column section

6. CONCLUSIONS

The present work is concerned with the theoretical study of jacketed and original columns and also finite element analysis carried out for jacketed RC columns with a commercially available finite element analysis package NISA/DISPLAY-IV. Based on the theoretical and finite element analysis study carried out, the following conclusions have been drawn.

1. Uni-axial load carrying capacity of original columns increases by introducing a jacketing layer of varying thickness. Also, it can be observed that the jacket thickness increases the load carrying capacity of jacketed columns.
2. The load carrying capacity increases with increasing the size of original column and with increasing grade of structural concrete strength in the jacket and with the thickness of the jacket.
3. The thickness of the jacket that should be provided depends on grade of structural concrete strength in the original column and jacket ie., if higher grade of concrete is used the thickness of the jacket is less and vice-versa.
4. The uni-axial load carrying capacity of the confined columns improves, because the compressive strength of the confined concrete enhances by the confinement effect.

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