# Finite Element Analysis of Jacketed Reinforced Concrete Column Subjected to Bi-Axial Load with Varying Stirrups in Longitudinal Direction

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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 100mm and varying outer stirrups for jacketed RC columns subjected to biaxial compressive loading. The biaxial load is computed by using Bresler's reciprocal load equation. The concentric load carrying capacities have been carried out based on the sheikh and Uzumeri's confined concrete model. The uni-axial load carrying capacity along both the axes (major and minor) has been carried out under balanced section condition.***

***Keywords: Uni-axial load, bi-axial load, NISA Display IV, 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] and it is tied using the lateral ties. The behavior of analytical model [2] ie load capacity under un-axial eccentric loading is calculated as per [4][5]. The FEM analysis is done to check the stresses and displacement [3].

## 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

| **Original Column Dimension (mm)** | **Jacketed Column Dimension** | **% of steel** | | **Stirrup Spacing (mm)** |
|---|---|---|---|---|
| | | Original Column | Jacketed Column | |
| 230x300 | 430x500 | 2% of gross area of original column | 1% of gross jacket area | 150, 200 |
| 230x450 | 430x650 | | | 150, 200 |
| 300x450 | 500x650 | | | 150, 250 |
| 300x600 | 500x800 | | | 150, 300 |

| Longitudinal steel provided | |
|---|---|
| original column | Jacketed Column |
| 4#20+2#12 | 8 #16 |
| 4#20+4#16 | 6 #20 |
| 4#25+4#16 | 6#20 |
| 8#25 | 8#20 |

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.

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 2: Comparison of axial compression and bi-axial moment component of original and jacketed column**

| Original column dimension (mm) | Concrete grades | | Bi-axial load & moments | | | Stirrup Spacing |
|---|---|---|---|---|---|---|
| | fci [Mpa] | fco [Mpa] | Pui [kN] | MuRy [kNm] | MuRx [kNm] | |
| 230x300 | 20 | 30 | 379.18 | 127.81 | 113.46 | 150 |
| | | | 379.29 | 127.81 | 113.50 | 200 |
| 230x450 | | | 509.20 | 215.74 | 115.51 | 150 |
| | | | 509.34 | 215.09 | 115.56 | 200 |
| 300x450 | | | 604.46 | 257.25 | 210.01 | 150 |
| | | | 604.66 | 257.34 | 210.11 | 200 |
| 300x600 | | | 700.51 | 409.40 | 251.58 | 150 |
| | | | 701.01 | 409.70 | 251.76 | 200 |

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

**Table-3 Geometrical and material properties**

| | |
|---|---|
| Original column dimensions(mm) | 230x300, 230x450, 300x450, 300x600 |
| Column height (m) | 3 |
| Jacket thickness (mm) | 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 |

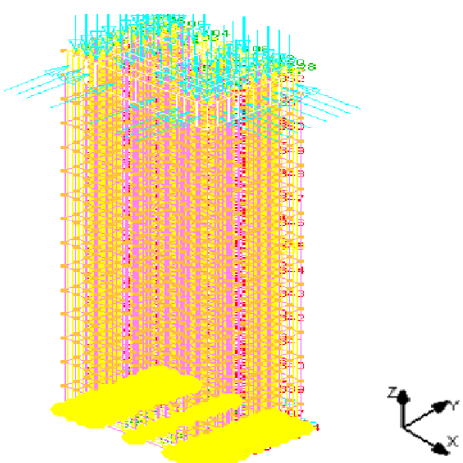



**Fig-1: Modeling of jacketed RC column**

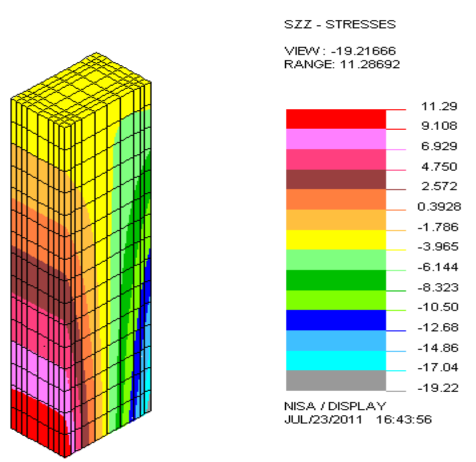
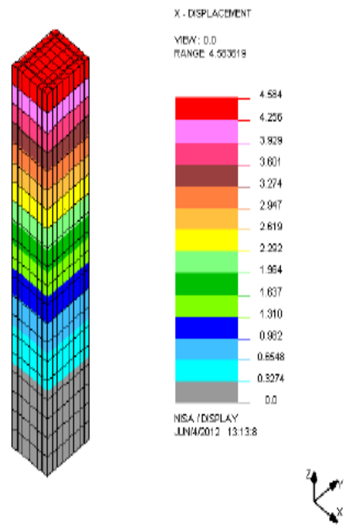



**Fig- 2 :Isometric view of normal stress distribution in the jacketed RC column**



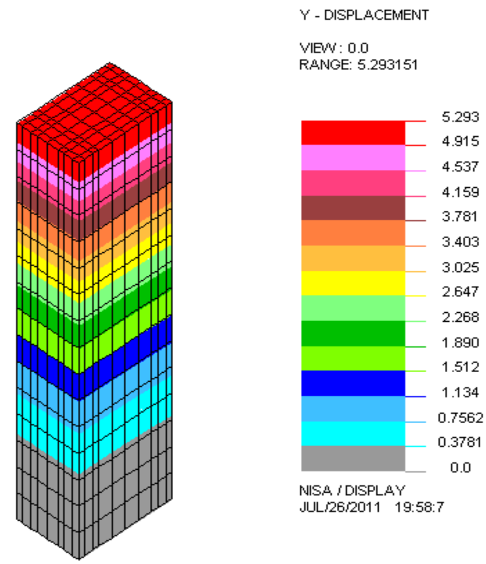




**Fig-3: Isometric view of displacement(x-axis) in the Jacketed RC column**

**Fig-4: Isometric view of displacement(y-axis) in the Jacketed RC column**

**Table-4 : Comparison of confined concrete strength of theoretical & finite element analysis**

| Column section | Theoretical [MPa] | FEM [MPa] | Stirrup spacing [mm] |
|---|---|---|---|
| 230x300 | 30.46 | 16.15 | 200 |
| 230x450 | 31.20 | 17.77 | 200 |
| 300x450 | 31.74 | 10.10 | 250 |
| 300x600 | 31.51 | 16.16 | 300 |

| Column section | Theoretical [MPa] | FEM [MPa] | Stirrup spacing [mm] |
|---|---|---|---|
| 230x300 | 30.50 | 16.11 | 150 |
| 230x450 | 31.97 | 24.02 | |
| 300x450 | 32.54 | 17.97 | |
| 300x600 | 32.64 | 22.45 | |

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 points as shown in the Fig. 3.

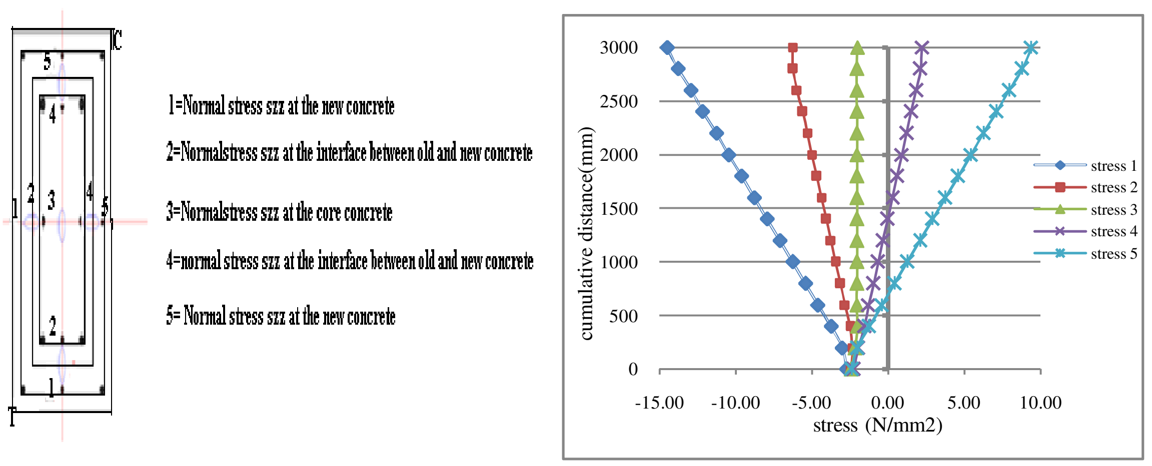



**Fig. 3. C/S of jacketed column**

**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.**

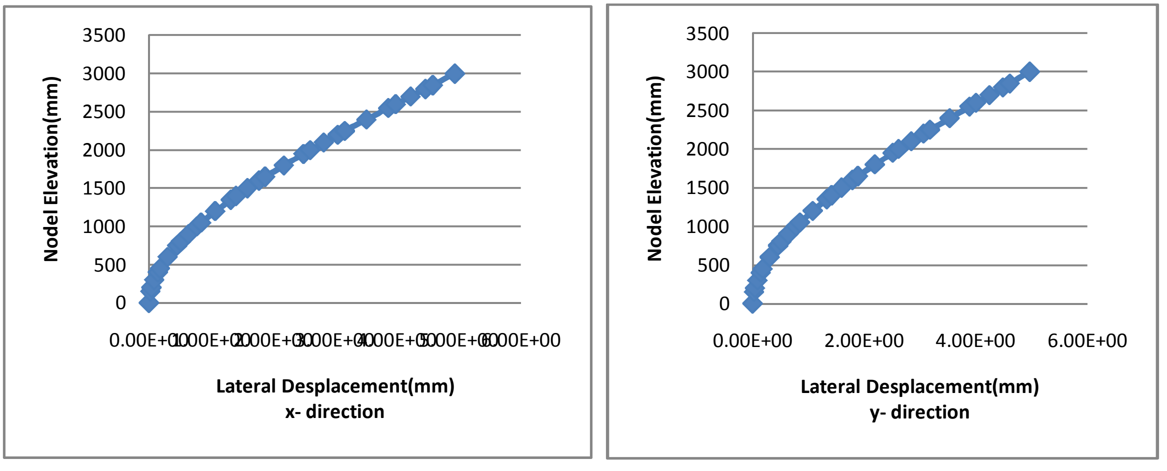



**Fig- 9: The lateral displacment along a longitudinal axis of the column for column section**

## 5. CONCLUSIONS

Based on the theoretical and finite element analysis study carried out, the following conclusions have been drawn.

1. It can be visualized that the higher the grade of concrete used for RC columns increases its strength.
2. Biaxial load carrying capacity of original columns increases by introducing a jacketing layer of 100mm thickness. The thickness of the jacket depends on the grade of the concrete used in original column, lower the concrete grade of concrete used, higher the concrete grade in jacket.
3. The accumulation of moment highly depends on eccentricity of column load.
4. The biaxial load carrying capacity of the confined columns improves, because the compressive strength of the confined concrete enhances by the confinement effect.

## REFERENCES

[1] Shamim A. Sheikh "A comparative study of confinement models", *ACI Journal*, July – august 1982, PP.296-603.

[2] Mohamed El Sayed and Tamer El Maaddawy, "Analytical model for prediction of load capacity of RC columns confined with CFRP under uniaxial and biaxial eccentric loading" *Materials and Structures,* **44**(2011)299–311.

[3] Minho Kwon, Enrico Spacone "*Three-dimensional finite element analyses of reinforced concrete columns*, Computers and Structures Vol.80, August2002, PP.199–212.

[4] *Reinforced Concrete Design*, 2nd Edition, by S.Unnikrishna Pillai and Devdas Menon, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2003.

[5] *Indian standard Code of practice for plain and reinforced concrete* (fourth revision), IS 456-2000, Bureau of Indian standard, July 2000, New Delhi.