FINITE ELEMENT ANALYSIS OF JACKETED REINFORCED CONCRETE COLUMN SUBJECTED TO AXIAL AND UNIAXIAL 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 axial and 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 maximum shear stress for the columns is also noted down. The displacement at core with respect to major axis is also plotted.

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

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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. Reinforced concrete (RC) 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. Rehabilitation and strengthening of reinforced concrete structures is a dynamically growing division of structural engineering. In recent years an increased application of new repair and strengthening systems of reinforced concrete load-carrying structures has been noted.

Jacketing is one of the most frequently used techniques to strengthen reinforced concrete (RC) columns. With this method, axial strength, bending strength, and stiffness of the original column are increased. Generally there are three different techniques are available for strengthening of RC columns such as RC jacketing, steel jacketing and composite jacketing.

The main purposes of jacketing are:

- To increase concrete confinement by transverse reinforcement, especially for circular cross sectional columns,
- To increase flexural strength by longitudinal reinforcement provided they are well anchored at critical sections,
- To increase shear strength by transverse reinforcement,
- To Increase the local capacity of structural elements,
- Reduction of the seismic demand by means of supplementary damping.

Some of the most widely used methods for repair / strengthening of RC columns include:

1. Jacketing of part or the entire member:
2. Heat tensioning of full thin steel plates or tie plates
3. Glueing of thin steel sheets on damaged members by using epoxy resin laid onto the steel sheets and concrete surfaces
4. Tying of the damaged parts of the column using steel ties
5. Mild steel fixed round the damaged element
6. Wrapping a column with a high strength fiber composite (HSFC) jacket

The model is taken as confined model [1][3] and it is tied using the lateral ties [2]. The behavior of analytical model 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. METHODOLOGY

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 AXIALLY AND UNI-AXIALLY LOADED COLUMNS

The theoretical analysis of jacketed RC column subjected to axial and 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. Stirrup spacing has been calculated as per IS456-2000.

Table -1: Reinforcement details

Column	Original column (mm)	Jacketed column (mm)	Longitudinal steel provided	
			Original column	Jacketed column
C1	450*450	650*650	8#20	16#25
C2				12#25
C3				12#12
C4		600*600		8#16
C5				4#16+8#12
C6				12#12

3.1 Axially Loaded Column

Table-2: confined and unconfined capacity of jacketed column C1 subjected to axial loading

Spacing	C1			Confined concrete strength (fcc) in MPa
	Confined capacity (KN)	Unconfined capacity (KN)	Strength gain factor(K)	
100	17549.15	11364.05	1.544	41.15
150	17519.56	11364.05	1.542	40.94
200	17485.28	11364.05	1.538	40.70
250	17443.95	11364.05	1.535	40.41
300	17392.99	11364.05	1.530	40.05

Table -3: confined and unconfined capacity of jacketed column C2 subjected to axial loading

Spacing	C2			Confined concrete strength (fcc) in MPa
	Confined capacity (KN)	Unconfined capacity (KN)	Strength gain factor(K)	
100	16734.44	11422.95	1.465	41.15
150	16704.85	11422.95	1.462	40.94
200	16670.56	11422.95	1.459	40.70
250	16629.24	11422.95	1.456	40.41
300	16578.28	11422.95	1.451	40.05

Table-4: confined and unconfined capacity of jacketed column C3 subjected to axial loading

Spacing	C3			Confined concrete strength (fcc) in MPa
	Confined capacity (KN)	Unconfined capacity (KN)	Strength gain factor(K)	
100	14883.30	11558.94	1.288	41.15
150	14853.70	11558.94	1.285	40.94
200	14819.43	11558.94	1.282	40.70
250	14778.10	11558.94	1.278	40.41
300	14727.14	11558.94	1.274	40.05

Table-5 : confined and unconfined capacity of jacketed column C4 subjected to axial loading

Spacing	C4			Confined concrete strength (fcc) in MPa
	Confined capacity (KN)	Unconfined capacity (KN)	Strength gain factor(K)	
100	13340.93	9676.41	1.378	41.15
150	13311.34	9676.41	1.375	40.94
200	13277.05	9676.41	1.372	40.70
250	13235.73	9676.41	1.367	40.41
300	13184.77	9676.41	1.362	40.05

Table-6: confined and unconfined capacity of jacketed column C5 subjected to axial loading

Spacing	C5			Confined concrete strength (fcc) in MPa
	Confined capacity (KN)	Unconfined capacity (KN)	Strength gain factor(K)	
100	13382.51	9673.4	1.383	41.15
150	13352.92	9673.4	1.380	40.94
200	13318.64	9673.4	1.377	40.70
250	13277.31	9673.4	1.372	40.41
300	13226.35	9673.4	1.367	40.05

Table-7: confined and unconfined capacity of jacketed column subjected to axial loading

Spacing	C6			Confined concrete strength (fcc) in MPa
	Confined capacity (KN)	Unconfined capacity (KN)	Strength gain factor(K)	
100	13245.56	9683.95	1.367	41.15
150	13215.97	9673.4	1.365	40.94
200	13181.69	9673.4	1.361	40.70
250	13140.36	9673.4	1.357	40.41
300	13089.40	9673.4	1.352	40.05

3.3 Uniaxially Loaded Column

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 P_u and M_u has been calculated for an original column of different column section. The obtained P_u and M_u of original column is compared with a jacketed column and is listed in the below table-8.

Table -8: Comparison of Uniaxial moment and axial compression component of column

Column	Uniaxial moment component (N-mm)		axial moment component (N)	
	Original column	Jacketed column	Original column	Jacketed column
C1	221704279	648906954	652105	2605609
C2		668931274		2617290
C3		641199734		2642655
C4		1140540180		2320201
C5		1042108511		2797519
C6		739570070		3054816

4 DESCRIPTION OF GEOMETRICAL AND MATERIAL PROPERTIES USED

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-9.

Table-9 Geometrical and material properties

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

5. FINITE ELEMENT ANALYSIS

The columns are modeled as one end free and other end hinged. In this study axial load and 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. Modeling of RC jacketed using NISA software is has shown in figure 2 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 1.

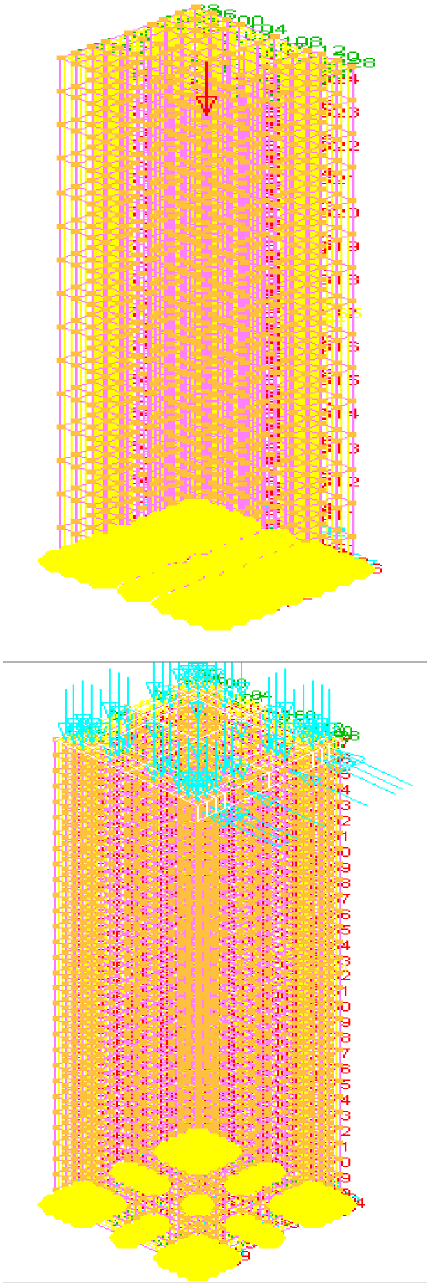


Fig 1: Modeling of jacketed RC column

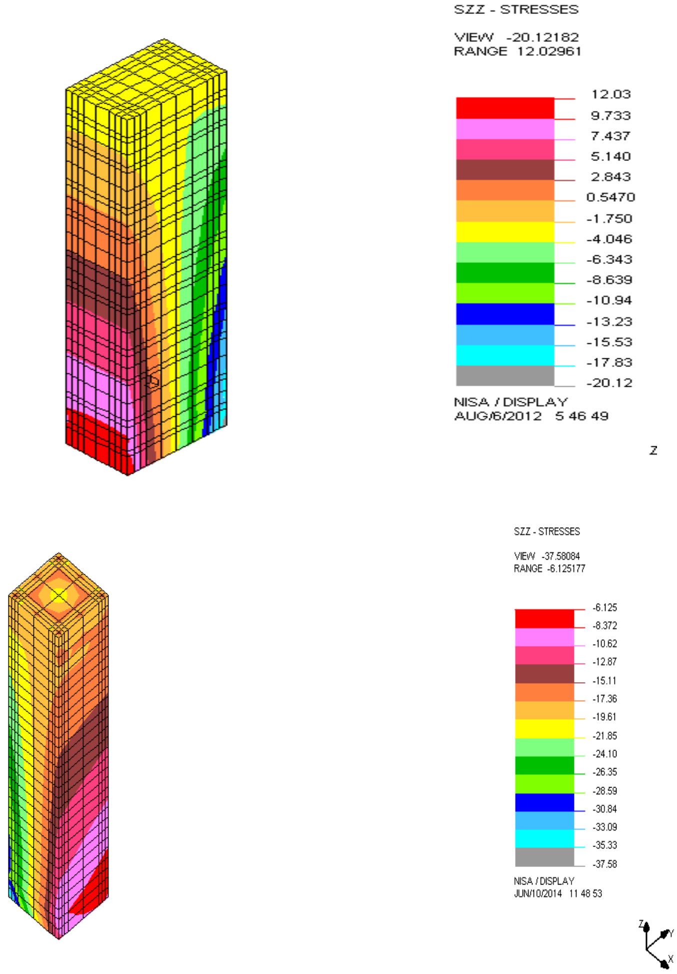
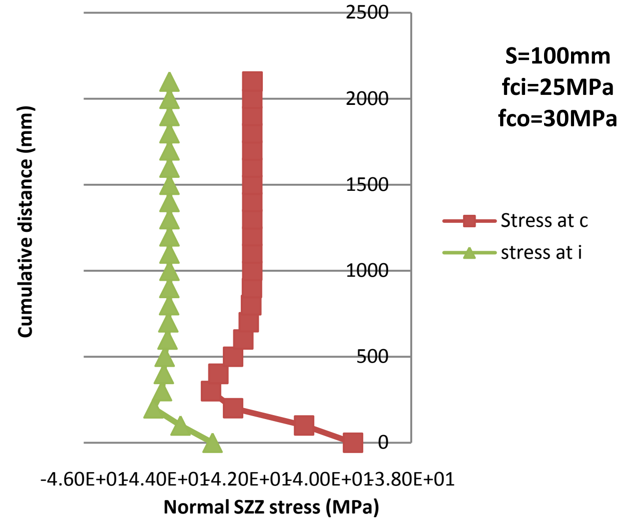
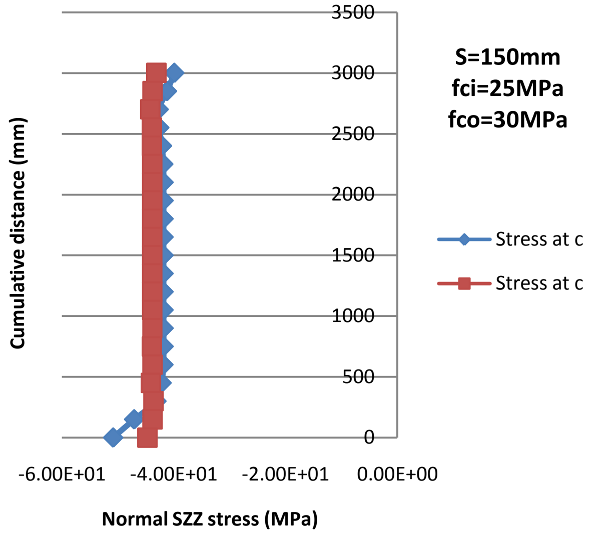


Fig-2 : Isometric view of normal stress distribution in the jacketed RC column





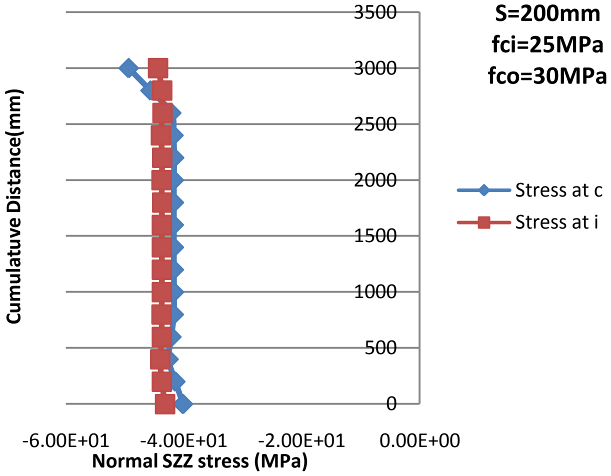


Table-10 Confined concrete strength of FEM (axial load)

spacing	C1	C2	C3	C4	C5	C6
100	31.22	30.97	30.19	30.66	34.05	30.72
150	35.89	34.53	34.87	33.86	37.46	33.62
200	38.82	36.62	37.85	35.57	39.53	35.34
250	40.85	37.30	39.92	36.54	40.84	36.37
300	42.36	36.63	35.70	35.70	41.68	35.49

Table-11 Confined concrete strength of FEM (uniaxial load)

spacing	C1	C2	C3	C4	C5	C6
100	29.65	33.91	32.61	37.5	31.91	32.48
150	33.67	36.46	35.28	42.61	34.42	34.60
200	37.86	39.32	38.26	47.48	37.27	37.83
250	42.21	42.56	39.35	50.49	40.48	40.58
300	46.46	45.58	41.74	57.85	43.49	44.08

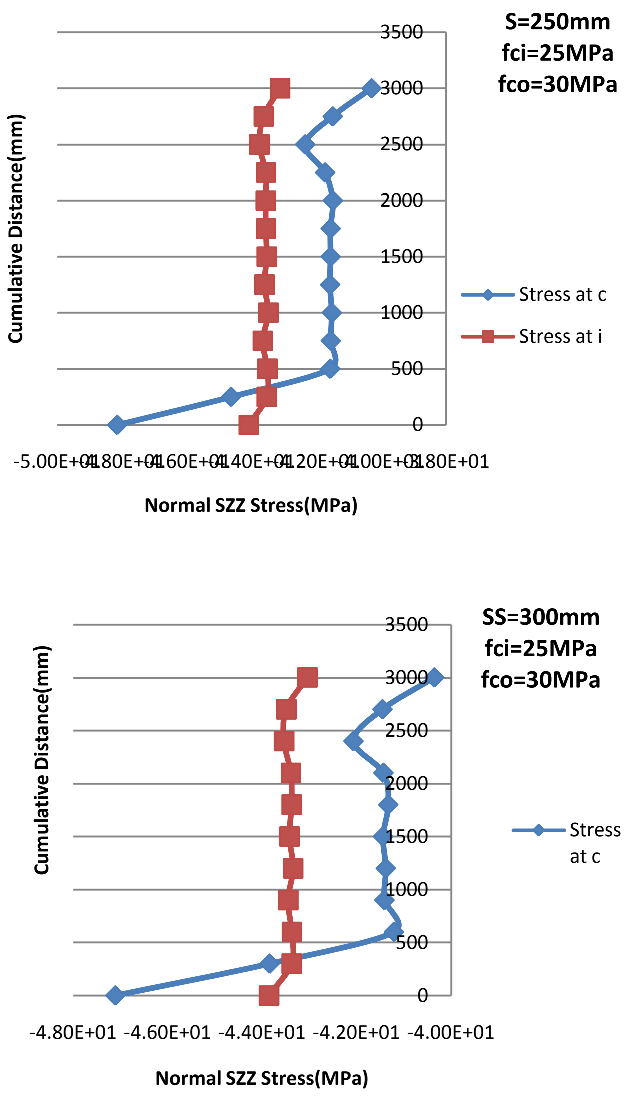
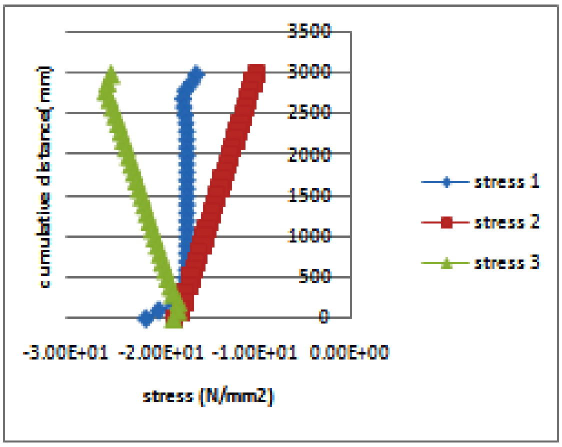
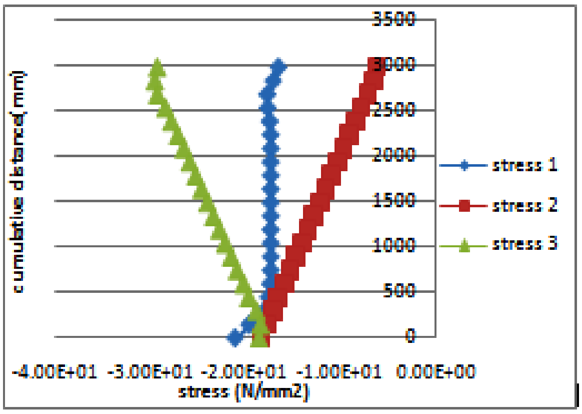


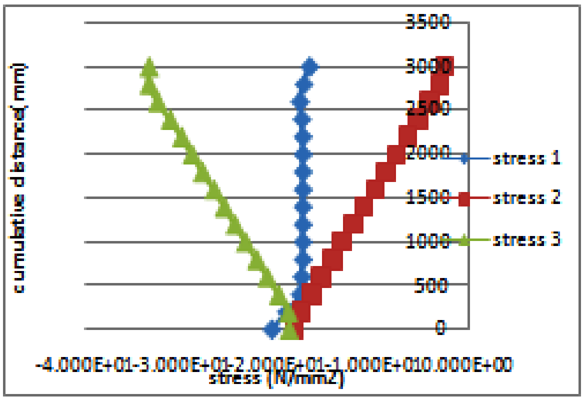
Chart 1: The variation of normal stresses in the central core of column and interface of the jacket and original column along the direction parallel to applied load for C1 (axial load).



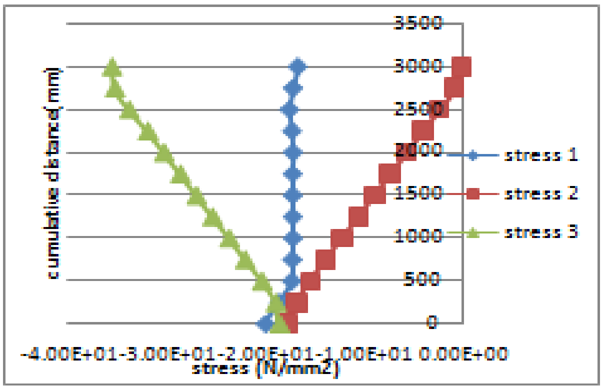
(a) C1 600 @ 100mm spacing



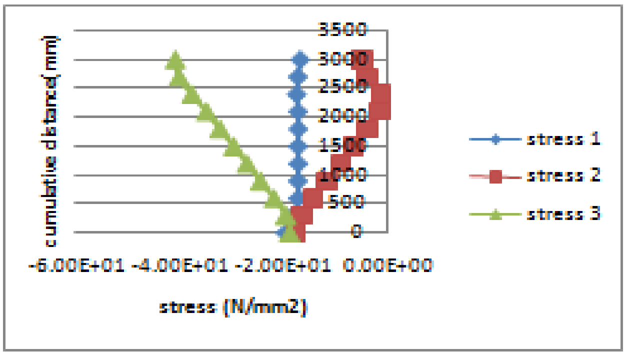
(b) C1 600 @ 150mm spacing



(c) C1 600 @ 200mm spacing



(d) C1 600 @ 250mm spacing

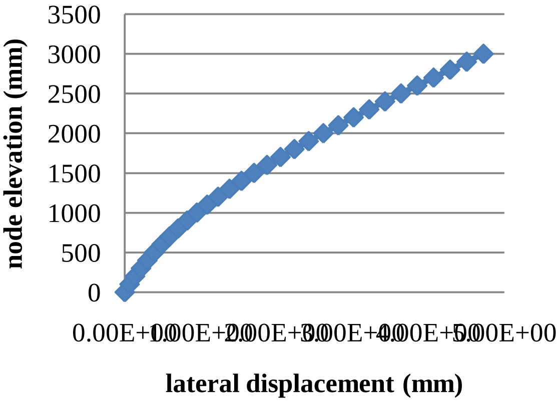


(e) C1 600 @ 300mm spacing

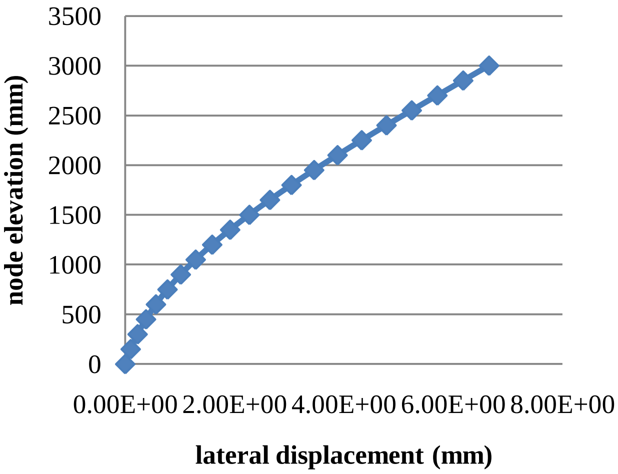
chart 2: The variation of normal stressess in the central core of column,interface of the jacket & original column and at the new concrete along the direction parallel to applied load for C1 column section.

Table 5.7: Maximum lateral displacement (mm) (uniaxial load)

spacing	C1	C2	C3	C4	C5	C6
100	3.84	3.77	3.75	5.06	3.63	3.67
150	5.37	5.46	5.24	7.04	5.09	5.09
200	6.90	6.15	6.22	9.09	5.97	6.01
250	8.43	10.70	8.76	10.34	9.05	9.11
300	9.98	8.94	7.22	13.11	8.42	8.46



(a) C1 600 @ 100mm spacing



(b) C1 600 @ 150mm spacing

Chart 3: The lateral displacement along a longitudinal axis of the column for column section C1.

6. CONCLUSION

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

1. The load carrying capacity increases with increasing the size of original column and with increasing grade of structural concrete strength in the original column or jacket and with the thickness of the jacket.
2. The uniaxial load carrying capacity of the confined columns improves, because the compressive strength of the confined concrete enhances by the confinement effect.
3. It may be concluded that the theoretical results are comparable with finite element results with -23.11 to 8.59% of errors.
4. Shear stress increases with increase in the spacing and vice versa. The minimum shear is 10.99 N/mm2 for C1 650 @100mm spacing and maximum of 27.22 N/mm2 for C1 600 @ 300mm spacing.
5. The displacement at the central core of the column is varied from minimum lateral displacement of 3.63mm for the column C2 600 @ 100mm spacing and maximum lateral displacement of 13.11mm for the column for the column C1 600 @ 300mm spacing.

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