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FINITE ELEMENT ANALYSIS OF JACKETED REINFORCED CONCRETE COLUMN SUBJECTED TO UNIAXIAL LOAD USING NISA SOFTWARE

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Abstract - Strengthening of the reinforced concrete structures is one of the most difficult and important tasks of civil engineering. Individual approach to the problem is a necessity since any ready-made solution can be applied. One of the prime objectives is to provide detailed technical and cost-effective analyses. Structures must be carefully examined in order to determine their technical condition, to find reasons for deterioration and strengthening as well as to establish service requirements of the reinforced structures. It is also essential to analyze their technical design, dig out open pits and carry out suitable measurements. Cost-effectiveness of each of the proposed strengthening techniques should be considered and compared to the cost of a new structure. The strengthening methods applied should ensure the required safety margin and guarantee a sufficient reliability over time Concrete is the 2nd prominent criteria utilized in the world after water. In thispaper the retrofitting is done for reinforced concrete columns for varies thickness to existing column. The confinement capacity is checked using the finite element software for different grade of mix proportion.

Keywords - Concrete, NISA, Laterial ties

I. INTRODUCTION

The rehabilitation of concrete structures has become increasingly important as we hear more and moreabout deterioration of the infrastructure. The problem is more severe due to limited funds available for rebuilding these structures. During the last decade theauthors have been involved in various aspects of rehabilitation of concrete structures. These includebringing together engineers from the East and the West, to discuss such problems and develop common solutions through international symposia.The American Concrete Institute’s (ACI’s) committee 364 on ”Rehabilitation of Concrete Structures” for a possible co-operation at global level. It was organizedin 1981 with a mission of developing and reporting information for the rehabilitation, renovation of

concrete and masonry structures. The committee has made efforts to present information on various aspects of rehabilitation, the most recent report being on guidelines and procedures for evaluating concrete structure. Along with a summary of this report, planned activities and benefit in the future.Recently, international symposia have been held with the sponsorship of ACI or its chapters in the far East.This brings the global interest and the need to have a

better communication and co-operation for the benefit of humankind. Another step in this direction was also taken when International Association of Concrete Repairs Specialists (IACRS) was established in 1988,with a bulk of its membership (over 60 percent) from rehabilitation contractors and engineers**.**

ACI 364 works with other ACI committees related to rehabilitation. These include: ACI 365 (Service Life Protection); ACI 369 (Seismic Repairs and Rehabilitation); ACI 546 (Repairs) and ACI 437(Evaluation).

II. LITERATURE REVIEW

1. K.C.G. Ong, Y.C. Kog, C.H. Yu and A.P.V Sreekanth (2002): extended the concept of Sheikh and Uzumeri’s model to jacketed RC columns subjected to axial loads, to predict the behaviour of jacketed columns when subjected toaxial loads. This model then used to analyze the three columns tested to failure by Aksan. Sheikh and Uzumeri model was able to predict peak axial loads that agree within ±10% of the experimental results. Also they have developed design

curves for jacketed RC column of column size (300mmx300mm). Using this design curves we can calculate the axial load carrying capacity of jacketed RC columns. In this work they have calculated the strength gain factor K for different volumetric ratio's to find out the effect of stirrups spacing on the factor K.

2. Attolico, S. Biondi, C. Nuti and M. Petrangeli: The paper presents the implementation of rebars buckling capabilities into a fibre beam element recently developed by the authors and the results of numerical analyses carried out on few representative concrete structures using this new element. The fibre model used for the implementation is an equilibrium based beam element using uniaxial constitutive modelling for concrete and steel. The existing uniaxial model for the longitudinal steel fibres has been replaced with a new one with buckling capabilities based on the Menegotto-Pinto constitutive law as modified by Nuti and co-workers to account for rebar buckling in the plastic regime. The model input parameters are the steel properties, the stirrups spacing and the longitudinal rebar diameter. Four hardening rules are used to modify and shift the skeleton branch of the model at each load reversal. Calibration of the model using available test data is presented and the effect of insufficient transverse reinforcement (i.e. large stirrups spacing) on the structural response and ultimate resistance of reinforced concrete bridge piers and frames is investigated.

3. M. Frangou, K. Pilakoutas and S. Dritsos: In this paper, a cost effective and efficient technique for strengthening RC columns is described. The susceptibility of the majority of the existing building stock to structural damage largely depends on the quality of design, detailing and construction. In many cases, the engineer canextend the life span of a building structure by utilizing simple repair or strengthening techniques. The choice of the repair/strengthening technique becomes, therefore, the decisive factor, since high cost would deter many building owners from executing essential repair works. The proposed technique involves post-tensioning metal strips around reinforced concrete columns, by using a strapping machine. The preliminary results of the experimental work carried out at Sheffield University indicate that such strengthening can increase member strength and ductility to higher levels than those possible by conventional reinforcement, at only a fraction of the time and cost required by alternative techniques.

4. Christina Claeson (2009): Finite element analyses of confined columns are presented based on a confinement dependent uniaxial concrete model, the importance of the yield strengths of the stirrups and the longitudinal reinforcement bars, the spacing of the stirrups, and the configuration of the cross-section, in combination with different load eccentricities are evaluated. It was found that the spacing of the stirrups and the reinforcement configuration are of the greatest importance for the post-peak behaviour. To achieve ductile structural behaviour of high strength concrete columns, a higher value of the volumetric stirrup ratio isrequired. However, it was found that, even for concretes currently accepted by the code, a higher ratio than that corresponding to the required maximum spacing of 15f is needed to obtain the same ductility as a concrete of grade K_{40}.

III. METHODOLOGY

For the analysis some assumptions have been madein this work. They are:

- The interface between the old and new concretehaving perfect bonding.
- Both the original and added ties having thedifferent spacing.
- Finding out the confinement capacity of columnsfor different grade.

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

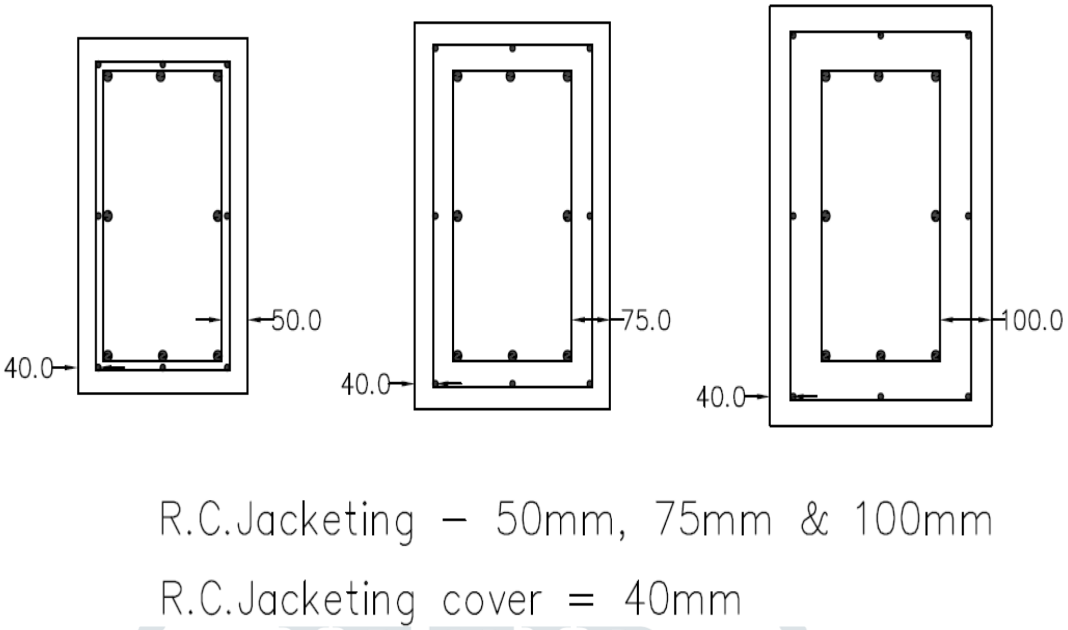


Figure 1

Original column dimension (mm)	Jacketed column dimension			Percentage of steel		Stirrup spacing (mm)
	For 50mm jacketing	For 75mm jacketing	For 100mm jacketing	In original column	In jacket	
230x 450	330x550	380x600	430x650	2% of gross area of original column	1% of gross jacket area	200
300x 300	400x400	450x450	500x500			300
300x 450	400x550	450x600	500x650			250
300x 600	400x700	450x750	500x800			300

Table 1 Details of the original and jacketed RC columns

Original Column size	Longitudinal steel provided				Area of steel				spacing
	Original column	50	75	100	Original column	50	75	100	Original column
230×450	4#20+4#16	10#10	4#20	6#20	2060.88	785.39	1256.63	1884.95	200
300×300	4#20+4#16	8#10	4#20	8#16	2060.88	628.31	1256.63	1608.49	300
300×450	4#25+4#16	10#10	8#16	6#20	2767.74	785.39	1608.49	1884.95	250
300×600	8#25	10#10	6#20	8#20	3926.99	628.31	1884.95	2513.27	300

Table 2 Reinforcement details of original and jacketed column have same spacing for original column and jacketed column

V. ANALYSIS FOR DESIGN STRENGTH OFCOLUMN

A. Original column analysis

This section deals with the behavior and design of short compression members subjected to axial compression combined with uniaxial bending i.e., bending with respect to either the major axis or minoraxis (but not both).This loading condition is statically equivalent to a condition of uniaxial eccentric compression where in the axial load (P) is applied at an eccentricitywith respect to the centroidal axis, M being the bending moment. The detailed calculations for determining the design strength of a uniaxially eccentrically loaded column with a rectangular cross- section (b x D) is described in detail. The notation D denotes the depth of the rectangular section in the plane of bending i.e., either D_x or D_y , depending on whether bending occurs with respect to the major axisor minor axis and the notation (b) denotes width of the section.

The design strength of an eccentrically loaded column is not a unique value, but comprises infinite sets of values of P and M (corresponding to $0 < e < \infty$) all of which are describable by means of a singlecurve, termed the design interaction curve. It was alsopointed out that the analysis for design strength basically entails two conditions: strain compatibility and equilibrium condition. Two different cases needto be distinguished, in first case the loading eccentricity is relatively high such that the NA islocated inside the section and in second case the loading eccentricity is relatively low such that the NA is located outside the section. In case of cold worked bars (F_e - 415 and F_e - 500), which have no specific yield point and is not bilinear. There was a linear and non-linear strain, the transition from linear elastic behavior is assumed to occur at a stress level equal to 0.8 times f_y in the characteristic curve, for the stress levels beyond $0.87f_y$ so that the strains on the design stress-strain curve corresponding to the various design stress levels.

B. RC jacketed column analysis

In the analysis of RC jacketed column remains same as in the analysis of original column. The design strength of an eccentrically loaded column depends on the eccentricity of loading. For uniaxialeccentricity (e), the design strength has two components; an axial compression (P) and a corresponding uniaxial moment component (M).

The design strength component in axial compression($P_{ub,x}$) :

$P_{ub,x} = (C_{oc} + C_{jc} + C_s)$

$C_{jc} = (0.362 * f_{ckj} * b * x_{ub})$$C_{oc} = (0.362 * f_{ckc} * b * x_{ub})$

$$C_s = \sum C_{si} =$$

Where,

C_{oc} = resultant force in original concrete (kN) C_{jc} = resultant force in jacketed concrete (kN)C_s = resultant force in steel (kN)

f_{ckj} = jacket concrete compressive strength(MPa)

f_{ckc}= core concrete compressive strength (MPa)A_{si} = area of steel in i^{th} row (mm)

Design strength component in flexure ($M_{ub,x}$) :$M_{ub,x} = (M_{oc} + M_{jc} + M_s)$

$M_{oc} = C_{oc}\ (0.5 D – 0.416 x_u)$

$M_{jc} = C_{jc}\ (0.5 D – 0.416 x_u)$

M_s= Where,

M_{oc} = Resultant moment in original concrete (kN-m)

M_{jc} = Resultant moment in jacketed concrete (kN-m)

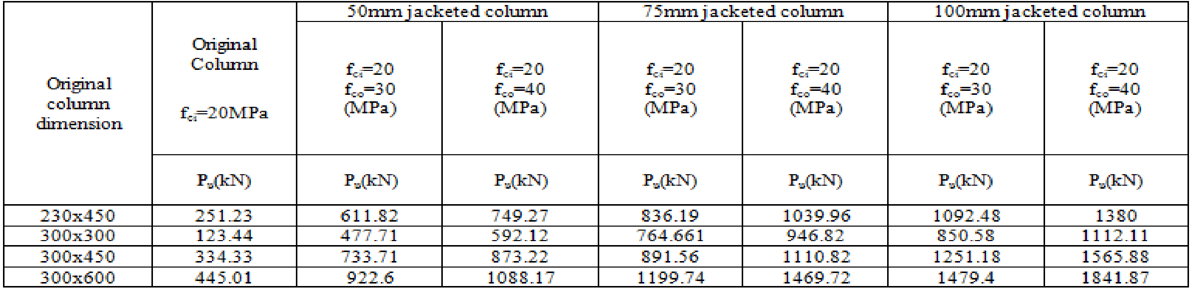
M_s = Resultant moment in steel (kN-m) C_{si} = Resultant force in i^{th} row steel (kN)

C. COEFFICIENT OF DETERMINATION

One use of the coefficient of determination is to test the goodness of fit of the model. It is expressed as a value between zero and one. A value of one indicates a perfect fit, and therefore, a very reliable model for future forecasts. A value of zero, on the other hand, would indicate that the model fails to accurately model the dataset. Coefficient of determination is used in trend analysis. It is computed as a value between 0 (0 percent) and 1 (100 percent). The higherthe value, the better the fit. Coefficient of determination is symbolized by R^2 because it is square of the coefficient of correlation symbolized by r. The coefficient of determination is an important tool in determining the degree of linear-correlation of variables ('goodness of fit') in regression analysis. In statistics, the coefficient of determination R^2 is used in the context of statistical models whose main purpose is the prediction of future outcomes on the basis of other related information. It is the proportion of variability in a data set that is accounted for by the statistical model. It provides a measure of how well future outcomes are likely to be predicted by the model.RESULTS AND DISCUSSION

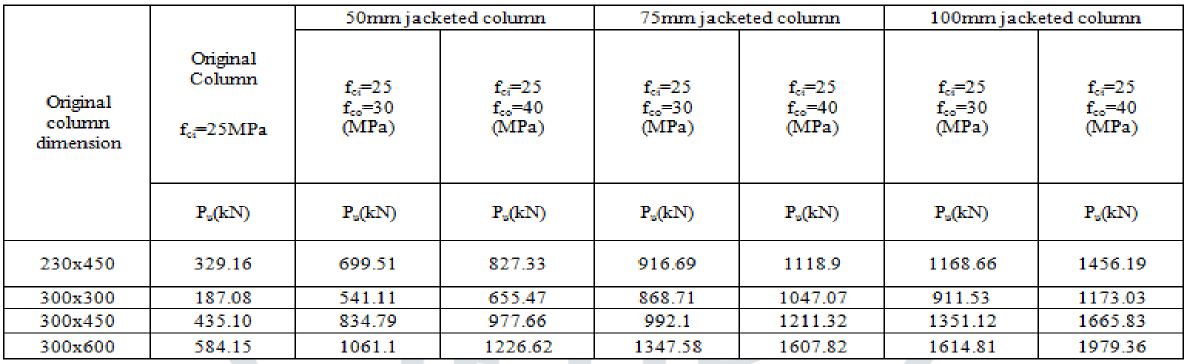
A. Theoretical original to jacketed P_u and M_u comparison

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 specifiedfactored load. The design strength of an eccentrically loaded column depends on the eccentricity of loading.For uniaxial eccentricity (e), the design strength has two components: an axial compression component(P_u) and a corresponding uniaxial moment component(M_u). The P_u and M_u has been calculated for anoriginal column of different column section for a concrete strength of 20MPa, 25MPa and 30MPa and for a jacketed column of different f_{ci} and f_{co} of jacketed thickness 50mm,75mm and 100mm. The obtained P_u and M_u of original column is compared with a jacketed column and is listed in the belowtable.



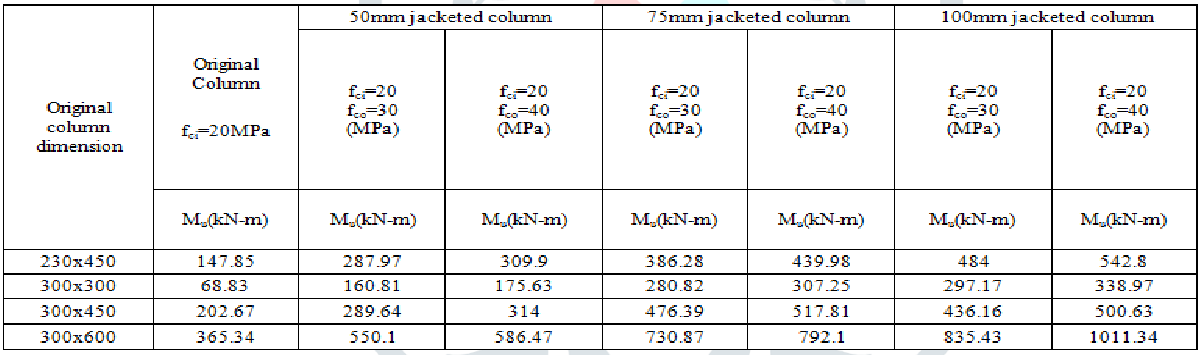
Original column dimension	Original Column f_{ci}=20MPa	50mm jacketed column		75mm jacketed column		100mm jacketed column	
		f_{ci}=20 f_{co}=30 (MPa)	f_{ci}=20 f_{co}=40 (MPa)	f_{ci}=20 f_{co}=30 (MPa)	f_{ci}=20 f_{co}=40 (MPa)	f_{ci}=20 f_{co}=30 (MPa)	f_{ci}=20 f_{co}=40 (MPa)
	P_u(kN)	P_u(kN)	P_u(kN)	P_u(kN)	P_u(kN)	P_u(kN)	P_u(kN)
230x450	251.23	611.82	749.27	836.19	1039.96	1092.48	1380
300x300	123.44	477.71	592.12	764.661	946.82	850.58	1112.11
300x450	334.33	733.71	873.22	891.56	1110.82	1251.18	1565.88
300x600	445.01	922.6	1088.17	1199.74	1469.72	1479.4	1841.87

Table 3. Comparison of axial compression component of original and jacketed column



Original column dimension	Original Column f_{ci}=25MPa	50mm jacketed column		75mm jacketed column		100mm jacketed column	
		f_{ci}=25 f_{co}=30 (MPa)	f_{ci}=25 f_{co}=40 (MPa)	f_{ci}=25 f_{co}=30 (MPa)	f_{ci}=25 f_{co}=40 (MPa)	f_{ci}=25 f_{co}=30 (MPa)	f_{ci}=25 f_{co}=40 (MPa)
	P_u(kN)	P_u(kN)	P_u(kN)	P_u(kN)	P_u(kN)	P_u(kN)	P_u(kN)
230x450	329.16	699.51	827.33	916.69	1118.9	1168.66	1456.19
300x300	187.08	541.11	655.47	868.71	1047.07	911.53	1173.03
300x450	435.10	834.79	977.66	992.1	1211.32	1351.12	1665.83
300x600	584.15	1061.1	1226.62	1347.58	1607.82	1614.81	1979.36

Table 4. Comparison of axial compression component of original and jacketed column



Original column dimension	Original Column f_{ci}=20MPa	50mm jacketed column		75mm jacketed column		100mm jacketed column	
		f_{ci}=20 f_{co}=30 (MPa)	f_{ci}=20 f_{co}=40 (MPa)	f_{ci}=20 f_{co}=30 (MPa)	f_{ci}=20 f_{co}=40 (MPa)	f_{ci}=20 f_{co}=30 (MPa)	f_{ci}=20 f_{co}=40 (MPa)
	M_u(kN-m)	M_u(kN-m)	M_u(kN-m)	M_u(kN-m)	M_u(kN-m)	M_u(kN-m)	M_u(kN-m)
230x450	147.85	287.97	309.9	386.28	439.98	484	542.8
300x300	68.83	160.81	175.63	280.82	307.25	297.17	338.97
300x450	202.67	289.64	314	476.39	517.81	436.16	500.63
300x600	365.34	550.1	586.47	730.87	792.1	835.43	1011.34

Table 5 Comparison of Uniaxial moment component of original and jacketed column

B. Axial load versus moment interaction curve

The 'interaction curve' is a complete graphical representation of the design strength of a uniaxially eccentrically loaded column of given proportions. Each point on the curve corresponds to the design strength values of Pu and M_u associated with a specific eccentricity (e) of loading. For designpurposes, the calculations of P_u and M_u are based on the design stress-strain curves and the resulting interaction curve is sometimes referred to as the design interaction curve. Using the design interaction curve for a given column section, it is possible to make quick judgement as to whether or not the section is safe under a specified factored load effect combination. When an eccentrically loaded column issubjected to P_u and M_u, for every load P_u there is a particular value of M_u which will cause failure. Thus there will be infinite combinations of P_u and M_u, which can safely act together for a given RC section.

In this work the interaction curves has been constructed for both square and rectangular column sections by varying the parameters such as cylinder compressive strength of both original and jacket concrete and jacket thickness. From the analysis results obtained the effects of the column size, jacket thickness, and grade of concrete used for original column and column jacketing. The following observations are made in this theoretical analysis study.The accumulation of moment highly dependson eccentricity of column load, the load versus moment curves have two distinct regions the initial part of the curve is close to linear and its slope depends on initial load eccentricity.

It can be visualized that the higher the grade of concrete used for RC columns increases its strength and decreases the eccentricity in column

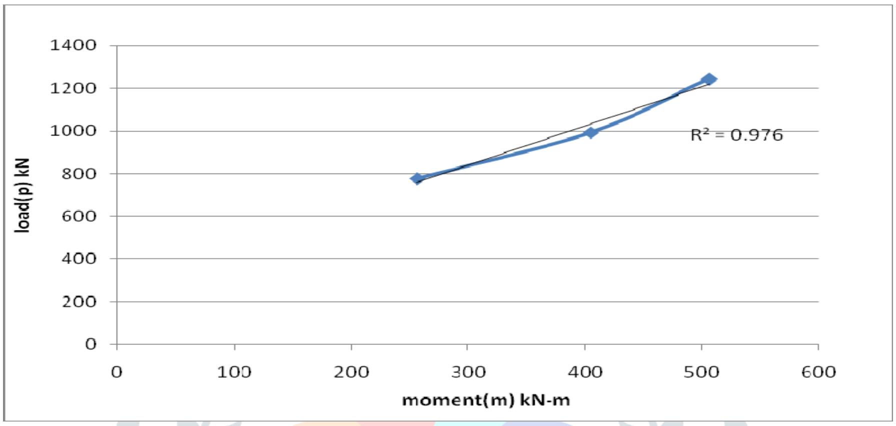


Figure 2. Column load versus moment for concrete strength f_{ci}= 30MPa & f_{co}= 30MPa and jacket thickness of 50mm,75mm &100mm (230mm x450 mm original column)

Column section	Theoretical f_{ci}=20MPa f_{co}=30MPa	FEM f_{ci}=20MPa f_{co}=30MPa	Theoretical f_{ci}=20MPa f_{co}=40MPa	FEM f_{ci}=20MPa f_{co}=40MPa
230x450	31.20	19.48	23.80	23.27
300x300	29.24	15.24	22.69	18.69
300x450	31.74	19.31	24.11	22.89
300x600	31.51	18.41	23.97	21.92

Table 6. Comparison of confined concrete strength of theoretical & finite element analysis with columns having same spacing ofinner and outer stirrups in longitudinal direction

Column section	Theoretical f_{ci} =30MPa f_{co} =30MPa	FEM f_{ci} =30MPa f_{co} =30MPa	Theoretical f_{ci} =30MPa f_{co} =40MPa	FEM f_{ci} =30MPa f_{co} =40MPa
230x450	45.97	20.59	35.26	24.44
300x300	45.67	22.77	35.46	26.56
300x450	47.00	20.33	35.50	24.47
300x600	47.10	22.42	36.45	26.22

Table 4.11 Comparison of confined concrete strength of theoretical & finite element with columns having different spacing of innerand outer stirrups in longitudinal direction

DISCUSSION

Due to confinement of core concrete by inner stirrups varied with outer 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. Thus the finite elementanalysis results also compared with results of columns having same spacing both in inner and outer stirrups with varied outer stirrups of jacketed columnsThe theoretical and finite element results obtained forthe different column sections, grades of concrete, and three different jacket thicknesses and for for samespacing and different spacing of columns are as shown in the tables 4.6 to 4.11, has been taken up for the comparison of columns having same spacing bothin inner and outer stirrups with varied outer stirrupsof jacketed columns .

It can be observed that due axial load along withuniaxial moment on column the column

Due to vary of stirrups in transverse direction the confinement capacity of column increases for column of size (230x450) of M20 and M30 0.64N/mm^2, for column of size (230x450) of M20 and M40 1.28N/mm^2, for column of size (230x450) of M25 and M30 0.66 N/mm^2, for column of size (230x450) of M25 and M40 0.68N/mm^2, for column of size(230x450) of M30 and M30 0.57N/mm^2, for column of size (230x450) of M30 and M40 0.71N/mm^2, for column of size (300x300) of M20 and M30 5.74N/mm^2, for column of size (300x300) of M20 and M40 5.94N/mm^2, for column of size (300x300) of M25 and M30 6.43N/mm^2, for column of size (300x300) of M25 and M40 6.6N/mm^2, for column of size (300x300) of M30 and M30 7N/mm^2, for column of size (300x300) of M30 and M40 7.38N/mm^2, for column of size (300x450) of M20 and M30 0.36 N/mm^2, for column of size (300x450) of M20 and M40 0.35N/mm^2, for column of size (300x450) of M25 and M30 1.11N/mm^2, for column of size (300x450) of M25 and M40 0.43N/mm^2, for column of size (300x450) of M30 and M30 0.49N/mm^2, for column of size (300x450) of M30 and M40 0.56N/mm^2, for column of size (300x600) of M20 and M30 1.31N/mm^2 for column of size (300x600) of M20 and M40 2.76N/mm^2, for column of size (300x600) of M25 and M30 3.23N/mm^2, for column of size (300x600) of M25 and M40 3.48N/mm^2, for column of size (300x600) of M30 and M30 3.39N/mm^2,, for column of size (300x600) of M30 and M40 3.68N/mm^2. The above results shows that varying the stirrups of outer jacket the confinement capacity will increases.

It can be observed that due axial load along with uniaxial moment on column the column is subjected to lateral deflection with respect to vertical in mmand from the results it has shown that deflection will be zero at the bottom and maximum at the free end(top).

CONCLUSION

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. Varying the stirrups of outer jackets the load carring capacity of column will increase when stirrups spacing are kept little closer compare to inner stirrups of column in vertical direction.

2. It can be visualized that the higher the grade of concrete used for RC columns increases its strength.
3. Varying the stirrups of outer jackets the shear capacity of column will increase when stirrups spacing are kept little closer compare to inner stirrups of column in vertical direction
4. Uniaxial 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.
5. The accumulation of moment highly depends on eccentricity of column load.
6. The load carrying capacity increases with increasing the size of original column and with increasing grade of structural concrete strength inthe original column or jacket and with the thickness of the jacket.

SCOPE FOR FUTURE STUDY

1. This work is fully concentrated about the theoretical and FE analysis which can be further studied by experimental means.
2. This study mainly concentrated on square and rectangular jacketed columns which can be further studied for different (shapes) types of columns.
3. This work is mainly concentrated on RC jacketing which can be further extended to steel and fiber reinforced polymer jacketing.
4. In the present study the column has beenmodeled as one end free and the other end is restrained in all three directions. In future theboundary conditions can be changed and the stress variations can be studied.

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