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Strength Characteristics of C-Shaped Equal Legged RC Columns and Rectangular Columns using Pu–Mu Interaction Diagrams

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Abstract
Interaction curve is a graphical representation of the ultimate load (Pu) and ultimate moment (Mu) carrying capacities. At the Present days use of rectangular columns and circular columns are common in construction filed as is it simple for analysis. Interaction curve for rectangular and circular column is provided by SP16:1980 RC handbook. Provision of C-shaped RC columns in the field of construction will increase the axial load carrying capacities of column and enhance the overall economy in construction, this paper work present the method to developing interaction curve for C-shaped equal legged RC column and Rectangular column, using ETABs software and analytical method by keeping constant area of steel and constant area of concrete in columns. Limit state method of design approach is adopted for analytical procedure.

Keywords: C-shaped RC Column; ETABs software; Grade of steel*;* Grade of concrete; Load and Moment; Rectangular RC Column

Introduction

Columns are the structural elements that support the superstructure, the transfer upright loads from superstructure to foundation. Inclined columns are called as strut. Columns takes the loads at the end and strong in compression. Columns are classified into several criteria based on loading pattern, slenderness Ratio, Type of reinforcement and shapes. Classification of columns based on shapes is as follows Rectangular, Square, Circular, L-section, T-section, Cross section columns. According to current Chinese code and technical specification, some frame structure with rectangular columns and specially shaped columns are designed on same cross section area, moments of inertia, stiffness of specially shaped frame structure, after analyzing the frame structure some advice are provided for the seismic design of the specially shaped column structures [1]. Different types of cross section effects to the interrelationship of axial load, moment and curvature was studied and result showed that there is a small negligible influence of shape of cross section on failure pattern envelope [2] studied the effect of confinement on load –Moment's interaction behavior of RC column. They have concluded that, the lateral reinforcement effects only in compression region, and it is also increase axial carrying capacity and moment of the section [3].

Interaction Curve

Interaction curve is a graphical representation of axial load (P_u) and ultimate moment (M_u).Load is taken in X axis and moments is taken in Y axis. The interaction diagram consists of various points on the curve corresponding's to load and moments. Each and every point on the curve is calculated based on stress strain relationship of the concrete. The main purpose of developing interaction curve is to check whether the concrete is safe or not and capacity of the column section. If the points lies within the section of the curve is said to be safe, if not, it is unsafe under corresponding load and moments. Typical interaction curve is shown in Fig1

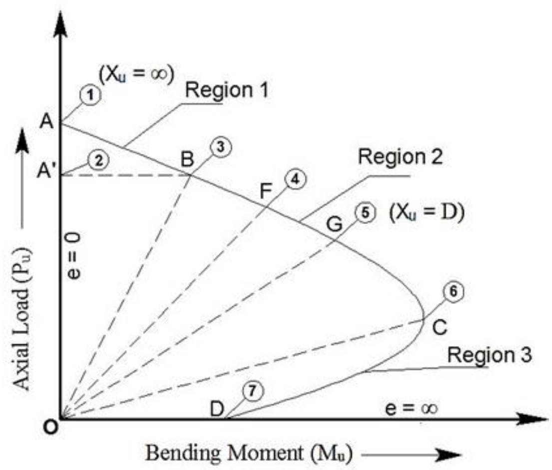

Fig.1: Typical interaction curve indicating different points and failure envelope

Significant points on Interaction curve for column

Fig.1. Represents the various points and they are listed below

Point 1: At zero eccentricity, Pure axial load and zero moment.

Point 2: At zero eccentricity, Maximum pure permissible axial compression

Point 3: Moment strength is maximum at maximum permissible axial compression

Point 4: Axial compression and capacity of moment when strain value is zero

Point 5: Axial compression and capacity of moment when 50% of strain value

Point 6: Axial compression and capacity of moment when balanced condition

Point7: Capacity of moment when axial force is zero, the whole curve has three prominent regions, namely Minimum eccentricity, Compressive control and tension control region.

Construction procedure of a Design Interaction Curve

The co-ordinates of the interaction curve, M_{uR} (on x axis) and P_{uR} (on y axis) can be calculated for any arbitrary position of neutral axis x_u. Having located (approximately) xu/D the co-ordinates of the interaction curve can be obtained with following procedure are adopted to develop the interaction curve for rectangular column

For the case of neutral axis lying inside the section K= Xu/D <1

Step1: Assume strength of steel, strength of concrete and diameter of reinforcing bars.

Step2: Axial load capacity of concrete = $0.361*f_{ck}*B*D$
Where, B= width of section;
D=depth of section
Step3: Axial load carrying capacity of steel
$\varepsilon_c = 0.0035\ [D-d_i^1]/D$
if $\varepsilon_{sc} > 0.002$ then the stress in concrete $f_{cc}= 0.446f_{ck}$ and
if $\varepsilon_{sc} < 0.002$ then $f_{cc}= 446\ \varepsilon_{sc}\ f_{ck}\ [1\text{-}250\ \varepsilon_{sc}]$
Total Axial load, $Pu=(0.361f_{ck}BD)+\sum A_{st}$(stress in steel - stress in concrete)
Ultimate moment, $Mu=0.361*f_{ck}*b*d*[C.G-d']$,
Where C.G is the distance of center of gravity from highly compressed edge,
b is the width and d is the depth of section above neutral axis

For the case of neutral axis situated outside the section K= Xu/D>1

- $(0.0035-0.75\varepsilon_{min})/(D+0.1D) = \varepsilon_{min}/0.1D$
- $\varepsilon_{cu} = 0.0035-0.75\ \varepsilon_{min}$
- $C_c^1 = C_c/(f_{ck}BD)$ and $Y_c^1 = Y_c/D$, where B is the width of the section and D is the overall depth of the section
- Axial load carrying capacity of concrete=$Cc^1*f_{ck}*B*D$ Stress calculation
- $\varepsilon_{sc} = \varepsilon_{cu}\ (D-d_1^1)/D$
- If $\varepsilon_{sc} > 0.002$ then the stress in concrete $f_{cc}= 0.446f_{ck}$ and if $\varepsilon_{sc} < 0.002$ then $f_{cc}= 446\ \varepsilon_{sc}\ f_{ck}\ [1\text{-}250\ \varepsilon_{sc}]$
- Total Axial load, $P_u= 0.361*f_{ck}BD + \sum$Ast (stress in steel - stress in concrete)
- Moment, $Mu= 0.361*f_{ck}BD[(D-C.G)-(Y^1_c*D)]$
- The stress in steel corresponding to a particular stain is obtained from table A of SP-16:1980

Table 1: Coefficients C_c^1 and Y_c^1

$K= X_u/D$	$C_c^1= C_c/f_{ck}BD$	$Y_c^1= Y_c/f_{ck}BD$
1	0.361	0.416
1.05	0.374	0.432
1.1	0.384	0.443
1.2	0.399	0.458
1.3	0.409	0.468
1.4	0.417	0.475
1.5	0.422	0.480
2.0	0.435	0.491
2.5	0.44	0.495
3.0	0.442	0.497
4.0	0.444	0.499

The values in Table 1 are the parameters specified in SP 16: 1980 RC Handbook, and the assumptions used in the design are as per the specifications of IS: 456-2000.

Interaction curve for Rectangular and C-shaped equal legged RC column

The rectangular and C-shaped equal Legged RC column is shown in Figure 2.Working stress method is based on the behavior of column under the working load. Limit state method of design is used to ensure the adequate factor of safety against failure. “Limit State Method” design approach is adopted for the analysis. The dimensions of the rectangular and C-shaped equal Legged RC are given in Table2

Table 2: Dimensions of the Rectangular and C-shaped Equal legged RC column

Parameter	**Rectangular column**	**C-shaped Equal legged RC Column**	**Units**
Concrete Cover	50	50	mm
Area of Steel	7430	7430	mm^2
Area of Concrete	2,80,000	2,80,000	mm^2
Total Numbers of Dia bars	18	24	mm
Size of Dia bars used	25 & 20	20	mm
Overall Depth	933.33	1000	mm
Thickness	300	200	mm
Spacing of bars	104.16	140	mm

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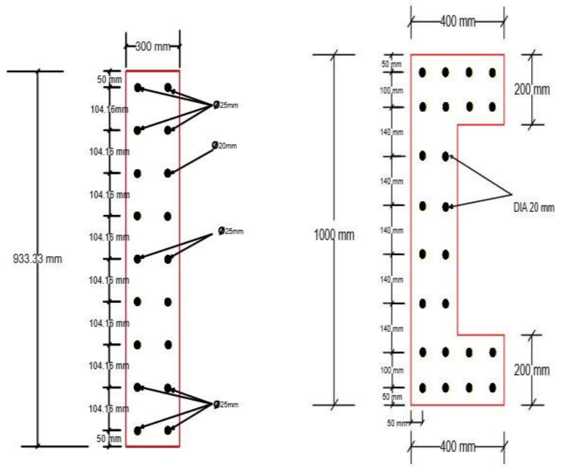
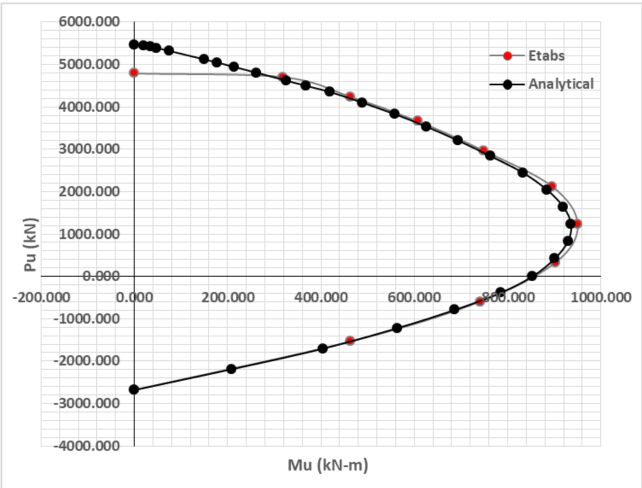
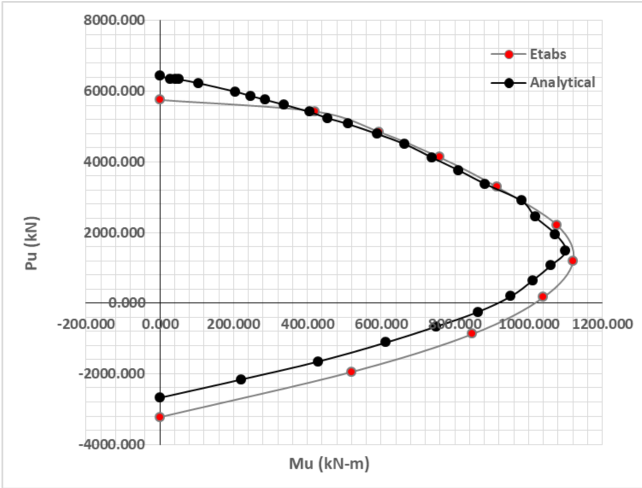


Fig 2: Typical Rectangular and C-shaped Equal legged RC column

Interaction curve for Rectangular RC Column by using Analytical Method and ETABs software

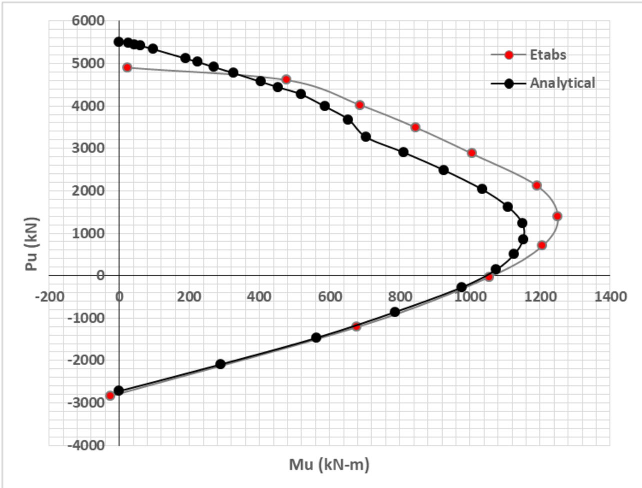


Graph 1: Comparison of Interaction curve for (M25 and Fe415) Rectangular RC column by using analytical method and ETABs method

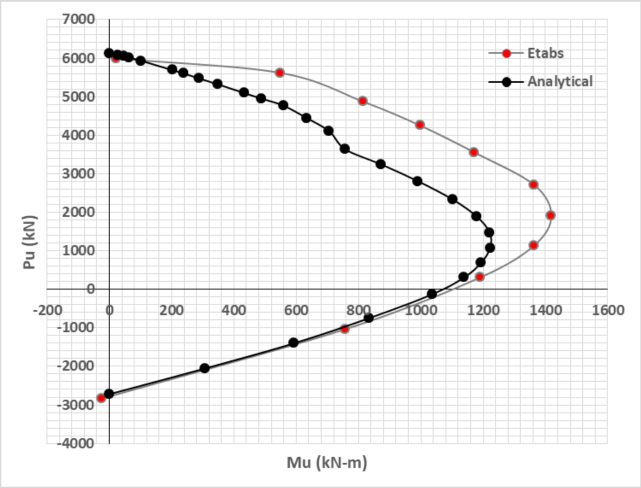


Graph 2: Comparison of Interaction curve for (M30 and Fe415) Rectangular RC column by using analytical method and ETABs method

Interaction curve for C-shaped Equal legged RC Column by using Analytical Method and ETABs software



Graph 3: Comparison of Interaction curve for (M25 and Fe415) C-shaped RC column by using analytical method and ETABs method



Graph 4: Comparison of Interaction curve for (M30 and Fe415) C-shaped RC column by using analytical method and ETABs method

Results

Comparisons of interaction Curve for Rectangular and C-shaped Equal legged RC column with 0' orientation

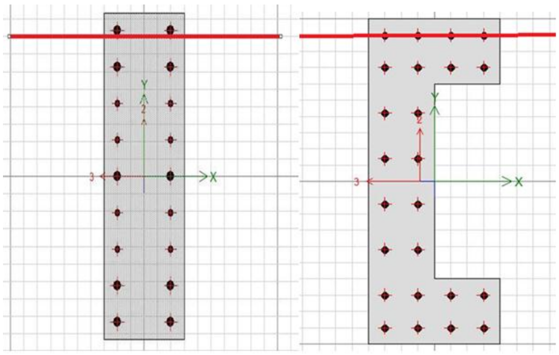
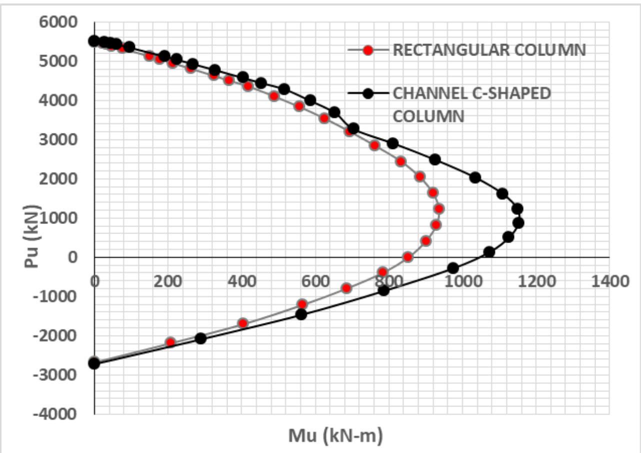
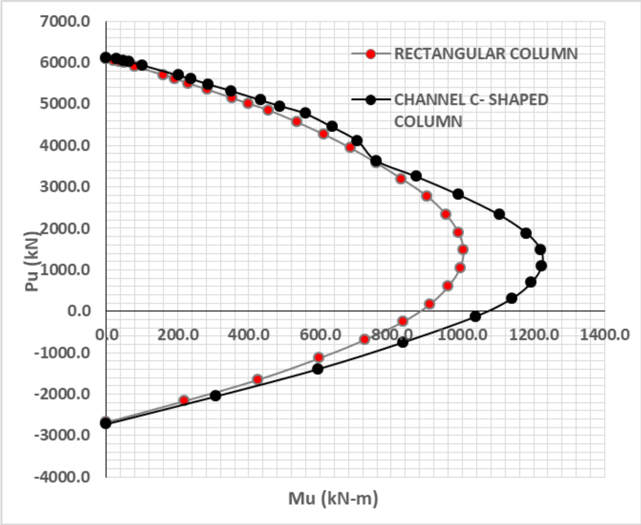


Fig.3. Rectangular and C-shaped Equal legged RC column with (0' degree) Orientation 1



Graph 5: Comparison of Interaction curve for (M25, Fe415, Orientation 1) Rectangular and C-shaped RC column



Graph 6: Comparison of Interaction curve for (M30, Fe415, Orientation 1) Rectangular and C-shaped RC column

Comparisons of interaction Curve for Rectangular and C-shaped Equal legged RC column with 90' orientation

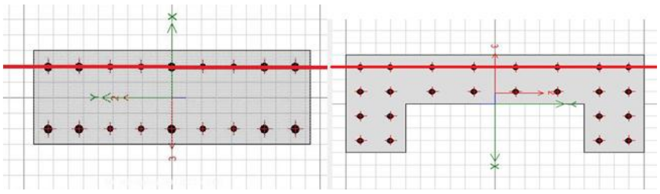
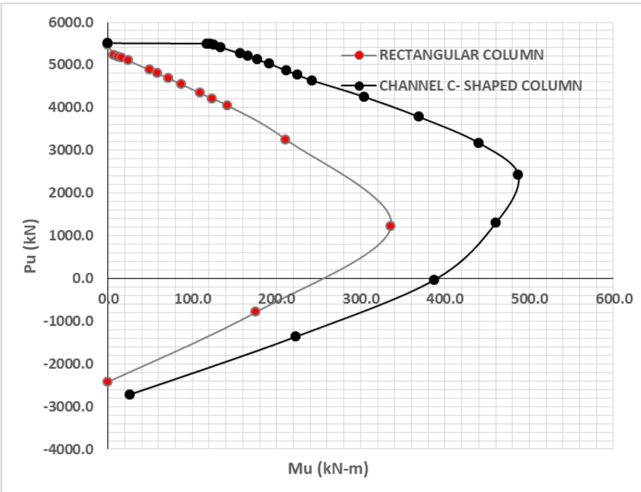
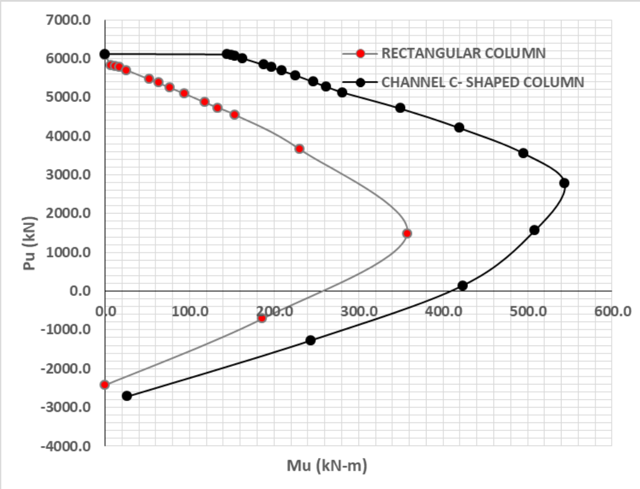


Fig.4. Rectangular and C-shaped Equal legged RC column with (90' degree) Orientation 2



Graph 7: Comparison of Interaction curve for (M25, Fe415, Orientation 2) Rectangular and C-shaped RC column



Graph 8: Comparison of Interaction curve for (M230, Fe415, Orientation 2) Rectangular and C-shaped RC column

Conclusion

1. Graph 1, 2, 3 and 4 shows that with increasing in the Grade of concrete (f_{ck}) or Grade of steel, the Maximum moment and load bearing capacity of Rectangular and C-shaped Equal legged RC Column increases.

2. The Pu-Mu interaction curve were developed by using analytical method and ETABs software, in this study result it is observed that in tension zone the results obtained by analytical and ETABs software match well but on the other part of curve a small considerable deviation is seen, this is due to following reasons,

- For the manual analytical calculation, parabolic stress block is considered but ETABS takes the Whitney's equivalent stress block for calculation, hence variations in results in load and moment.
- For the manual analytical calculation for stress in steel we used TABLE-A of SP 16 code book, but ETABS takes product of strain in steel and modulus of elasticity.
- For manual analytical calculation, the value of K ranges in between 1.05 to 4, but ETABS considered the value of K ranges in between the 1.05 to 1.2.

3. Comparison of interaction diagram develpoed Analytically for rectangular column with that of ETABs software showed that the load moment capacities falls on higher side for the results from ETABs which implies that for rectangular column ETABs over estimate the strength characteristics.

4. For C-shaped Equal legged RC column, Pu-Mu interaction diagram developed analytically falls on higher side in compression with that developed by ETABs which implies that ETABs underestimate the ultimate load and moment carrying capacities of C-shaped RC column,thereby providing over conservating design which could be optimize.

5. Graph 5, 6, 7 and 8 shows that Ultimate Load –Moment capacities for C-shaped RC column corresponding to **Orientation 1** and **2**, depicts that C-shaped RC column attains higher moment carrying capacities than Recatngular RC column.

6. For all possible **Orientation**, C-shaped Equal legged RC column has a higher ultimate strength characterstics than rectangular RC column column by keeping constant area of steel and concrete.

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