DEVELOPING OF AN EQUIVALENT RECTANUGLAR COLUMN FOR AN L-SHAPED RC COLUMN HAVING SIMILAR ULTIMATE LOAD MOMENT CHARACTERISTICS

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Abstract - *The structural characteristics of rectangular and circular columns can be easily analysed because the axis of centre of gravity lies within the section of the columns, whereas the centroidal axis lies outside the section in case of L shaped columns. Due to this, the section characteristics of L sections vary when compared to the other type of normal sections i.e.; rectangular and circular columns. Therefore this work deals with the study and analysis of strength parameters and nature of L section with respect to the rectangular column. This is a work on L column, as there is a lack of adequate codal provisions of this type of columns. In this project the behaviour of L shaped Columns are interpreted in the form of* ***Interaction Diagrams.*** *In this work an attempt is made to obtain interaction curve for symmetrical L-shaped column and compare with that of equivalent rectangular column of different B/D ratio.*

***Key Words*: Xu , Pu, Mu, NA, Interaction curve.**

1. INTRODUCTION

Columns are important elements which support the structures. They are the compression members and their failure may cause damage to the whole building. A column located in the building corner. In recent days irregular shaped columns are providing at the building corners and at enclosure of elevator shafts. The column may be of the shapes rectangular, circular, square, L shaped, T (tee) shaped etc. The size and cross section of the column depends on structure, height of the building and the loads acting on the structural member. The main aim of providing column is to resist against axial compression(P) and bending moments(M_x M_y).These load and moment develop due to external loads, such as dead load, live load, and lateral forces resulting from wind load and seismic action and by unbalanced moments at connecting beams, vertical misalignments. IS code (IS 456-2000) and design aid (SP-16) follows the strength criteria as a support for designing reinforced concrete columns wherein the failure is defined when it comes to a limiting strain and stress in concrete and the reinforcement. An interaction diagram may be plot for any column including given specifications such as grade, percentage of steel, reinforcement detailing pattern, dimension and shape of column by evaluating strain at various locations within the column considered, there by evaluating stress that return provides load and moment values, such numerous values of ultimate load and moment resisting capacity could be evaluated at different locations once the set of ultimate load and moment resistance values are obtained it could be graphically represented as an **interaction diagram** where load moment envelop serves as a failure curve implying that any combination of load and moment that falls within the envelop is safe and the load-moment combination that falls on the curve as the maximum load-moment resisting capacity of the section. Therefore interaction diagrams are one of the importance factor in design of columns.

2. INTERACTION DIAGRAM

Interaction diagram shown in fig-1 is a graph illustrating the capacity of a structural concrete member to resist a range of combinations of moment and axial force. The interaction diagram of the columns is drawn with a view to determine if the maximum axial load and moment exceeds the strength of the column. By changing the location of the neutral axis, giving different size of compressive and tension zones, each case will lead to a different capacity calculated from the strain distribution. Each point on the curve show design strength values of P_u and M_u linked to a specific eccentricity of loading wherein;

P_u : ultimate load carrying capacity of concrete.

M_u : ultimate moment carrying capacity of concrete.

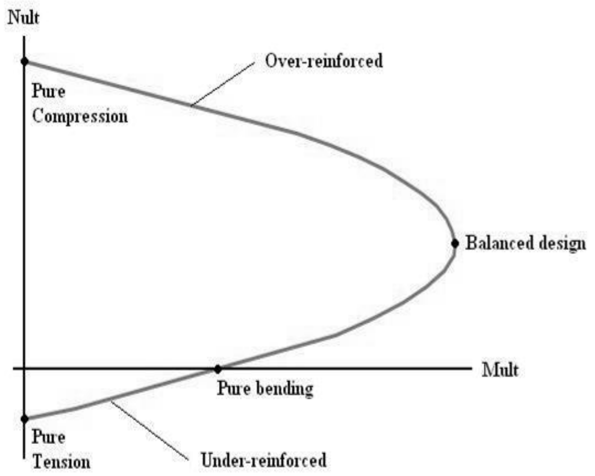

Fig-1: Interaction curve

2.1 Salient points on the interaction curve

The salient points marked 1 to 5 in the interaction curve in fig-2 corresponds to the failure strain profiles.

- The point 1 in fig-2 corresponds to the axial loading condition ith e=0. In this case of pure axial compression, $M_{uR} = 0$ and P_{uR} is indicated as P_{u0} given by the equation

  $$P_{u0}= 0.446\ f_{ck} A_c + X\ f_y A_s$$

  Where A_c = Area of concrete excluding area of steel incorporated in the section
  A_s= Area of steel present in the section
  f_y= Grade of steel
  X= 0.77 and 0.75 for steel grades of Fe 415 and Fe 500 respectively
- The point 1′ in fig-2 corresponds to the axial loading condition with the mandatory minimum eccentricity e_{min}.
- The point 3 in fig-2 corresponds to the condition where neutral axis position is equal to the depth of the section i.e x_u = D where e = e_d. For e < e_d, the entire column section is under compression and the neutral axis is located outside the section (x_u > D), with 0.002 < e_{cu} < 0.0035. For e > e_d, the neutral axis is located within the section (x_u < D), with e_{cu} = 0.0035 at the highly compressed edge. Point 2 represents general case, with neutral axis outside the section (e < e_d).
- The point 4 in fig-2 corresponds to the balanced failure condition with both concrete and steel undergoing maximum yield thereby representing pure flexure condition.
- The point 5 in fig-2 corresponds to the pure bending condition and at this stage the concrete suffers pure tensile failure.

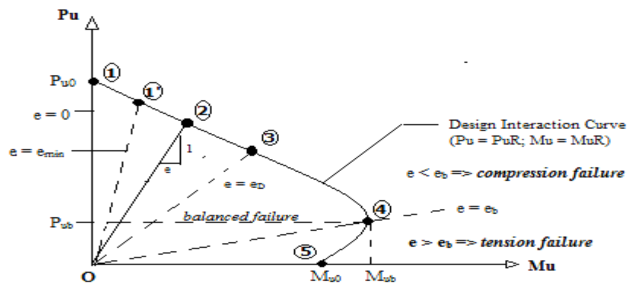

Fig-2: Salient points on the interaction curve

3. METHODOLOGY

The procedure basically involves two stages design of interaction curve :

1. when neutral axis is inside the section
2. when neutral axis is outside the section.

3.1. N-A lies inside the section (K= X_u/D <1)

Step1:

Assume data like f_y ,f_{ck} ,Diameter of the bar

Step2:

Axial load carrying capacity of concrete (kN)

P_{uc}= 0.361*f_{ck}*Area

Step3:

Axial load carrying capacity of steel f_{cc}

- e_{sc}= 0.0035 [D-d']/D
- If e_c>0.002 then f_{cc}= 0.446*f_{ck}
- e_c< 0.002 f_{cc}= 0.446*e_c*f_{ck}*[1-250*e_c]
- P_{us}=Stress in steel – stress in concrete
- Total Axial load,
  P_u= P_{uc} + P_{us}
- Ultimate moment, M_u= 0.361*f_{ck}*bd *[C.G-d']

3.2. N-A lies outside the section (K= X_U/D <1)

- To find strain value:
- (0.0035-0.75*e_{cb})/(D+0.1D)=e_{bb}/0.1D
- e_{cu}=0.0035-0.75e_{cb}
- Cc' =Cc/(f_{ck}* B*D) and Yc' =Yc/D
- P_{uc}=Cc'*f_{ck}*B*D
-

Stress calculation

- e_{cb}= e_{cu}(D-d')/D> 0.002
- If e_c>0.002 then f_{cc}= 0.446*f_{ck}
- e_c< 0.002 f_{cc}= 0.446*e_c*f_{ck}*[1-250*e_c]
- P_{us} = stress in steel – stress in concrete
- Total Axial load,
  P_u= P_{uc} + P_{us}
- Moment, M_u= (C_c' *f_{ck}*B*D)*[CG-Y_c'*d]

TABLE-1: Coefficients C_c' and Y_c' when the neutral axis lies outside the section

$K=X_u/D$	Coefficient $C_c'= C_c/f_{ck}BD$	Coefficient $Y_c'= Y_c/f_{ck}BD$
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

4. RESULTS

Using Spread Sheet interaction curve were developed for L-shaped column and rectangle of same area of concrete and steel, in the developed excel sheet grades of cement, reinforcement spacing, size of sections etc can be modified. To develop interaction curve codes like SP -16 and IS: 456-2000 is used ,the position of NA is placed at different points on the section including inside and outside. Values of M_u and P_u were calculated to plot the interaction curve.

L SECTON :

COULMN SIZE : 600 X 600 mm

BREADTH : 200 mm

DIA OF BAR : 16 mm

NUMBER OF BARS : 16

GRADE OF CONCRETE : 30 N/mm^2

GRADE OF STEEL : 415 N/mm^2

NA VARIES ALONG WEB OF THE SECTION:

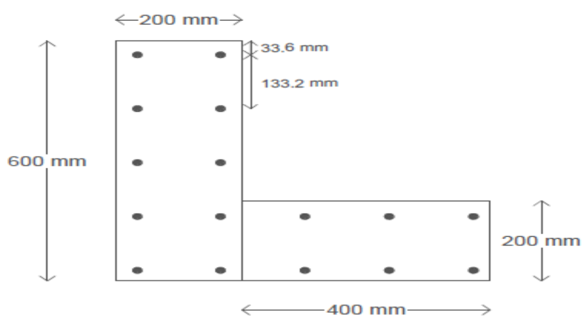

Fig-3: Dimensions of the L- sections considered for the analysis

Table-2: Values of P_u and M_u when NA is inside the section of the L section

NA (mm)	Total axial load carried by column (kN)	Total moment carried by column (kN-m)
0	-1161.01	-5.89215
33.6	-943.11	71.0182
166.8	-369.726	235.093
300	242.9077	321.508
433.2	1217.786	339.2851
566.4	2497.456	359.2177
600	2783.674	352.1417

Table-3: Values of P_u and M_u when NA is outside the section of the L section

NA (mm)	Total axial load carried by column (kN)	Total moment carried by column (kN-m)
630	2904.92	334.5598
660	3001.041	321.2904
720	3151.227	301.3147
780	3256.766	286.1581
840	3341.522	274.9822
900	3400.917	265.8135
1200	3551.617	242.88
1500	3611.407	233.5203
1800	3634.289	2292326
2400	3657.595	224.7906
Infinity	3687.65	0

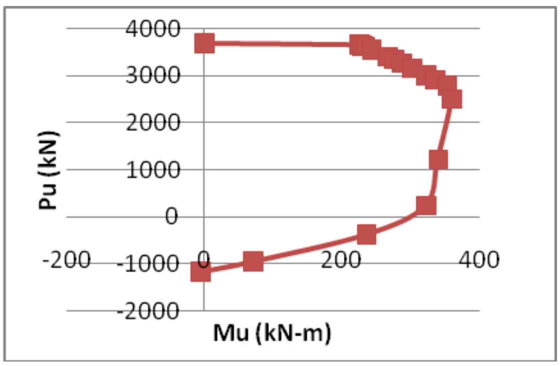

Chart-1: Interaction curve for L-shape concrete column

NA VARIES ALONG FLANGE OF THE SECTION:

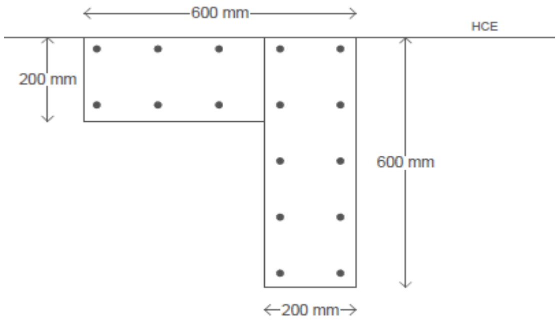

Fig -4: Dimensions of the L- sections considered for the analysis

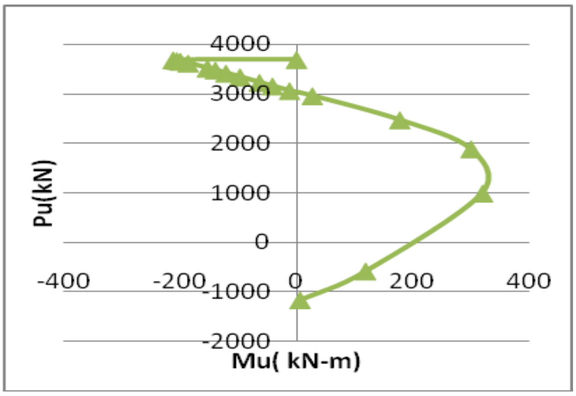

Chart-2: Interaction curve for L-shape concrete column

Table-4: Values of P_u and M_u when NA is inside the section of the L section

NA (mm)	Total axial load carried by column (kN)	Total moment carried by column (kN-m)
0	-1161.01	5.89
33.6	-579.865	118.502
166.8	992.558	319.260
300	1886.366	299.630
433.2	2471.217	177.209
566.4	2955.848	27.045
600	3059.528	-12.109

Table-5: Values of P_u and M_u when NA is outside the section of the L section

NA (mm)	Total axial load carried by column (kN)	Total moment carried by column (kN-m)
630	3153.22	-41.474
660	3225.904	-63.733
720	3337.381	-97.173
780	3413.081	-121.188
840	3473.081	-139.462
900	3513.826	-152.932
1200	3614.57	-186.252
1500	3652.465	-199.576
1800	3666.277	-205.615
2400	3679.807	-211.844
Infinity	3688.98	0

RECTANGLE SECTION:

COULMN SIZE : 870 X 230 mm

DIA OF BAR : 16 mm

NUMBER OF BARS : 16

GRADE OF CONCRETE : 30 N/mm^2

GRADE OF STEEL : 415 N/mm^2

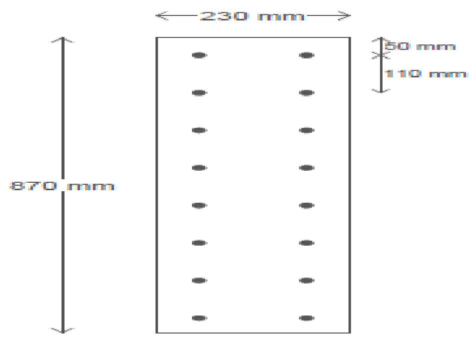

Fig -5: Dimensions of the rectangle sections considered for the analysis

Table-6: Values of P_u and M_u when NA is inside the section of the rectangle section

NA (mm)	Total axial load carried by column (kN)	Total moment carried by column (kN-m)
0	-1161.01	0
50	-891.33	107.46
160	-332.46	210.22
270	226.84	421.02
380	786.584	484.62
490	1345.13	490.89

600	1861.57	453.97
710	2287.57	403.19
820	2789.91	283.92
870	2963.64	239.14

Table-7: Values of P_u and M_u when NA is outside the section of the rectangle section

NA (mm)	Total axial load carried by column (kN)	Total moment carried by column (kN-m)
913.5	3066.71	205.66
957	3147.31	180.40
1044	3272.05	142.48
1131	3357.9	114.73
1218	3426.42	93.97
1305	3471.46	78..26
1740	3591.51	38.24
2175	3635.75	23.49
2610	3653.17	16.27
3480	3670.81	8.81
Infinity	3688.98	0

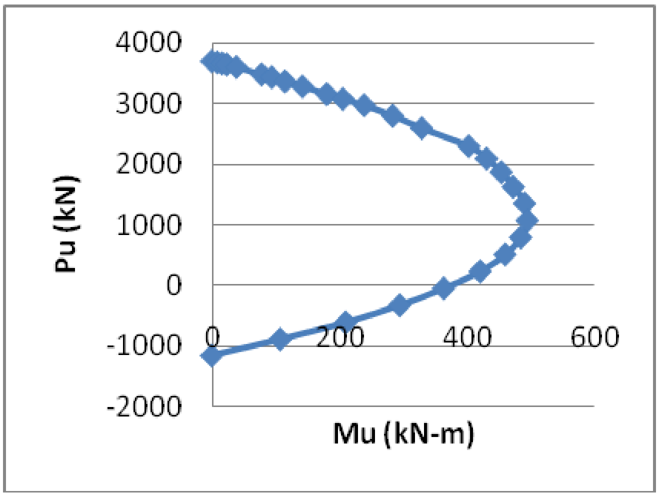

Chart-3: Interaction curve of Rectangular section.

For the rectangle section of (870 x 230) mm we get the B/D=0.264, Similarly, B/D ratio of rectangle is varied but the area of steel and concrete is kept same. The interaction diagram of L-section is compared with rectangular of different B/D ratio column and it is shown below.

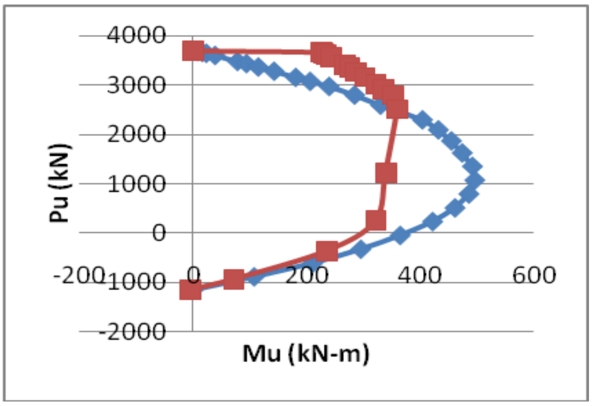

Chart-4: Interaction curve of L section compared with rectangle concrete column of B/D=0.264

Chart-4 to Chart-9 represent the interaction curve of L section where HCE is consider along web section compared with the rectangle section of different B/D ratio.

Chart-10 to Chart-15 represent the interaction curve of L section where HCE is consider along flange section compared with the rectangle section of different B/D ratio.

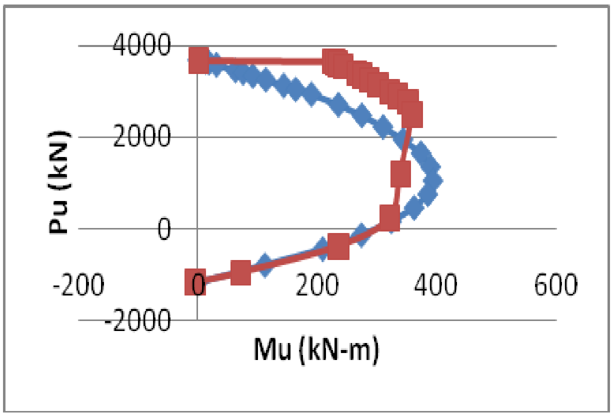

Chart-5: Interaction curve of L section compared with rectangle concrete column of B/D=0.449

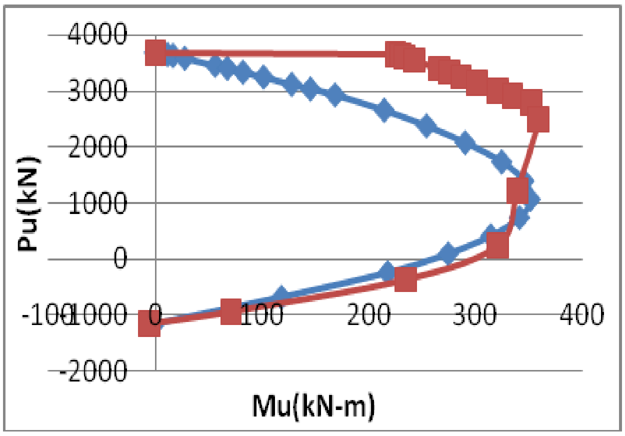

Chart-6: Interaction curve of L section compared with rectangle concrete column of B/D=0.612

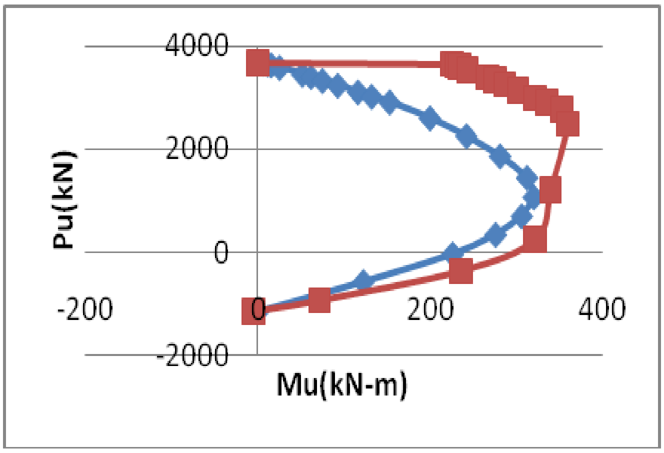

Chart-7: Interaction curve of L section compared with rectangle concrete column of B/D=0.799

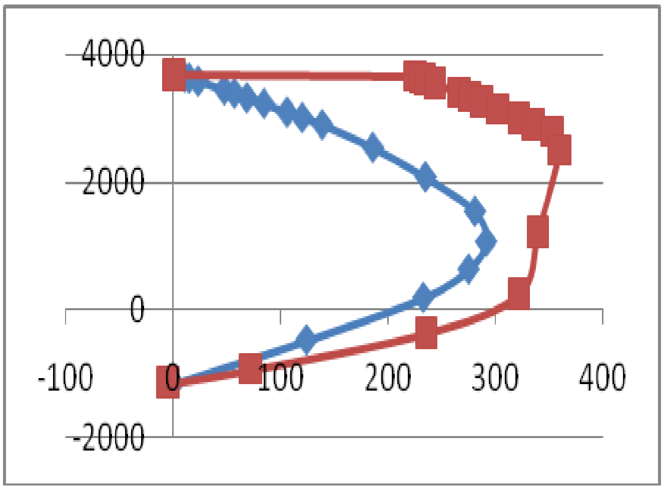

Chart-8: Interaction curve of L section compared with rectangle concrete column of B/D=1.01

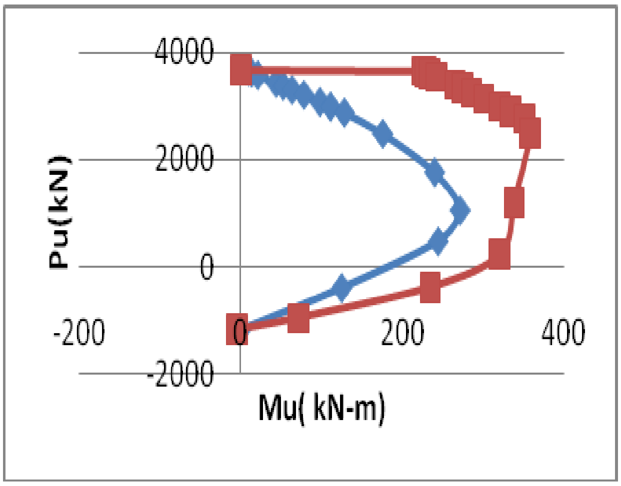

Chart-9: Interaction curve of L section compared with rectangle concrete column of B/D=1.24

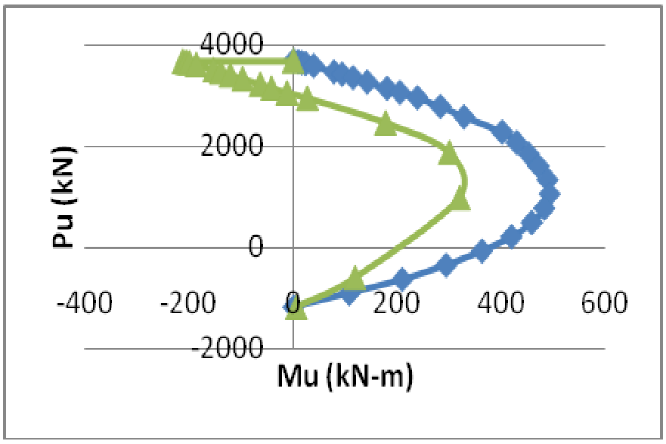

Chart-10: Interaction curve of L section compared with rectangle concrete column of B/D=0.264

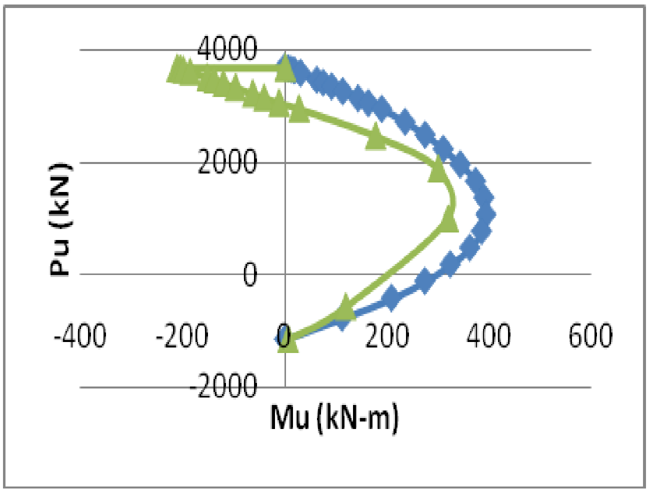

Chart-11: Interaction curve of L section compared with rectangle concrete column of B/D=0.448

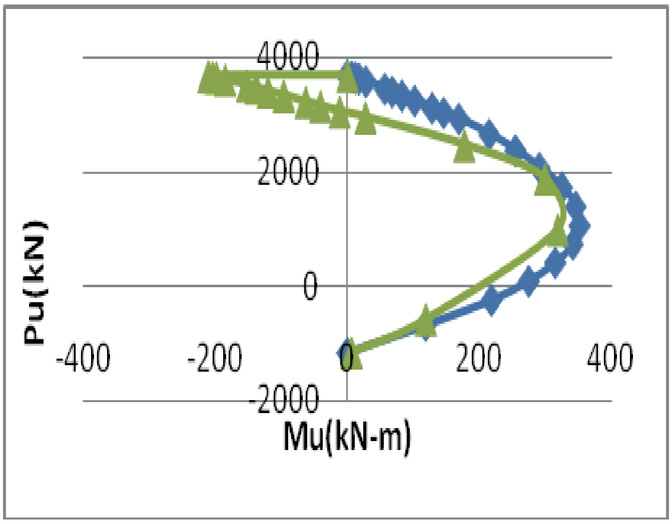

Chart-12: Interaction curve of L section compared with rectangle concrete column of B/D=0.612

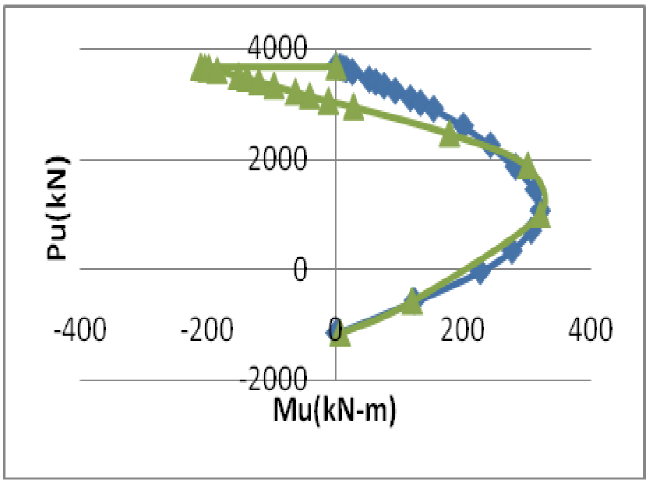

Chart-13: Interaction curve of L section compared with rectangle concrete column of B/D=0.799

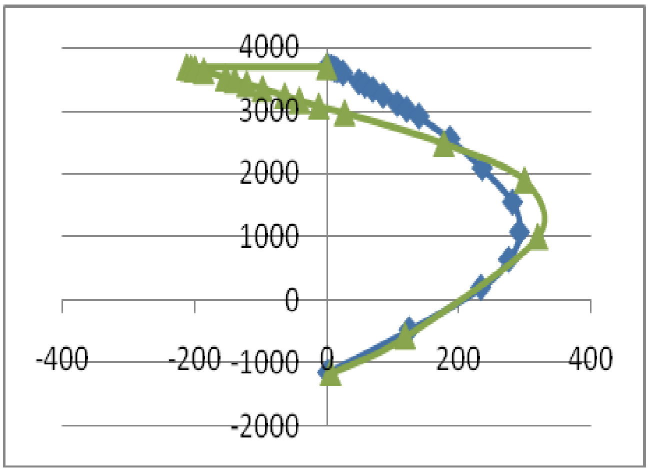

Chart-14: Interaction curve of L section compared with rectangle concrete column of B/D=1.01

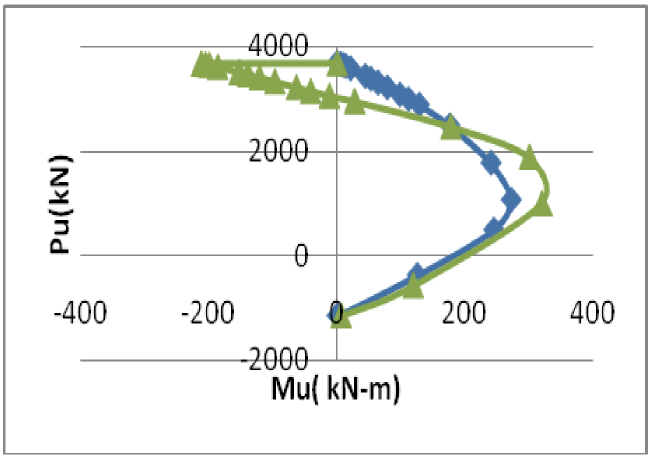

Chart-15: Interaction curve of L section compared with rectangle concrete column of B/D=1.24

5. CONCLUSIONS

The paper involves comparing the behavior of L-shaped column when its area of steel and area of concrete is kept same as that of the rectangle section. The results obtained in the work leads to the following conclusions.

- The ultimate load carrying capacity of L section where HCE consider at web when compared with rectangle shows 0.036% variation which can be concluded that load carrying capacity will be same for both sections since area of steel and concrete kept same.

- As we change the size of rectangular section the ultimate moment carrying capacity varies, here comparison is made when HCE is consider at web and variation 27.456, 8.77, 2.06 % decrease as B/D ratio of rectangular section 0.264, 0.449, 0.612 varied respectively and 11.09, 18.77, 24.529 % increase as B/D ratio of rectangular section 0.799, 1.01, 1.24 varied respectively.

- similarly, ultimate load carrying capacity of L section where HCE consider at flange is compared with rectangle shows 0.036% variation.

- Similarly, the size of rectangular section varied the ultimate moment carrying capacity when HCE is consider at flange and capacity 35.52, 18.924, 9.24 % decrease as B/D ratio of rectangular section 0.264, 0.449, 0.612 varied respectively and we observe that there will be 0.02% variation when compared with B/D ratio of 0.799 of rectangular section and there is 8.62, 15.024 % increase as B/D ratio of rectangular sectiona1.01, 1.24 varied respectively.

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