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Numerical Analysis of Slender Partially Encased Composite Columns

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Abstract-This paper presents the behaviour of slender partially encased composite (PEC) columns under eccentric axial load causing symmetrical single curvature bending. The load versus deflection response of slender partially encased composite column is formulated using the Newmark's iterative procedure. A parametric study is conducted using this method to identify the potential variables that can significantly affect the behaviour of slender partially encased composite column. The geometric properties that can greatly affect the behaviour of PEC columns include the column cross-sectional dimensions, length of the column, longitudinal spacing of the transverse links, thickness of the steel flange and web plates, and initial load eccentricity. The effects of these parameters on the axial capacity and second order deflection of the slender column is studied. The axial capacity of a partially encased composite columns are found to decrease significantly as the overall slenderness ratio increases, particularly for columns with slender plates. The load eccentricity ratio also has a significant impact on the capacity and deflection of these columns. Besides, a reduction in load carrying capacity has been found with increasing the flange slenderness ratio. On the other hand, link spacing-to-depth ratio has no effect on the axial capacity and lateral deflection of slender PEC column. Effect of overall column slenderness ratio and flange plate slenderness ratio are also studied on the P-M curve of the slender PEC column. The results are presented in the paper.

Keywords- *steel; concrete; composite; slender columns; eccentric loads, axial capacity; deflection.*

I. INTRODUCTION

An innovative structure may be composed of various types of building materials. As building materials, steel has high tensile strength and ductility and concrete has high compressive strength and good resistance to corrosion With the method of composite construction, it is now possible to combine the positive features of steel construction and structural concrete, without having to accept the drawbacks. A steel concrete composite column is a compression member, comprising either a concrete encased hot-rolled steel section or a concrete filled tubular section of hot-rolled steel and is generally used as a load-bearing member in a composite framed structure. Typical cross-sections of composite columns with fully and partially encased steel sections and concrete filled tubular sections are illustrated in Fig. 1. Steel-concrete composite columns are very effective in providing the required stiffness to limit the lateral drift of the building to the acceptable level as well as to resist the lateral seismic and wind loads. The introduction of steel rolled shapes and high strength concrete has made it possible to design columns of large slenderness.

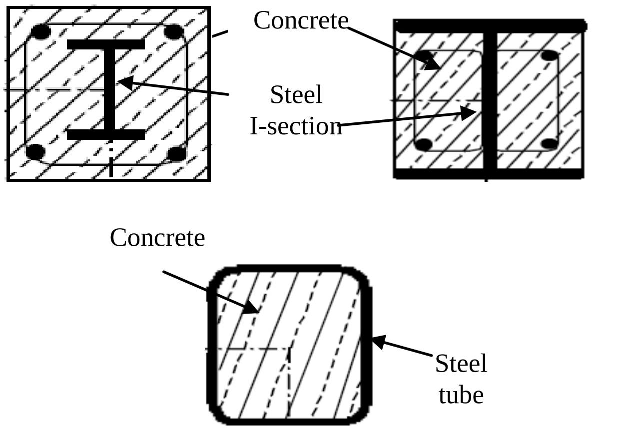

Figure 1: Typical cross-sections of (a) Fully encased composite column (FEC), (b) Partially encased composite column (PEC) and (c) Concrete filled tubular sections (CFT).

Partially encased composite (PEC) columns consisting of thin walled built up steel section with concrete infill cast between the flanges, is a relatively new concept in composite construction. Transverse links are provided between the flanges at regular intervals to enhance the resistance to local instability of the thin steel plates. Typical cross-section and 3D view of the steel skeleton of a PEC column is shown in Fig. 2. This innovative composite system reduces the cost of construction using relatively low-cost concrete by minimizing the use of higher cost steel. Besides, it also helps to overcome the complexities related to erection and design of connections of more commonly used composite columns. Several research works performed [1-7] on partially encased composite columns are manifested. Their research includes both numerical and experimental works. Their motive was to establish the behaviour and the design provisions for this new type of composite column under various loading conditions. Short (length-to-depth ratio of 5) column behaviour of partially encased composite column was the major focus included in these research works. Nevertheless, a few long column tests (length-to-depth ratio of 20) were carried out by (Chicoine et al. [4] under static loading condition. This test database is not sufficient to establish a design guideline for slender PEC columns. Therefore, extensive research work is required to fully understand the behavior of slender PEC columns under eccentric loading.

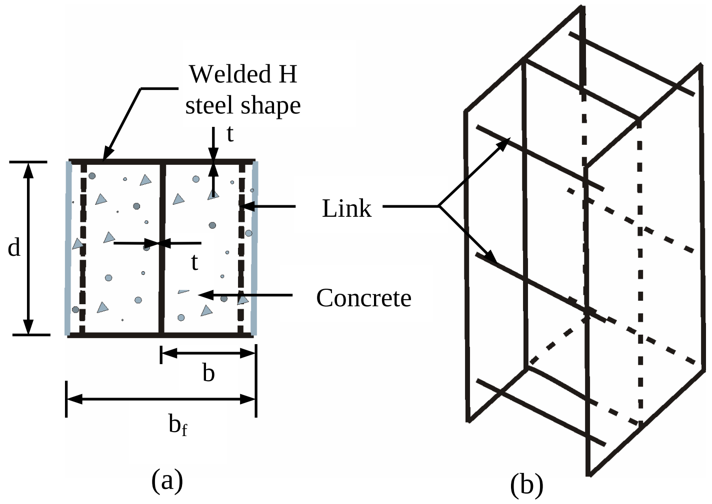

Figure 2: Partially encased composite columns, (a) cross section and (b) 3D view of the steel configuration.

II. OBJECTIVES AND SCOPE

The primary objective of this study is to investigate the structural behaviour of slender partially encased composite columns subjected to eccentric axial loading. To this end, Newmark's numerical iterative procedure is used to develop the load deflection curves of partially encased composite columns subjected to symmetrical single curvature bending about major axis of the column cross-section. This procedure is then used to determine the influence the overall column slenderness ratio and load eccentricity ratio of the axial capacity and lateral deflection of the column. A parametric study is conducted on four references PEC columns with variable overall slenderness ratio and load eccentricity ratio. Five different slenderness ratios—10, 15, 20, 25 and 30—has been employed in the parametric study to cover the short and intermediate slender PEC columns. The load eccentricity ratios used in this study are 0.1, 0.2, 0.3, 0.4 and 0.5. The flange plate slenderness ratio has been selected as 25, 30 and 35. Finally, link spacing-to-depth ratio has been taken as 0.5 and 0.7. The effects of these parameters were studied on 450 mm × 450 mm cross-section. The parametric columns were analyzed under monotonic loading conditions with bending about the strong axis.

III. LOAD DEFLECTION RESPONSE OF SLENDER COLUMN

The behaviour of a slender column of length L, subjected to eccentric loading is greatly influenced by the second order bending moment at midheight resulting from the deflection due to applied eccentric loading. The resulting deflection at mid height of the column is termed as second order deflection. For columns having a small slenderness ratio this second order deflection is negligible. However for slender columns this value becomes significant and controls the maximum moment of the column. Consequently, the bending moment strength of a slender column subjected to eccentric axial load is much lower than that of its cross-section. The second order deflection therefore plays a prominent role in identifying the

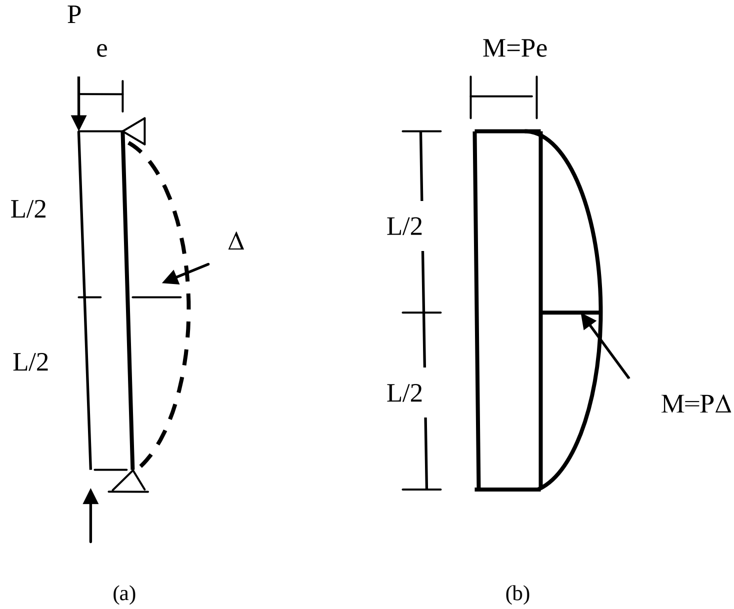

Figure 3: (a) Column subjected to eccentric loading (b) Bending moment diagram of the column

strength of slender PEC columns. Newmark's numerical iterative procedure is implemented to compute this second order deflection for slender PEC columns under symmetrical single curvature bending for a given axial load and applied eccentricity.

In this study a pin ended PEC column of length L, subjected to eccentric axial loading as shown in Fig. 3(a), is selected. The bending moment diagram of the column is shown in Fig. 3(b). The bending moment diagram has two parts – a constant moment (Pe) from the applied eccentricity and a variable moment (PΔ) resulting from the deflection (Δ) of the column from its original position.

Newmark's numerical iterative procedure [8] is used to determine the equilibrium configuration for a given combination of axial load and end moments that were applied to column. The column is subdivided into segments or stations of equal length for which initial deflections have been assumed based on the applied end moments. The first-order moments and the second-order moments due to slenderness effects are computed and summed at each station. The curvature corresponding to the total moment at each station are retrieved from the cross section moment-curvature curve for the given axial load level in order to define the distribution of curvature along the column length. Then the conjugate beam method is used to compute the deflection at each of the stations. If the computed deflections and the initial deflections are within prescribed limits of 0.05%, an equilibrium solution is obtained. If not, the computed deflections are substituted for the assumed deflections and the process is repeated until the deflections converged. For each value of axial load, similar procedure is adopted. Thus for a specific eccentricity, the load deflection curve is plotted. Using the value from load deflection curve, moment at mid height of composite slender column is determined by multiplying the axial load to the summation of assumed eccentricity and second order deflection at mid height of column. In case of drawing load deflection curve at different slenderness ratios, eccentricity of column has been fixed and length of column has been varied and the above procedure has been followed. For fully encased composite structural system Mirza et al. [9] numerical works have been carried out following this iterative method to determine the stiffness of columns.

From the load deflection curve, the ultimate capacity of column is determined by calculating the moment from deflection. In connection with it, for the specific cross-section, interaction diagram of the column is drawn using the strain compatibility relationship as applied for reinforced concrete columns. From the load moment interaction diagram, for a specific eccentricity, angle of straight line intersecting the interaction diagram, is determined. The corresponding point represents the axial load capacity of the column at a specific moment and eccentricity. The value of moment is noted. To determine the axial load capacity of a composite slender column, this value of moment is considered as the moment capacity of the column. Both values of axial load and mid height deflection are assumed and trial was done using Newmark's formula for several times to obtain the desired moment. The trial from which the required value of the cross-sectional moment is achieved has been noted. This axial load is the ultimate axial load capacity of the composite slender column at the specific eccentricity. Similar procedure is followed for determining the axial load capacity at other eccentricities. The load eccentricity of the column is then fixed and length of column has been varied and the procedure described above has been followed to determine capacity of column at different slenderness ratios.

IV. DESIGN OF PARAMETRIC STUDY

The potential variables that can significantly affect the behaviour of slender partially encased composite columns are the overall column slenderness ratio, flange plate slenderness ratio, load eccentricity ratio and link spacing. This paper demonstrates the effect of the overall column slenderness ratio and load eccentricity ratio in combination with flange plate slenderness ratio and link spacing. The column cross-section was fixed at 450mmx450mm. Four reference columns were designed with variable plate thickness and link spacing. The properties of these columns are shown in Table I. In each of these columns the overall slenderness ratio and load eccentricity ratio was varied. The global stability of the column is controlled by the overall slenderness ratio, which is defined as the ratio of the length of the column, L, to the depth of the column cross-section, d. Five different slenderness ratios— 10, 15, 20, 25 and 30—were employed in the parametric study to cover the range of short, intermediate and a wide range of slender columns. The load eccentricity ratios which can be obtained by dividing the initial eccentricity, e, of the applied axial load by the depth of the column cross-section, d, used in this study are 0.1, 0.2 0.3, 0.4 and 0.5. The flange slenderness ratio has been selected as 25, 30 and 35. Finally, link spacing-to-depth ratio has been taken as 0.5 and 0.7. The effects of the selected parameters on the load deflection response, axial capacity and deflection of PEC columns under single curvature bending about major axis are presented in the subsequent sections.

TABLE I. GEOMETRIC PROPERTIES OF THE REFERENCE COLUMNS

Column	*Width (b_f) (mm)*	*Depth (d) (mm)*	*Thickness(t) (mm)*	*Link Spacing (s) (mm)*
P_a	450	450	9	225
P_b	450	450	9	315
P_c	450	450	7.5	225
P_d	450	450	7.5	315

A. *Effect of load eccentricity (e/d) ratio*

The behaviour of a PEC column under bending induced by an eccentrically applied axial load is found to be greatly affected by the initial load eccentricity ratio. Table II to V shows the effect of column load eccentricity (e/d) ratio on the axial capacity and mid-height deflection of the column. For column P_b with L/d ratio of 15, increasing in the e/d ratio from 0.1 to 0.2, 0.3, 0.4 and 0.5 reduces the ultimate load capacity by 25%, 40%, 52% and 61% respectively and increases the lateral deflection by 43%, 67%, 72% and 74% respectively with respect to the column with e/d ratio of 0.1. Again, for column P_b with L/d ratio of 25, increasing the e/d ratio from 0.1 to 0.2, 0.3, 0.4 and 0.5 decreases the ultimate load capacity by 20%, 33%, 45% and 54% and increases the deflection by 44%, 70%, 76% and 79% respectively. Both of the analysis results show that reduction in ultimate load capacity and

TABLE II. EFFECT OF LOAD ECCENTRICITY RATIO AT SLENDERNESS RATIO 15

Column	*e/d*	*L/d*	*b/t*	*s/d*	*P_u(kN)*	*Δ_u(mm)*	*% variation in P_u*	*% variation in Δ_u*
P_b	0.1				9510	13.59	_	_
	0.2				7155	19.43	25	43

	0.3	15	25	0.7	5745	22.71	40	67
	0.4				4550	23.39	52	72
	0.5				3740	23.65	61	74

TABLE III. EFFECT OF LOAD ECCENTRICITY RATIO OF AT SLENDERNESS RATIO 25

Column	***e/d***	***L/d***	***b/t***	***s/d***	***P_u(kN)***	***Δ_u(mm)***	***% variation in P_u***	***% variation in Δ_u***
P_b	0.1				6975	35.13	_	_
	0.2				5580	50.7	20	44
	0.3	25	25	0.7	4665	59.69	33	70
	0.4				3835	61.9	45	76
	0.5				3235	62.97	54	79

increase in lateral deflection accelerated with the increase in load eccentricity ratio.

TABLE IV. EFFECT OF LOAD ECCENTRICITY RATIO AT SLENDERNESS RATIO 15

Column	***e/d***	***L/d***	***b/t***	***s/d***	***P_u(kN)***	***Δ_u(mm)***	***% variation in P_u***	***% variation in Δ_u***
P_d	0.1				8055	15	_	_
	0.2				6170	21.77	23	45
	0.3	15	30	0.7	4920	25.17	39	68
	0.4				3885	25.78	52	72
	0.5				3150	25.65	61	72

For column P_d with L/d ratio of 15 and 25, for the previous increment, the ultimate load capacity was reduced by 23%, 39%, 52%, 61% and 19%, 32%, 44%, 53% respectively. At the same time, deflection was increased by 45%, 68%, 72%, 72% and 46%, 71%, 76%, 76% respectively. Similar to column P_b, ultimate load capacity was reduced and deflection was increased significantly with increasing the load eccentricity ratio.

TABLE V. EFFECT OF LOAD ECCENTRICITY RATIO OF COLUMN AT SLENDERNESS RATIO 25

Column	***e/d***	***L/d***	***b/t***	***s/d***	***P_u(kN)***	***Δ_u(mm)***	***% variation in P_u***	***% variation in Δ_u***
P_d	0.1				5795	38.66	_	_
	0.2				4720	56.62	19	46
	0.3	25	30	0.7	3930	65.91	32	71
	0.4				3230	68.02	44	76
	0.5				2700	68.15	53	76

Figs. 4 to 7 present the relation between axial and mid-height deflections obtained by the proposed analytical method for the columns subjected to different initial load eccentricities. The eccentricity ratio was varied from 0.1 to 0.5 producing moment about the major axis of column.

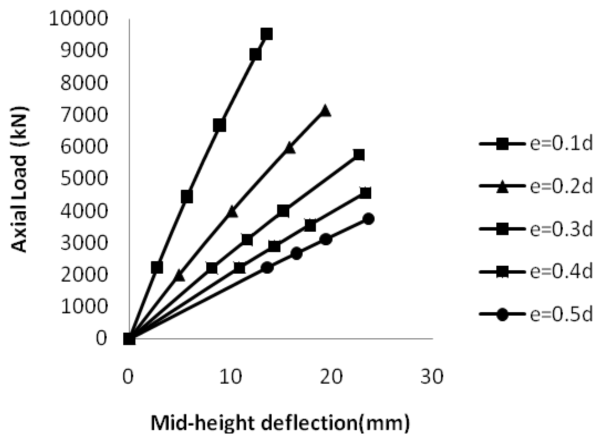

Figure 4: Load Deflection curve of P_b column with L/d ratio 15

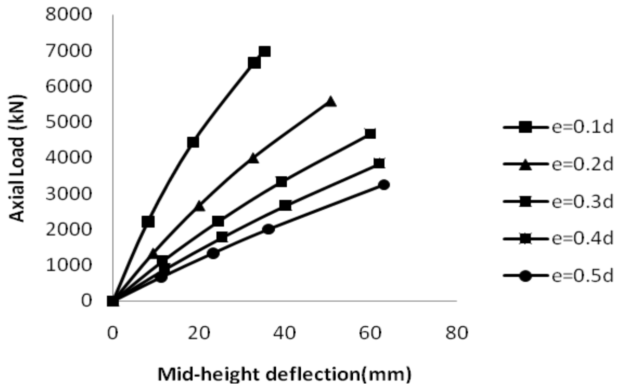

Figure 5: Load Deflection curve of P_b column with L/d ratio 25

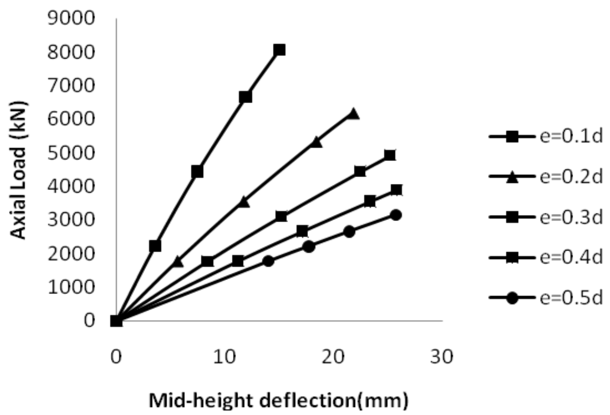

Figure 6: Load Deflection curve of P_d column with L/d ratio 15

These columns have slenderness ratio of 15 and 25 and pinned at the ends were subjected to single curvature bending.

It is clear that column capacity is strongly affected by the amount of eccentricity. As the eccentricity increases, the load-carrying capacity drops significantly with an increase in the mid height deflection.

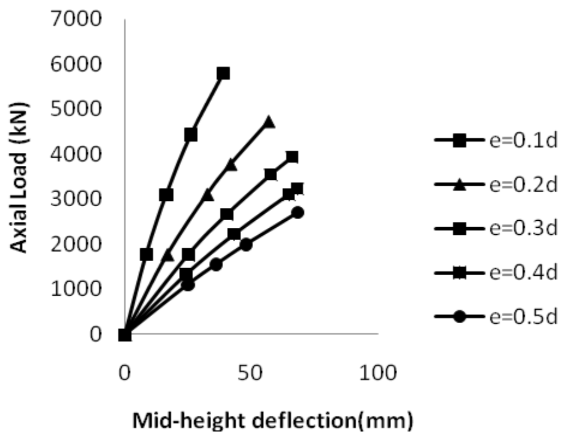

Figure 7: Load Deflection curve of P_d column with L/d ratio 25

B. Effect of overall column slenderness (L/d) ratio

The global stability of the column is controlled by the overall slenderness ratio, which is defined as the ratio of the length of the column, L, to the depth of column cross-section, d. In the parametric study five different slenderness ratios- 10,15,20,25 and 30- were employed. Tables VI to VII show the effect of overall column slenderness (L/d) ratio on the selected output parameters at the peak load point. For column P_a, if L/d ratio is increased by 5, 10, 15 and 20 the ultimate load capacity is reduced by 10%, 20%, 30% and 38% respectively and the lateral deflection is increased by 120%, 280%, 476% and 709% respectively. Again, for column P_b, an increase in the L/d ratio by 5, 10, 15 and 20 decreases the ultimate load capacity by 10%, 20%, 30% and 38% and increases the deflection by 121%, 280%, 477% and 710% respectively which are almost similar to column P_a. Both of the analysis results show that reduction in ultimate load capacity and increase in deflection accelerated with the increase in slenderness ratio. For column P_a and P_b, main distinguishing feature is the spacing of transverse links. The ultimate load capacity variation rate is observed to be similar for these columns with the applied variation in the overall slenderness ratio. Therefore, the effect of the spacing of the transverse links can be taken as insignificant for slender columns. For column P_d, an increase in the L/d ratio by 5, 10, 15 and 20 reduces the ultimate load capacity by 7%, 15%, 22% and 30% respectively. Again, lateral deflections increased by 123%, 285%, 487% and 728% respectively. The ultimate load capacity is higher for columns P_a or P_b as compared to columns P_d. This is due to the presence of slender flange plates of column P_d.

TABLE VI. EFFECT OF SLENDERNESS RATIO AT LOAD ECCENTRICITY RATIO 0.2

Column	*L/d*	*e/d*	*b/t*	*s/d*	*P_u(kN)*	*Δ_u(mm)*	*% variation in P_u*	*% variation in Δ_u*
P_a	10				7965	8.81	_	_
	15				7205	19.35	10	120
	20	0.2	25	0.5	6395	33.45	20	280
	25				5615	50.77	30	476
	30				4910	71.25	38	709

TABLE VII. EFFECT OF SLENDERNESS RATIO AT LOAD ECCENTRICITY RATIO 0.2

Column	*L/d*	*e/d*	*b/t*	*s/d*	*P_u(kN)*	*Δ_u(mm)*	*% variation in P_u*	*% variation in Δ_u*
P_b	10				7915	8.79	_	_
	15				7155	19.43	10	121
	20	0.2	25	0.7	6355	33.4	20	280
	25				5580	50.7	30	477
	30				4880	71.17	38	710

TABLE VIII. EFFECT OF SLENDERNESS RATIO AT LOAD ECCENTRICITY RATIO 0.4

Column	*L/d*	*e/d*	*b/t*	*s/d*	*P_u(kN)*	*Δ_u(mm)*	*% variation in P_u*	*% variation in Δ_u*
	10				4165	11.58	_	_
	15				3885	25.78	7	123
P_d	20	0.4	30	0.7	3560	44.63	15	285
	25				3230	68.02	22	487
	30				2910	95.83	30	728

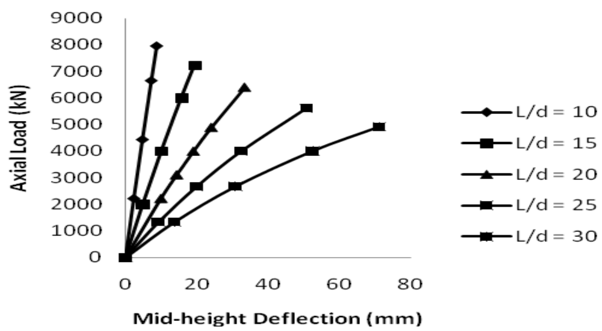

Figure 8: Load Deflection curve of P_a column with e/d ratio 0.2

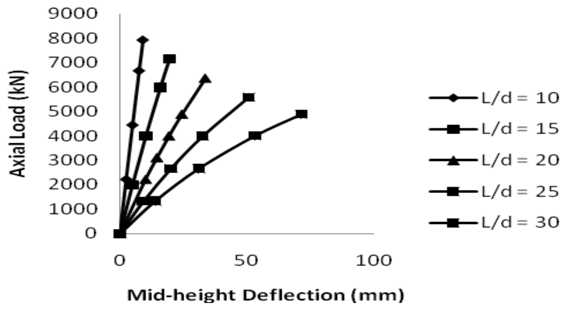

Figure 9: Load Deflection curve of P_b column with e/d ratio 0.2

The effects of overall column slenderness ratio on PEC columns at a fixed load eccentricity ratio are presented in Figs. 8 to 10. The load versus deflection responses for the columns

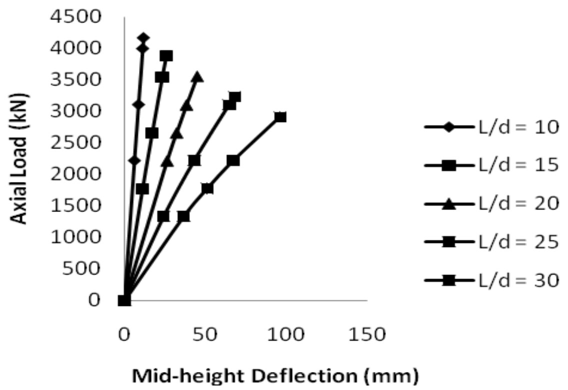

Figure 10: Load Deflection curve of P_d column with e/d ratio 0.4

with five different slenderness ratios 10 to 30, subjected to an initial load eccentricity ratio of 0.2 and 0.4 is shown. From these figures it is clear that increase in the slenderness ratio increases the lateral deflection at mid height with a significant reduction in the load carrying capacity. It also shows that for L/d ratio 10, curve shows linear pattern. It implies that, at this length of column, initial deflection is more dominant than secondary deflection. At other slenderness ratios, nonlinear curves have been found and deflection at mid-height of column increases exponentially with the increase in the slenderness ratios.

C. *Effect of flange plate slenderness (L/d) ratio*

The flange plate slenderness ratio is defined as the ratio of the half-width of the flange, b, to its thickness, t. This parameter was varied between 25 and 35, with an intermediate value of 30. The ultimate capacity of a PEC column is significantly affected by this parameter, since it controls the occurrence of local instability in the flange plate of the column. Table IX and X shows the effect of flange plate slenderness (b/t) ratio on the behaviour of slender partially encased composite column. Increasing b/t from 25 to 30 and 25 to 35 causes a reduction of 13% and 21% respectively in the axial load capacity of PEC column, P_a. The average reduction in the axial capacity is 17%. At the same time, lateral deflection is

TABLE IX. EFFECT OF FLANGE PLATE SLENDERNESS RATIO

Column	*e/d*	*L/d*	*b/t*	*s/d*	*P_u(kN)*	*Δ_u(mm)*	*% variation in P_u*	*% variation in Δ_u*
P_a			25		6395	33.45	_	_
	0.2	20	30	0.5	5580	38.3	13	15
			35		5025	40.72	21	22

TABLE X. EFFECT OF FLANGE PLATE SLENDERNESS RATIO

Column	*e/d*	*L/d*	*b/t*	*s/d*	*P_u(kN)*	*Δ_u(mm)*	*% variation in P_u*	*% variation in Δ_u*
P_b			25		4665	59.69	_	_
	0.3	25	30	0.7	3930	65.91	16	10
			35		3410	67.77	27	14

increased by 15% and 22% respectively. Again, for column P_b, an increase in the b/t ratio by 5 and 10 decreases the ultimate load capacity by 16% and 27% and increases the deflection by 10% and 14% respectively. Both of the analysis results show that reduction in ultimate load capacity and increase in deflection accelerated with the increase in flange plate slenderness ratio.

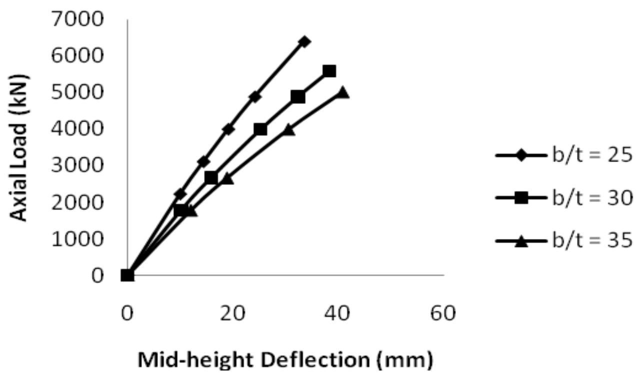

Figure 11: Load Deflection curve of P_a column with e/d 0.2 and L/d 20

The effects of flange plate slenderness ratio on PEC columns at a fixed load eccentricity ratio and slenderness ratio are presented in Figs 11 and 12. The load versus deflection curves for the columns with three different flange plate slenderness ratios 25, 30 and 35, subjected to an initial load

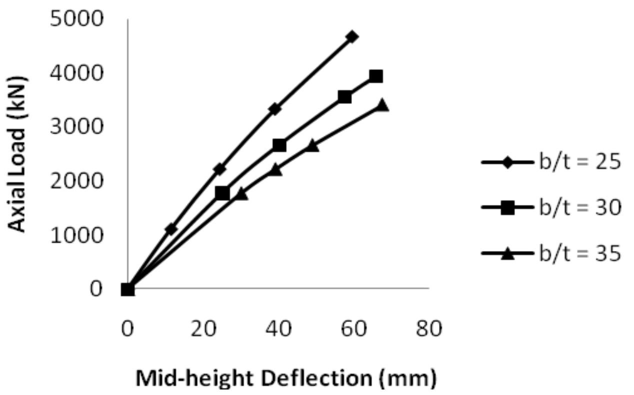

Figure 12: Load Deflection curve of P_b column with e/d 0.3 and L/d 25

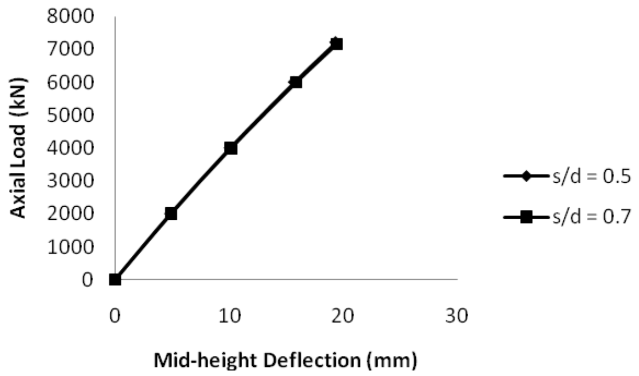

Figure 13: Load Deflection curve of P_d column with e/d 0.3 and L/d 15

eccentricity ratio of 0.2 and 0.3 are shown. From these figures it is clear that increase in the flange plate slenderness ratio increases the lateral deflection at mid height accompanied by a significant reduction in ultimate load carrying capacity of column.

D. Effect of link spacing to depth (s/d) ratio

Local flange buckling in a PEC column takes place in the unsupported length of the flange plate, i.e., in the flange panel between two successive links. Therefore, link spacing is clearly an important parameter affecting the behaviour of these columns. The effect of link spacing is studied by varying the ratio of link spacing, s, to the column cross-section, d. Two values of s/d ratio 0.5 and 0.7 have been studied in the parametric study. As shown in Table XI, changing the s/d ratio from 0.5 to 0.7 has negligible effect on the peak load. The axial capacity and second order deflection of slender columns are not affected at all by the s/d ratio.

TABLE XI. EFFECT OF LINK SPACING-TO-DEPTH RATIO

Column	*e/d*	*L/d*	*b/t*	*s/d*	*P_u(kN)*	*Δ_u(mm)*	*% variation in P_u*	*% variation in Δ_u*
P_b	0.2	15	25	0.5	7210	19.35	_	_
				0.7	7155	19.43	1	0.5

The load versus deflection curves for the columns with two different link spacing-to-depth ratios 0.5 and 0.7, subjected to an initial load eccentricity ratio of 0.2 and slenderness ratio 15 are shown in Fig.13. It can be clearly seen that the two graphs overlap, i.e. variation in ultimate capacity of axial load and lateral deflection is totally negligible with changing the spacing-to-depth ratio.

E. Effect of slenderness ratio on P-M curve

The effects of slenderness ratio on the load-moment curve of partially encased composite columns have been shown in Fig. 14. In order to study the variation of strength, composite columns of slenderness ratio 5, 25 and 30 have been selected. From the interaction diagrams, it can be clearly seen that the area of the failure envelope reduces significantly with the increase of the slenderness ratio of partially encased composite columns. Prominent reduction in strength has also been observed when the composite columns become more slender. Besides, considerable reduction in strength has been found in tension zone compared to the same in compression zone of the three interaction diagrams. From a short column to a slender column (L/d = 5, 25, 30), an average reduction of 10% has been noted, whereas between the two selected slender columns, a reduction of 7% has been found when the average value has been taken. Besides, for a short column, balanced point is obtained at a comparatively early stage than a slender column.

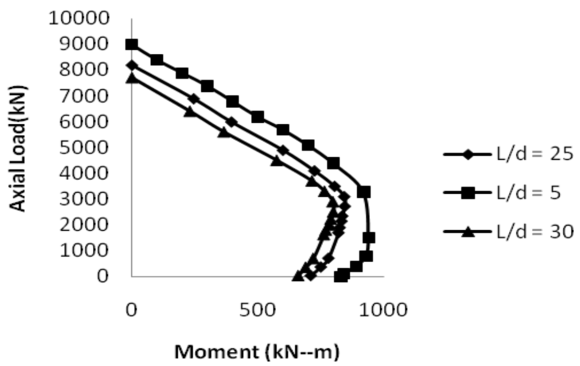

Figure 14: Variation of P-M curve with slenderness ratio

As a result, tension zone reduces as the composite columns become more slender.

F. Effect of flange plate slenderness ratio on P-M curve

The effects of flange plate slenderness ratio on the load-moment curve of partially encased composite columns have been illustrated in Fig. 15. A specific slenderness ratio of 25 has been taken to conduct this parametric study. Two different flange plate slenderness ratios (b/t =25, b/t = 30) have been selected to observe the influence of this parameter on strength of slender partially encased composite columns. The interaction diagrams shows a significant reduction in the axial load and moment capacity of slender PEC columns with the

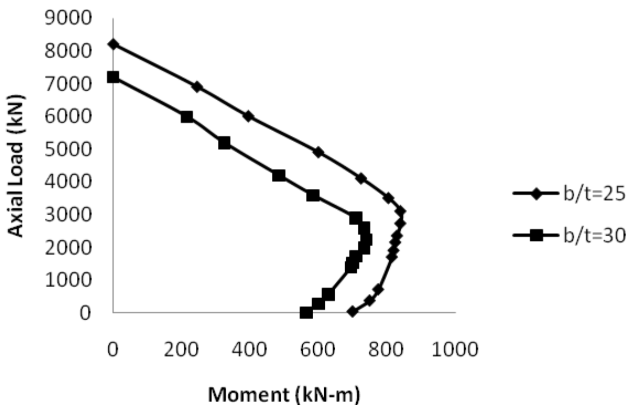

Figure 15: Variation of P-M curve with flange plate slenderness ratio

increase of the flange plate slenderness ratio. An average reduction of 20% has been noted, when the flange plate slenderness ratio has been varied from 25 to 30. Besides, formation of balanced point occurs at an earlier stage when flange plate slenderness ratio is 25 compared to when it becomes 30. Consequently, as the flange plate slenderness ratio increases, the tension zone of the interaction diagram decreases and compression zone increases.

V. CONCLUSIONS

The behaviour of slender partially encased composite column has been studied using Newmark's iterative procedure. A parametric study is conducted using this method to identify the potential variables that can significantly affect the behaviour of slender partially encased composite column. The variable parameters include load eccentricity ratio (e/d), slenderness ratio (L/d), flange plate thickness ratio (b/t) and link spacing-to-depth ratio (s/d). The effects of these parameters have been studied by formulating the load deflection response of the parametric columns. The effects of these parameters on the axial capacity and second order deflection of slender PEC column has been demonstrated. The axial capacity of a partially encased composite column has been reduced prominently as the overall slenderness ratio increases, particularly for columns with slender plates. This reduction is more prominent in columns with larger link spacing. Besides, exponential increase in lateral deflection has been observed with the increase in the slenderness ratio. Effect of second order deflection on total deflection has been found to be insignificant when L/d ratio is 10. For the eccentrically loaded columns, load carrying capacity has been found to drop significantly with an increase in eccentricity. The effect of the ratio of initial load eccentricity to the overall depth of the column cross-section has been observed to increase the lateral displacement of slender columns significantly and has been found more pronounced for columns with higher L/d ratio. The axial capacity of the PEC column has been found to be reduced by an average value of 10% when the flange b/t ratio is changed from 25 to 35. Effect of slenderness ratio and load eccentricity ratio is negligible when b/t ratio is varied. Besides, lateral deflection of slender column has been increased when b/t ratio is increased within this range. The axial capacity and deflection of the PEC column has been observed to be unaffected by the range of link spacing selected in this parametric study. Among the selected parameters, slenderness ratio and flange plate slenderness ratio have been varied to observe the influence of these parameters on P-M curve of slender column. Decrease in strength has been found with the increase of slenderness ratio and flange plate slenderness ratio of slender partially encased composite column. At the same time, failure envelope becomes smaller with the increase of these two parameters. Moreover, a smaller tension zone has been observed in the P-M curve as slenderness ratio and flange plate slenderness ratio increases.

VI. REFERENCES

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