ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 10, April 2013

Analysis of Multi-storey Building Frames Subjected to Gravity and Seismic Loads with Varying Inertia

Kulkarni J.G., Kore P. N., S. B. Tanawade

Abstract— This paper presents an elastic seismic response of reinforced concrete frames with 3 bay, 5 bay and 7 bay 9 storey structures which have been analyzed for gravity as well as seismic forces and their response is studied as the geometric parameters varying from view point of predicting behavior of similar structures subjected to similar loads or load combinations. The structural response of various members when geometry changes either physically, as in case of linear haunches provided beyond the face of columns at beam column joints or step variations as in case of purported T-section due to monolithic action in between beams and slabs, when the slab is available in compression zone of the beam was also studied. Every attempt has been made to describe the things in dimensionless forms. Results, if is expected, can be readily extended and/or extrapolated for other structures too. For the sake of clarity various types and kinds of structures analyzed and results so obtained have been grouped into various categories. This paper also highlighted on response of reinforced concrete frames for variation of axial force for spread of haunch and storey drift.

Index Terms— **Bare Frame, Multi-Storey Structure, Storey Drift, Spread Of Haunch.**

I. INTRODUCTION

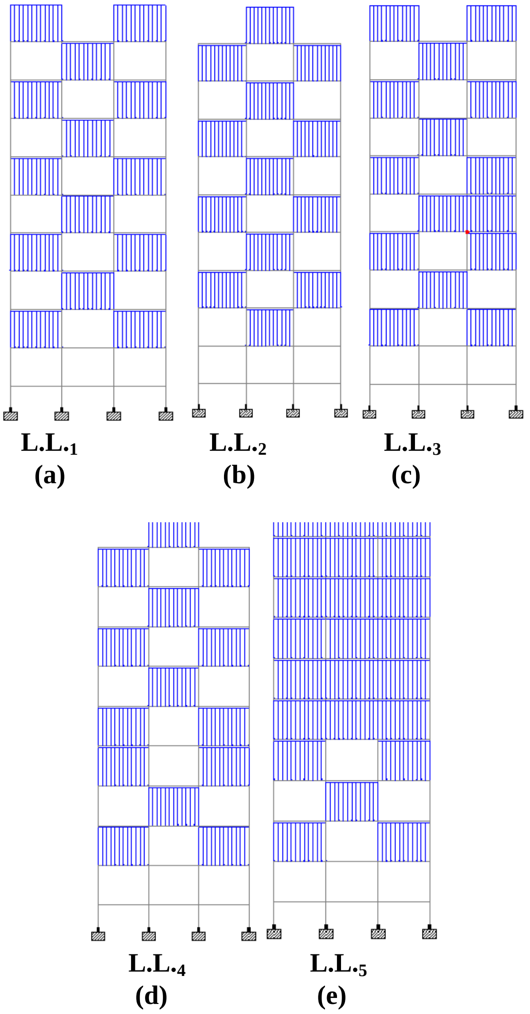
There is growing responsiveness of multi-storey reinforced concrete structures, to accommodate growing population. Generally such structures have prismatic sections which are common in developing countries, which resist applied loads without any appreciable deformation of one part relative to another. It is the need to accomplish some function, one of them is to receive loads (usually known as service loads) at certain points & transmit them safely to other points, that prompts the designer to give life to a structure furthermore since it is the need for a safe, serviceable, feasible and aesthetically pleasing fulfillment of a structure. The ultimate aim of structural analysis is to design all the structural elements of a *structural system* in such a way that they perform their functions satisfactorily and at the same time assist design to become efficient, elegant and economical which helps to choose the right type of sections consistent with economy along with safety of the structure.

II. OBJECTIVE OF STUDY

In order to make multi-storey structures stronger and stiffer, which are more susceptible to lateral (earthquake and/or wind) forces, the cross sections of the member (particularly columns) increases from top to bottom (4), makes the structure uneconomical owing to safety of the structure. When the given frame with all prismatic sections is subjected to different types of loads & their combination it exhibits a typical bending moment distribution pattern i.e. specific to certain type of load combination. When the bending moments gets so distributed, it can be easily verified that a certain portion of every beam shall carry a sagging moment producing compression at top. Slab being cast monolithically with beams & since they happen to set in the compression zone it promotes a T action in sagging moment zone, such a T beam but imaginary & has only to be conceived. This is not actually available in the form of T section as & an isolated section. When properties of such a T section are considered in analysis, one always find that it has larger inertia than the corresponding rectangular section, which depends on the width of flange (2), in turn depends upon the length of sagging moment zone i.e. distance between points of zero moment consistent with whatever flange width actually materializes. At the same time beyond the points of contra flexure i.e. in hogging moment zones the inertia of beam shall be as that of the same rectangular section referred to above. Naturally, response of such beam will be totally different from that of the beam considered in first interaction. It is expected that such a beam would attract larger bending moment near about the centre & would attract lesser moments near the ends. It was decided to find how these changes would occur as such using the bending moment diagrams of each beam which was split into three parts, with end segments having same cross section as before & the central one acting as a T section. The dimensions of T are appropriately decided (8) & the structure was reanalyzed after revising loads on all these beams to cope up with the requirements. Similarly the haunches are assumed at support i.e. beyond center line of column (the flare angle of haunch has been taken as 45^0); however for the purpose of comparison the spread of haunch as observed only beyond the face of the column (7). Various haunch spread beyond the face of the columns are considered and their effect studied on variation of axial force and bending moment at various locations and finally on the sway.

III. DESCRIPTION OF STUDY BUILDING STRUCTURE

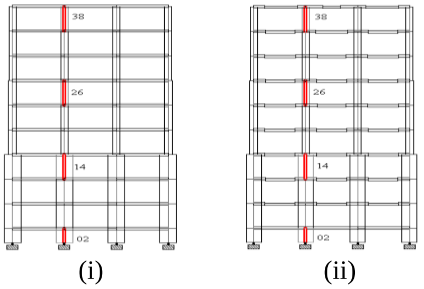
In order to study the behavior of reinforced concrete frames, three different configurations i.e. 3 bay, 5 bay and 7 bay, 9 stories with beam depths varying from 350 mm to 600 mm are modeled and analyzed numerically. The members are prismatic and/or non prismatic (viz. stepped and tapered members); subjected to loads i.e. dead load, live load, earthquake load and their combinations for limit state of collapse and serviceability criteria are considered. Here five different live load patterns (6) viz. L.L.$_{1}$, L.L.$_{2}$, L.L.$_{3}$, L.L.$_{4}$, and L.L.$_{5}$ are accounted which produce maximum mid span moment for beams i.e. L.L.$_{1}$ & L.L.$_{2}$ as shown in Fig.1 (a) & (b), maximum column moment i.e. L.L.$_{3}$ as shown in Fig.1 (c), maximum joint moment i.e. L.L.$_{4}$ as shown in Fig. 1 (d), and maximum axial force in column i.e. L.L.$_{5}$ as shown in Fig. 1 (e). These frames are modeled and analyzed in STAAD pro analysis software package (10). All structures are analyzed based on matrix methods of stiffness analysis (1 & 3).


L.L.$_{1}$ (a) L.L.$_{2}$ (b) L.L.$_{3}$ (c)

L.L.$_{4}$ (d) L.L.$_{5}$ (e)

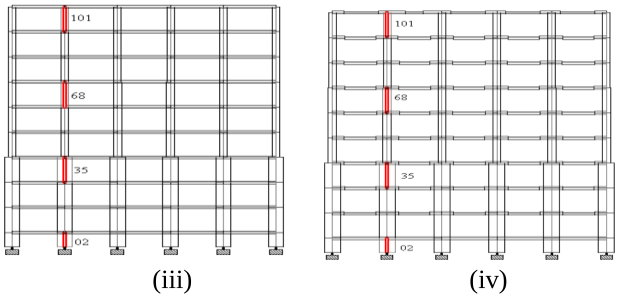
Fig. 1 Five different live load patterns considered to produce maximum mid span moment for beams (L.L.$_{1}$ & L.L.$_{2}$), maximum column moment (L.L.$_{3}$), maximum joint moment (L.L.$_{4}$) and maximum axial force in column (L.L.$_{5}$).

The sections of columns of bare frames are reduced from top to bottom, which is kept same for every 3 storey i.e. 1-3, 4-6 and 7-9, in order to achieve an economy in bare frames itself. In all cases, span length and story elevations are 4 and 3 meters, respectively. A typical frame of this type is shown in Fig. 2 a (i, iii & v) above.



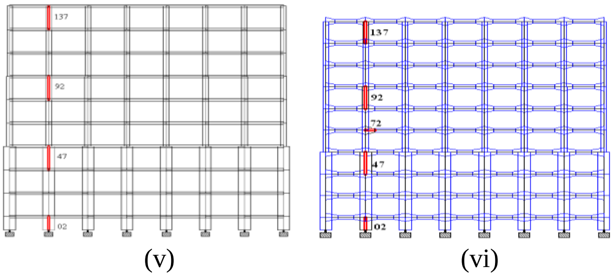
(i) (ii)

(a) Typical prismatic frame with 3 Bay and with idealised T beams considered in between points of contra flexures.



(iii) (iv)

(b) Typical prismatic frame with 5 Bay and with idealised T beams considered in between points of contra flexures.



(v) (vi)

(c) Typical prismatic frame with 7 Bay and with idealised haunch joints provided beyond column faces at beam column joints

Fig 2. Different Configurations Of 9 Storey 3 Bay, 5 Bay And 7 Bay Structures

With a view to get a feel of integral action developed between slab and beam promoting a T action in the structure an idealized imaginary structure with section behaving as T beam in the structure have been shown in Fig. 2 a (ii) and b (iv). Properties of T are determined using the exact distance between the points of contra flexure located actually on the beam (8) using the bending moment diagram of the frame with beam of depth 350 mm for all the beam segments. The same is done for 5 bay 9 storey structures as been shown in Fig. 2 (b). For 7 bay 9 storey structures the analysis has been made first on the frame consisting of only prismatic sections, afterwards a change in the cross-section in the form of haunch provided and the effect of same was also considered as shown in Fig. 2 c (vi). The spreads of haunches beyond face of column were considered at 0.05B, 0.075B, 0.1B, 0.125B, 0.15B where B is Bay width. While expressing the considered parameters such as axial force and bending moment, instead of using absolute values, for sake of facilitating, a ratio has been taken with the values obtained by conventional approach i.e. ratio of axial force (R_a) is the ratio of actual axial force to conventional axial force and for ratio of bending moment (R_m) is the ratio of actual bending moment to that of conventional one.

IV. PARAMETRIC STUDY

Analysis has been made to study and compare following parameters:

1) To study the variation of internal forces i.e. axial force and bending moment at specified locations as shown in Fig. 2 a, b, c.
2) To study distribution of lateral displacements (sway).
3) To study the effect of varying inertia of beam due to introduction of T-action for 3 and 5 bay as shown in Fig. 2 a (ii), b (iv) and haunches beyond the face of columns for 7 bay as shown in Fig. 2 c (vi).

V. RESULTS AND DISCUSSION

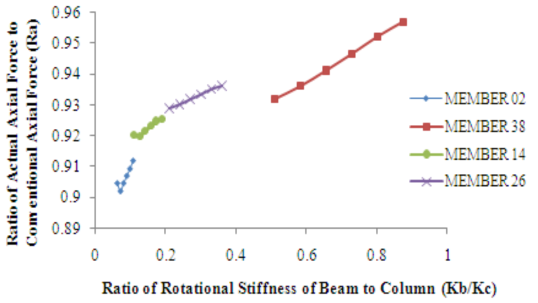
For 3 bay and 5 bay structure a beam depth of 350 mm is considered only to study the effect of varying inertia of beam due to introduction of T-action in beam as shown in Fig. 2 (a & b) above and for 7 bay structure for all beam depths ranging from 350 mm to 600 mm is considered to study the effects of varying inertia of beam due to introduction of haunches beyond column faces as shown in Fig. 2 (c) above. Forces induced viz. axial force and bending moment in various worst loaded column segments is considered for this purpose. In order to facilitate the direct comparison between prismatic and non prismatic frames the latter have been analyzed for same geometry by locating the exact distance between points of contra flexure for the same loading combination for which the prismatic frame yielded the maximum design force in the members so selected as shown in Fig.2 a, b and c indicated by member number.

A. 3- Bay 9 storey structures:

To study the variation of axial force in left most column in various segments typically chosen to have the change of cross-section in the immediate neighborhood viz. 02, 14, 26, 38 are considered as shown in Fig. 2 (a). Variation of axial force in the column segments is found to be linear for the members as we move towards top as seen in Graph No. 01 and the corresponding values are provided in Table I. The variation in members located at base shows little drop initially and further shows liner variation. It may be noted that the conventional method of considering the load attracted by column using adjoining contributory area overestimates load in column, average percentage of which is found as 5.9%, 7.25%, 9.47% and 10.23% for members 38, 26, 14, 02 respectively. This variation suggests that the conventional method estimate loads in better fashion away from the base of structure.

Table I:Variation of Axial Force in Member No. 02, 14, 26, 38 with K_b/K_c ratio for 3 Bay 9 storey Structures

$\frac{K_b}{K_c}$	Mem-Ber 02	$\frac{K_b}{K_c}$	Mem-Ber 14	$\frac{K_b}{K_c}$	Mem-Ber 26	$\frac{K_b}{K_c}$	Mem ber 38
0.06	0.905	0.11	0.92	0.21	0.929	0.51	0.932
0.07	0.902	0.13	0.92	0.24	0.93	0.58	0.936
0.08	0.905	0.14	0.922	0.27	0.932	0.66	0.941
0.09	0.907	0.16	0.923	0.30	0.933	0.73	0.947
0.10	0.909	0.17	0.925	0.33	0.935	0.8	0.952
0.11	0.912	0.19	0.925	0.36	0.936	0.87	0.957

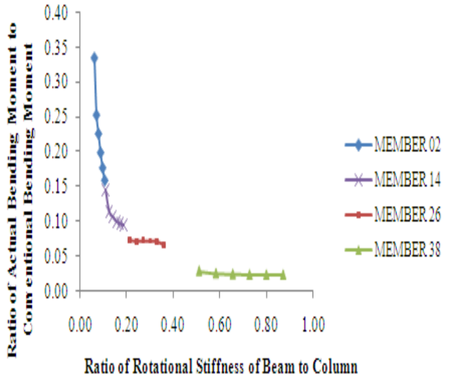


Graph No. 1
Variation of Axial Force in Member No. 02, 14, 26, 38
with Kb/Kc ratio for 3 Bay 9 storey Structures

Bending moment in the column segments is found to increase with decrease in the values of K_b/K_c ratio for considered beam depths as seen in Graph No. 02 and the corresponding values are provided in Table II. An increase is found in the lowest segment and subsequently reduces as segments at higher levels are considered. It is found that bending moment attracted by column at bottom of segment is largest for the smallest K_b/K_c at joint, the values are found to reduce by 52.65%, 34.57%, 10.32%, and 18.34% for members 02, 14, 26, and 38 respectively as K_b/K_c increases.

Table II: Variation of Bending Moment in Member No. 02, 14, 26, 38 with K_b/K_c ratio for 3 Bay 9 storey Structures

$\frac{K_b}{K_c}$	Mem-Ber 02	$\frac{K_b}{K_c}$	Mem Ber 14	$\frac{K_b}{K_c}$	Mem-Ber 26	$\frac{K_b}{K_c}$	Mem ber 38
0.062	0.336	0.110	0.146	0.210	0.073	0.509	0.029
0.071	0.253	0.125	0.115	0.240	0.071	0.582	0.026
0.079	0.226	0.141	0.107	0.270	0.072	0.655	0.025
0.088	0.199	0.157	0.101	0.300	0.071	0.727	0.024
0.097	0.177	0.172	0.097	0.330	0.071	0.800	0.024
0.106	0.159	0.188	0.095	0.361	0.065	0.873	0.024



Graph No. 2
Variation of Bending Moment in Member No. 02, 14, 26, 38
with Kb/Kc ratio for 3 Bay 9 storey Structures

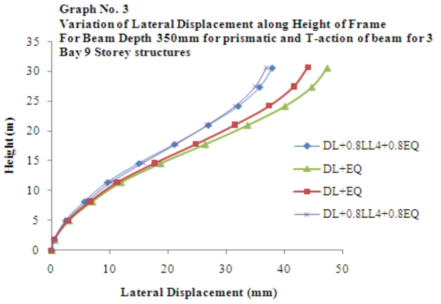
Following Load Combinations Sampled At Random And Worst Loading Combinations As Appropriate For Study Of Variation Of Lateral Displacement Along Height Of Frame.

1) DL+ EQ
2) DL + 0.8LL_4 + 0.8EQ

Table III: Variation of Lateral Displacement along Height of Frame for 3 Bay 9 Storey Structures For Beam Depth 350 Mm

Height (m)	Lateral Sway for Prismatic Section (mm)		Lateral Sway for Non-prismatic Section (mm)	
	DL+ EQ	DL+0.8LL$_4$ +0.8EQ	DL+ EQ	DL+0.8LL$_4$ +0.8EQ
30.6	47.296	37.917	43.961	36.932
27.4	44.625	35.751	41.536	34.962
24.2	40.026	32.077	37.334	31.587
21.0	33.585	26.92	31.401	26.811
17.8	26.305	21.093	24.715	21.411
14.6	18.655	14.962	17.636	15.626
11.4	11.881	9.551	11.263	10.231
8.2	6.954	5.595	6.618	6.058
5.0	2.9433	2.386	2.8147	2.611
1.8	0.4653	0.4	0.444	0.429

Provision of T-beam in the portion between points of zero moments results in the decreased value of sway as seen from Table III. The sway is found to reduce for loading combination (D.L. + E.Q.) along height of frame. However for (D.L. + 0.8L.L.$_4$ + 0.8E.Q.) it is found that the sway increases up to about 50% height of the structure after which it reduces as seen in Graph No. 3. However all these maximum displacement in all loading cases is less than the maximum permissible relative lateral displacement as (0.004H) per IS: 1893: 2002(9).



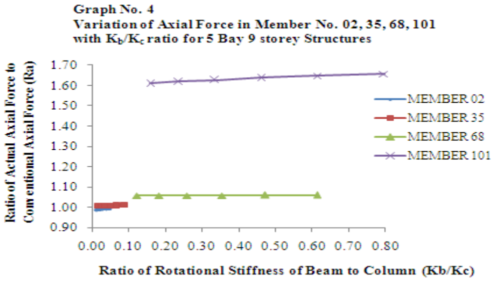
B. For 5- bay 9 storey structures

Graph No. 04 shows variation of 'Ra' in members 02, 35, 68, & 101 for 5 bay 9 storey structures as shown in Fig. 2 (b) with K_b/K_c as beam depth changes from 350 mm to 600 mm and the corresponding values are provided in Table IV. It could be seen very clearly that for members 02, 35, and 68 variation is almost linear and 'R_a' remains almost constant. It may be noted that the conventional method of considering the load attracted by column using adjoining to contributory area underestimates load in column for lowest beam depth considered in analysis. It is found that the average percentage of which is found as -38.779 %, -5.608 %, -0.7739 % and 1.0944 % for members 101, 68, 35, 02 respectively but for the members located at the base of the structure i.e. member 02 the values are found to be overestimated. This variation suggests that the conventional method estimates loads in better fashion at and near the base of structure. This being the worst loaded portion one may rely on values obtained from conventional approach in proximity of base.

Table IV: Variation of axial Force in Member No. 02, 35, 68, 101 with K_b/K_c ratio for 5 Bay 9 storey Structures

$\frac{K_b}{K_c}$	Mem-Ber 02	$\frac{K_b}{K_c}$	Mem Ber 35	$\frac{K_b}{K_c}$	Mem-Ber 68	$\frac{K_b}{K_c}$	Mem Ber 101
0.010	0.985	0.017	1.006	0.122	1.058	0.158	1.610
0.015	0.987	0.026	1.007	0.182	1.059	0.236	1.619
0.021	0.988	0.037	1.007	0.259	1.059	0.336	1.628
0.029	0.990	0.050	1.008	0.355	1.059	0.461	1.637
0.038	0.991	0.067	1.009	0.472	1.059	0.613	1.647
0.049	0.993	0.087	1.010	0.613	1.060	0.796	1.658

Variation of axial force in the members is found to be almost constant as K_b/K_c increase. The conventional load calculated on the basis of contributory area closely approximates the true load for almost the 2/3rd height of frame from bottom and true load attracted is 60% to 70% larger at the topmost level than conventional load.

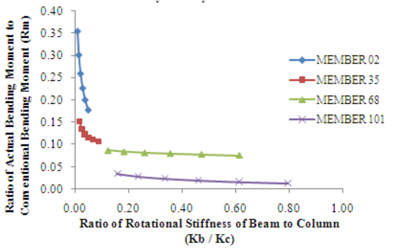


Graph No. 05 shows variation of bending moment of selected column segments as (K_b/K_c) changes and the corresponding values are provided in Table V. It is found that bending moment attracted by column at bottom of segment is largest for the smallest (K_b/K_c) at joint, the value are found to reduce by 50.062%, 29.98 %, 12.844% and again increases by 60.60 % for members 02, 35, 68, & 101 respectively as (K_b/K_c) increases. Variation of bending moment in the members is found to decrease with increase in values of K_b/K_c and it is found to be almost linear for top members.

Table V: Variation of Bending Moment in Member No. 02, 35, 68, 101 with K_b/K_c ratio for 5 Bay 9 storey Structures

$\frac{K_b}{K_c}$	Mem-Ber 02	$\frac{K_b}{K_c}$	Mem Ber 35	$\frac{K_b}{K_c}$	Mem-Ber 68	$\frac{K_b}{K_c}$	Mem Ber 101
0.010	0.355	0.017	0.153	0.122	0.087	0.158	0.035
0.015	0.301	0.026	0.135	0.182	0.084	0.236	0.029
0.021	0.259	0.037	0.123	0.259	0.082	0.336	0.024
0.029	0.226	0.050	0.116	0.355	0.080	0.461	0.020
0.038	0.200	0.067	0.111	0.472	0.078	0.613	0.017
0.049	0.177	0.087	0.107	0.613	0.076	0.796	0.014

Graph No. 5
Variation of Bending Moment in Member No. 02, 35, 68, 101 with Kb/Kc ratio for 5 Bay 9 storey Structures

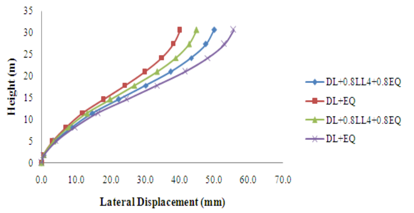


Provision of T-beam in the portion between points of zero moments results in the decreased value of sway as seen from Table VI. The sway is found to reduce for loading combination (D.L. + L.L.$_4$) and (D.L. + E.Q.). However for (D.L. + 0.8L.L.$_4$ + 0.8E.Q.) it is found that the sway is going to increase up to the full height of the structure as seen in Graph No.6. However all these maximum displacement in all loading cases is less than the maximum permissible relative lateral displacement as (0.004H) per IS: 1893: 2002$^{(9)}$.

Table VI: Variation of lateral displacement along height of frame for 5 bay 9 storey structures for beam depth 350 mm

Height (m)	Lateral Sway for Prismatic Section (mm)		Lateral Sway for Non-prismatic Section (mm)	
	DL+ EQ	DL+0.8LL$_4$+ 0.8EQ	DL+ EQ	DL+0.8LL$_4$+ 0.8EQ
30.6	40.173	50.103	55.762	44.971
27.4	38.211	47.697	53.058	42.764
24.2	34.819	43.454	48.32	38.941
21.0	29.962	37.379	41.535	33.478
17.8	24.201	30.192	33.479	26.994
14.6	17.889	22.304	24.675	19.914
11.4	11.816	14.717	16.261	13.141
8.2	7.052	8.77	9.655	7.808
5.0	3.069	3.798	4.154	3.369
1.8	0.511	0.605	0.651	0.542
0	0	0	0	0

Graph No. 6
Variation of Lateral Displacement Along Height of Frame For Beam Depth 350mm for prismatic and T-action of beam for 5 Bay 9 Storey structures



C. For 7- bay 9 storey structures:

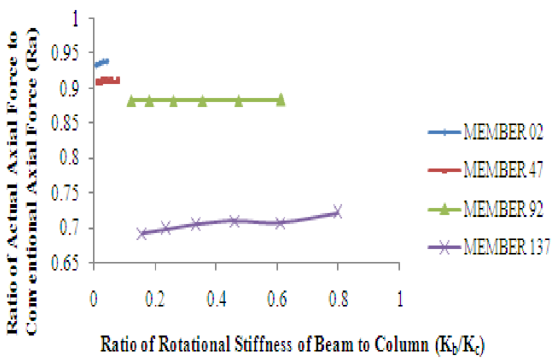
Variation of ‘R$_a$’ in member 2, 47, 92, and 137 with K$_b$/K$_c$ as beam depth changes from 350 mm to 600 mm for 7 bay 9 storey structures as shown in Fig. 2 (c). It could be seen very clearly that for member 02, 47, and 92 variation is almost linear and ‘R$_a$’ remains almost constant as seen in Graph No. 7 and corresponding values are provided in Table VII. Contrary to this absolute a change in ‘R$_a$’ to show increase in beginning and temporary small reduction at K$_b$/K$_c$ of 0.059 is seen in member No. 137, it may be noted that the value of ‘R$_a$’ in this case is form to increase by about 4.1%, it may be noted that the conventional method of considering the load attracted by column using adjoining to contributing area over estimates load in column for lowest beam depth considered in analysis. It is found that 44.3%, 13.3%, 10.1%, and 7.1% for members 137, 92, 47, 02 respectively. This variation suggests that the conventional method estimates loads in better fashion at and near the base of structure. This being the worst loaded portion one may rely on values obtained from conventional approach in proximity of base.

Variation of axial force in the column segment is found to be almost linear for the members as we move towards top. The variation in the members located at top there is a fraction drop is observed at end and again it shows linear variation. The conventional axial force calculated on contributory area closely approximates the true load in column segment at 1/3rd height of frame and it reduces for topmost level.

Table VII: Variation of Axial Force in Member No. 02, 47, 92, 137 with K$_b$/K$_c$ ratio for 5 Bay 9 storey Structures

$\frac{K_b}{K_c}$	MEMBER 02	$\frac{K_b}{K_c}$	MEMBER 47	$\frac{K_b}{K_c}$	MEMBER 92	$\frac{K_b}{K_c}$	MEMBER 137
0.009	0.933	0.015	0.908	0.122	0.883	0.158	0.693
0.013	0.935	0.023	0.909	0.182	0.883	0.236	0.699
0.018	0.936	0.032	0.909	0.259	0.883	0.336	0.705
0.025	0.937	0.044	0.909	0.355	0.883	0.461	0.710
0.033	0.938	0.059	0.910	0.472	0.883	0.613	0.708
0.043	0.939	0.077	0.910	0.613	0.884	0.796	0.721

Graph No. 7
Variation of Axial Force in Member No. 02, 47, 92, 137 with Kb/Kc ratio for 5 Bay 9 storey Structures



Graph No. 08 shows variation of bending moment selected column in segments has K$_b$/K$_c$ changes and corresponding values are provided in Table VIII. It is found that bending moment attracted by column at bottom of segment is largest for the smallest K$_b$/K$_c$ at joint, the value are found to reduce by 48.61%, 35.89%, 10.30% and 53.21% for members 2, 47, 92, 137 respectively as K_b/K_c increases. Variation of bending moment in column is found to decrease with increase in values of K_b/K_c and it is found to be linear for top members.

Table VIII: Variation of Bending Moment in Member No. 02, 47, 92, 137 with K_b/K_c ratio for 5 Bay 9 storey Structures

$\frac{K_b}{K_c}$	MEMBER 02	$\frac{K_b}{K_c}$	MEMBER 47	$\frac{K_b}{K_c}$	MEMBER 92	$\frac{K_b}{K_c}$	MEMBER 137
0.009	0.488	0.015	0.205	0.122	0.102	0.158	0.042
0.013	0.419	0.023	0.177	0.182	0.100	0.236	0.036
0.018	0.362	0.032	0.158	0.259	0.097	0.336	0.030
0.025	0.317	0.044	0.145	0.355	0.095	0.461	0.026
0.033	0.281	0.059	0.137	0.472	0.093	0.613	0.023
0.043	0.251	0.077	0.131	0.613	0.092	0.796	0.020

Graph No. 8
Variation of Bending Moment in Member No. 02, 3, 68, 101 with Kb/Kc ratio
for 5 Bay 9 storeyed Structure

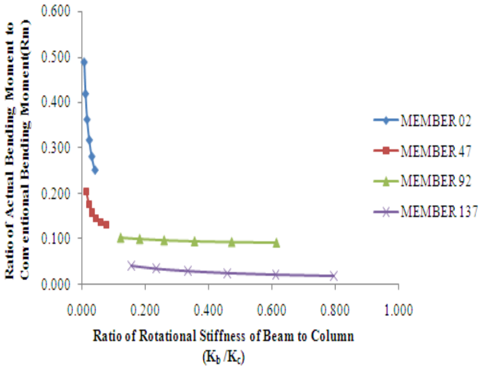
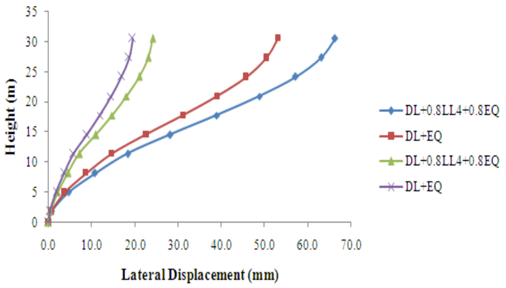


Table IX: Variation of lateral displacement along height of frame for 5 bay 9 storey structures for beam depth 350 mm

Height (m)	Lateral Sway for Prismatic Section (mm)		Lateral Sway for Non-prismatic Section (mm)	
	DL+ EQ	DL+0.8LL$_4$+ 0.8EQ	DL+ EQ	DL+0.8LL$_4$+ 0.8EQ
30.6	53.161	66.339	19.437	24.105
27.4	50.51	63.101	18.601	23.104
24.2	45.79	57.189	16.92	21.003
21.0	39.08	48.809	14.538	18.035
17.8	31.162	38.9	11.875	14.712
14.6	22.591	28.202	8.876	10.987
11.4	14.682	18.307	5.803	7.157
8.2	8.656	10.789	3.638	4.468
5.0	3.701	4.605	1.718	2.084
1.8	0.593	0.714	0.346	0.38
0	0	0	0	0

Due to provision of haunch results in decreased value of sway. The sway is found to increase for loading combination (D.L. + 0.8L.L.4 + 0.8E.Q.) as seen from Table IX and Graph No. 9. However for load cases (D.L. + E.Q.) it is found that the sway is going to reduce up to the full height of the structure. The largest load is attracted by the right most lowest segment of column which is varying from 75.77% for spread of haunch 0.05B to 79.26% for spread of haunch 0.15B of the conventional axial force considered for the worst load combination of 1.5 (DL + EQ).

Graph No. 9
Variation of Lateral Displacement Along Height of Frame
For Beam Depth 350mm for prismatic and T-action of beam for 5 Bay 9 Storey structures



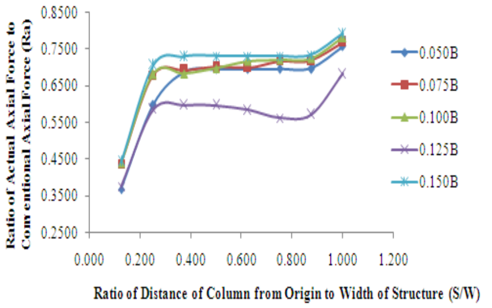
D. *Variation of Axial Force at Joint Due to Spread of Haunch*

For the load combination (1.5 D.L. + 1.5 E.Q.) the variation is observed to be increasing linearly for the members located at the base level of structure, then for intermediate levels it remains almost constant but terrace level it slightly increases again as seen from Graph No. 10 and corresponding values are provided in Table X. For 0.125 B spread of Haunch it shows declined variation and again slight increment.

Table X: Variation of axial force for spread of haunch for Beam depth 450 mm and L/C (1.5DL+1.5EQ)

S / W	0.050B	0.075B	0.100B	0.125B	0.150B
0.125	0.3686	0.4389	0.4400	0.3766	0.4435
0.250	0.5986	0.6796	0.6824	0.5857	0.7070
0.375	0.6895	0.6924	0.6838	0.5983	0.7300
0.500	0.6952	0.7010	0.6988	0.5976	0.7317
0.625	0.6954	0.6999	0.7186	0.5838	0.7316
0.750	0.6954	0.7176	0.7222	0.5634	0.7317
0.875	0.6972	0.7199	0.7250	0.5711	0.7348
1.000	0.7577	0.7694	0.7822	0.6828	0.7926

Graph No. 10
Variation of axial force for spread of haunch for Beam depth 450 mm
and L/C (1.5DL+1.5EQ)



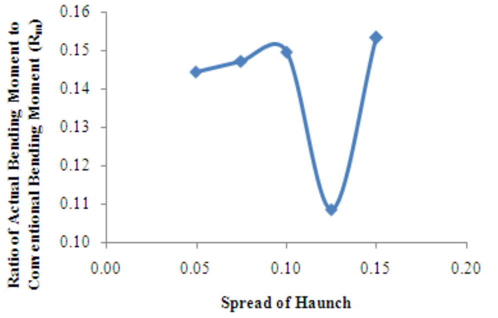
E. Variation of Bending Moment at Joint Due to Spread of Haunch

Variation of Bending Moment at joint due to spread of haunch for Load Case (0.9 DL + 1.5 EQ) as shown in Graph No. 11 and corresponding values are provided in Table XI. As spread of haunch increases, the bending moment at end of left haunch increases continuously at about spread of haunch 0.050 B to 0.100 B and it further decreases as spread of haunch beyond this value.

Table XI: Variation of bending moment at joint No. 44 in beam No. 72 with spread of haunch for load (0.9 DL + 1.5 EQ)

Spread of Haunch	Ratio of Actual Bending Moment to Conventional Bending Moment (R_m)
0.050 B	0.14443
0.075 B	0.14718
0.100 B	0.14969
0.125 B	0.10864
0.150 B	0.15320

Graph No. 11
Variation of bending moment at joint No. 44 in beam No. 72 with spread of haunch for load case (0.9 DL + 1.5 EQ)



VI. CONCLUSION

From the data revealed by the analysis for the structures with various loading combinations tried following conclusions are drawn:

1. The conventional axial force calculated on contributory area closely approximates the true load in column segment at higher levels for 3 bay 9 storey structures and the 2/3rd height of frame from bottom and larger at the topmost level for 5 bay 9 storey structures and the column segment at 1/3rd height of frame and it reduces for topmost level for 7 bay 9 storey structures.
2. Column segments at lower level attract larger axial forces as compared to bay variation i.e. as number of bays going to increase the axial forces in the column at bottom segments increases. The same is with bending moment.
3. Variation of bending moment in column segments is found to increase with decrease in the values of K_b/K_c for 3 bay 9 storey structures and decrease with increase in values of K_b/K_c and it is found to be linear for top members for 5 & 7 bay 9 storey structures.
4. For high rise structures, the higher axial forces and deformations especially in the columns, and concentration of them over a greater height may cause bending moment parameter to become predominant.
5. Provision of non prismatic sections in beams prove to attract more load in turn carry more forces such as axial force and bending moment and reduces the lateral sway as compared to prismatic sections which is already in permissible limit as per IS 1893:2002(09).

REFERENCES

[1] V.N. Vazirani & M. M. Ratawani, (1985) Analysis of structures 10th edition Khanna Publishers.

[2] Dr. V. L. Shah & Dr. S. R. Karve, (Feb.2005) Illustrated design of reinforced concrete building 5th edition Structure publication.

[3] Weaver Jr. and Gere J.M., (1986) “Matrix analysis of framed structure”, CBS Publishers and distributor, New Delhi.

[4] Taranath. S. B., (1984): "Structural analysis and design of tall buildings", McGraw-Hill Book Company.

[5] Smith. B. S. and Coull. A., (1991): "Tall building structures: Analysis and Design", John Wiley & Sons.

[6] S. S. Bhavikatti (2009) Advanced R.C.C. Design 2nd edition New Age International Publishers.

[7] Smith. B. S. and Coull. A., (1991): "Tall building structures: Analysis and Design", John Wiley & Sons.

[8] I.S. 456-1993, Indian standard code of practice for plain and reinforced concrete (fourth revision), Bureau of Indian standards, New Delhi.

[9] I.S. 1893(Part 1)-2002, Criteria for earthquake resistant design of structure, general provision and building, Bureau of Indian standards, New Delhi.

[10] STAAD Pro 2006 structural analysis and design commercial software.

AUTHOR BIOGRAPHY

Kulkarni Jayant G.
B.E. (Civil), M.E. (Civil - Structures)
F.I.E. (I), LM-ISTE, LM-ISRMTT, M-ISSE

Kore Pralhad N.
B.E. (Civil), M.E. (Civil - Structures)

Tanawade S. B.
B.E. (Civil), M.E. (Civil - Structures)