ANALYSIS OF PARTIALLY BRACED MULTISTOREYED BUILDING FRAMES SUBJECTED TO GRAVITY AND EARTHQUAKE LOADS

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ABSTRACT

The structure in high seismic areas may be susceptible to the severe damage. Along with gravity load structure has to withstand to lateral load which can develop high stresses. Now-a-days, shear wall in R.C.structure and steel bracings in steel structure are most popular system to resist lateral load due to earthquake, wind, blast etc. bracing is a highly efficient and economical method of resisting horizontal forces in a frame structure. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing stiffness and strength against horizontal shear. Through the addition of the bracing system, load could be transferred out of the frame and into the braces, by passing the weak columns while increasing strength. In this study R.C.C. building is modeled and analyzed for 3-bay and 4-bay G+11 structure in three Parts viz.,

(i) Model without RC bracing (bare frame), (ii) Model completely RC braced (fully braced frame), (iii) Model with partially RC baywise braced frames. The computer aided analysis is done by using STAAD-PRO to find out the effective lateral load system during earthquake in high seismic areas.

I INTRODUCTION

The construction of RC building is a very common practice in urban India for last 25 years. In the last decade significant developments in architectural expression and increasing demand for taller buildings resulted in a systematical evolution of structural systems. In India RCC structures were predominant in these developments and profiting from the inherent properties of this material, new RCC framing system emerged. Most of the RC buildings were designed for gravity loads only. These buildings performed very poorly during Bhuj earthquake of January 2001 and Killari earthquake of September 1993. Since then the earthquake design is made mandatory for design of high rise buildings. For resisting earthquake forces large sections for members need to be provided, this leads to increase in material cost. Other alternative to resist EQ forces is providing bracings [5] in the structure which reduce the section size and also increase lateral stiffness, lateral strength as well as lateral stability of frames

1.1 Zip Type of Bracing

Under dynamic loading, bracing act as good energy dissipaters. Fig 1 shows an example of Zip type of bracing. Conventional inverted V braced frames[6] exhibit a design problem arising from the unbalanced vertical force generated by the lower braces when one of them buckles. The unbalanced force must be carried by the floor beam, resulting in large beam and relatively inefficient structural system.

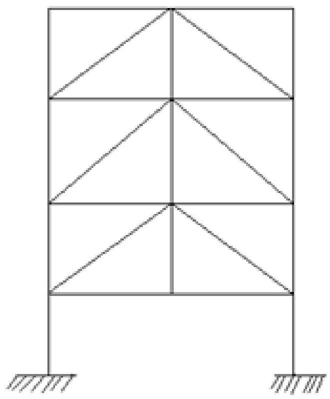


Figure 1. Zip braced frame

This adverse effect can be mitigated by adding zipper columns or vertical members connecting intersection points of the braces above the ground floor.

1.2 Analysis of Multistoried Building Subjected To Various Loads

Multistoried buildings [7] are designed for gravity loads as well as lateral loads and their combination. Is code providing these loading combination for which structure need to be analyzed and designed. In the analysis the internal forces in the component structures, displacements are found out. The designed structure must be safe for strength as well as serviceability

We know that bare frames are found to be more flexible and have large section requirement to withstand forces induced. The same can be minimized by making structure more rigid. In this volume use of bracing to increase the stiffness of the structure has been resorted too. The zip type of bracing system has been used. A number of structures with different heights and widths- with and without braces have been analyzed. The responses of braced frames of different types have been compared with each other and the same also have been compared with unbraced frame. Since analyzer are problem specific it is felt necessary that an attempt must be made to generalize the same and results so obtained that, such results and findings can be directly used to predict the behavior of real life structures. With this view point all parameters in dimensionless form, to include geometry of frame, axial forces, shear forces; bending moments, displacements, location of bracing etc. have been used.

II STRUCTURAL ANALYSIS

2.1 Methods of structural analysis [2]

To perform an accurate analysis structural engineer must determine such information as structural loads, geometry, support conditions and material properties. The results of such an analysis typically include support reactions, stresses and displacements. This information is then compared to criteria that indicate the conditions of failure. Advanced structural analysis may examine dynamic response, stability and non linear behavior.

The structural analysis is basically done by three approaches.

i. Mechanics of material approach- Applied to very simple structural elements under relatively simple loading condition.
ii. Elasticity theory approach- Applied to general geometry under general loading condition.
iii. Finite element approach- Applied at highly complex geometry and loading conditions.

Regardless of approach formulation is based on the same three fundamental relations i.e. equilibrium, constitutive and compatibility. The solutions are approximate when any of these relations are only approximately satisfied.

To design safe structures structural engineers must fully understand the structural behavior of these structures(9). In the long past, the structural engineers gained the knowledge into the structural behaviors by carrying out experimentations using a physical model of the real structure in the laboratory. Based on the test results, the behavior of the prototype structure can be understood and generalized. However physical modeling has its limitations, as it is expensive and time consuming. Thus mathematical modeling has been a viable alternative.

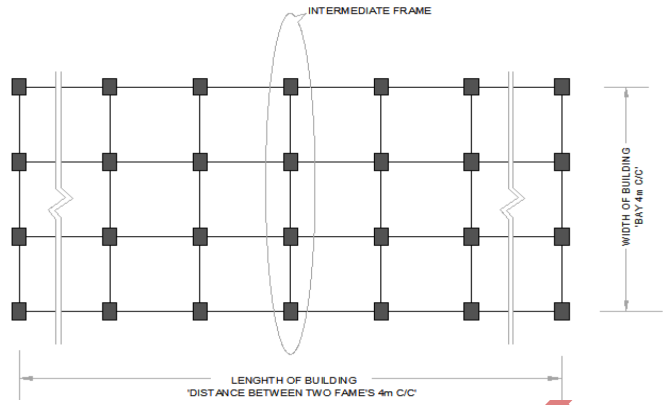
2.2 Methods of Earthquake Analysis (4)

Earthquake analysis of building is required to know how the building is going to behave at the time of earthquake. There are two methods of earthquake analysis static analysis and dynamic analysis. Static analysis does not give us clear idea of how the structure is going to behave during earthquake but gives approximate forces and displacements. Dynamic analysis gives somewhat accurate results. This method requires large amount of computational work. Moreover, to carry out this analysis ground motion data is required.

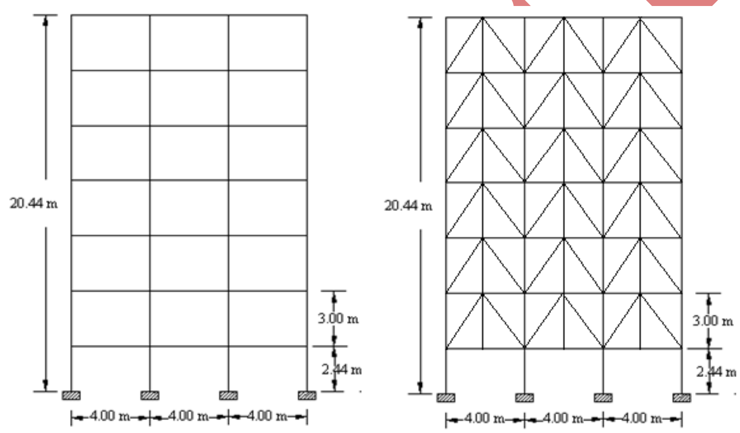
2.3 Problem Definition

Plane frame is one in which all the members and applied forces lie in same plane. The joints between members are generally rigid. The stress resultants are axial force, bending moment and corresponding shear force. As plane frames were used for the project so linear elastic plane frame analysis is performed for the different models of the building using STAAD III (8) analysis package. The frame members are modeled with rigid end zones. Equivalent static analysis is performed on the models of the building considered in this study.

If the base of the structure is suddenly moved, as in a seismic event, the upper part of the structure will not respond instantaneously, but will lag because of the inertial resistance and flexibility of the structure. The resulting stresses and distortions in the building are the same as if the base of the structure were to remain stationary while time-varying inertia forces are applied to the upper part of the building. Generally, the inertia forces generated by the horizontal components of ground motion require greater consideration for seismic design(3) since adequate resistance to vertical seismic loads is usually provided by the member capacities required for gravity load design. These forces are called inertia forces that is F = ma. In the equivalent static analysis procedure, the inertia forces are represented by equivalent static forces. Fig.2 shows various configurations used for structural analysis and Table 1 shows Models used for this analysis.



(a) Plan of a building



(a) Bare frame ***(b) Fully zip braced frame***

Figure 2. Configurations used for analysis

Table 1: Models used for this analysis

Sr. No.	Model	Frame Types	Storey Variation	Bay Variation	Beam depth(mm)
1	I	Bare Frame	G+11	3 and 4	350 to 600
2	II	Fully Braced Frame	G+11	3 and 4	350 to 600
3	III	Bay wise Braced Frame	G+11	3 and 4	350

2.4 Load Combinations

In the limit state design of reinforced concrete structures, following load combinations shall be accounted as per I.S. 1893 (Part I) – 2002[1], where the terms D.L., I.L., and E.L. stand for the response quantities due to dead load, imposed load and designated earthquake load respectively.

Combinations for limit state of collapse	Combinations for limit state of serviceability
1) 1.5 (DL + LL) 2) 1.2 (DL + LL ± EQ) 3) 1.5 (DL ± EQ) 4) 0.9 DL ± 1.5 EQ	1) (DL + 0.8 LL + 0.8 EQ) 2) (DL + LL) 3) (DL + EQ)

III RESULTS AND DISCUSSION

3.1 Bare Frames and Frames with Zip Type of Bracing

Table 2: Variation of axial force, Ra, shear force, Rs and bending moment, Rm in segment C_1 of *bare frame* having specific no. of bays as depth of beam is changed

No. of bays	Axial force, R_a (G+11)					
	Beam Depth					
	350	400	450	500	550	600
3	2569.43	2617.54	2662.93	2705.46	2745.1	2781.85
4	2567.68	2614.63	2659.11	2701.03	2740.32	2776.96

No. of bays	Shear force, R_s (G + 11)					
	Beam Depth					
	350	400	450	500	550	600
3	47.425	47.092	46.824	46.617	46.465	46.361
4	48.784	48.362	48.017	47.747	47.543	47.401

No. of bays	Bending moment, R_m (G+11)					
	Beam Depth					
	350	400	450	500	550	600
3	361.846	310.087	269.285	236.905	211.021	190.157
4	365.786	312.601	270.835	237.812	211.502	190.357

Table 3: Variation of axial force, Ra, shear force, Rs and bending moment, Rm in segment C_1 of *fully braced frame* having specific no. of bays as depth of beam is changed

No. of bays	Axial force, R_a (G+11)					
	Beam Depth					
	350	400	450	500	550	600
3	2873.23	2885.09	2896.83	2908.58	2920.43	2932.4
4	2882.04	2893.92	2905.65	2917.35	2929.14	2941.04

No. of bays	Shear force, R_s (G + 11)					
	Beam Depth					
	350	400	450	500	550	600
3	89.741	88.464	87.763	87.506	87.579	87.886
4	96.402	94.997	94.177	93.813	93.793	94.021

No. of bays	Bending moment, R_m (G+11)					
	Beam Depth					
	350	400	450	500	550	600
3	176.333	170.318	165.199	160.767	156.869	153.386
4	188.157	181.62	176.022	171.149	166.847	162.997

Table 4, 5 and 6 shows variation of axial force, Ra, shear force, Rs and bending moment, Rm respectively in member C_1 in partially braced frames with 3-bay (Mem. C1, L.C.7) bottom node

Table 4: Variation of Axial force in member C_1 in *partially braced frames*

Ln	R_a for one bay braced at a time	Ln	R_a for two bay braced at a time	Ln	Bare Frame	Fully braced fr.
2.398	0.946	4.804	0.923	2.398	1	1.118
3.091	0.934	4.868	1.201	3.091	1	1.118
3.401	1.234	5.438	1.117	3.401	1	1.118
				4.804	1	1.118
				4.868	1	1.118
				5.438	1	1.118

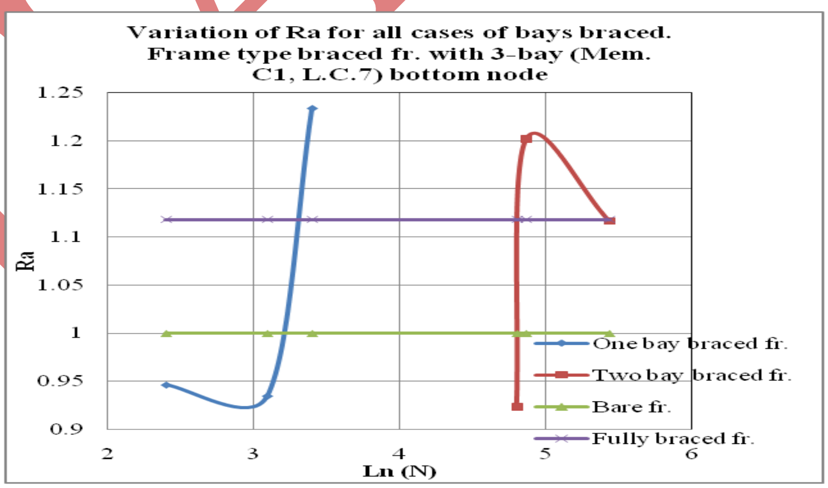


Figure 3. Variation of Ra for all cases of bays braced and Frame type braced fr. with 3-bay (Mem. C1, L.C.7) bottom node

Table 5: Variation of Shear force in member C_1 in *partially braced frames*

Ln	R_s for one bay braced at a time	Ln	R_s for two bays braced at a time	Ln	Bare Frame	Fully braced fr.
2.398	0.749	4.804	1.007	2.398	1	1.892
3.091	1.073	4.868	1.731	3.091	1	1.892
3.401	1.948	5.438	1.965	3.401	1	1.892
				4.804	1	1.892
				4.868	1	1.892
				5.438	1	1.892

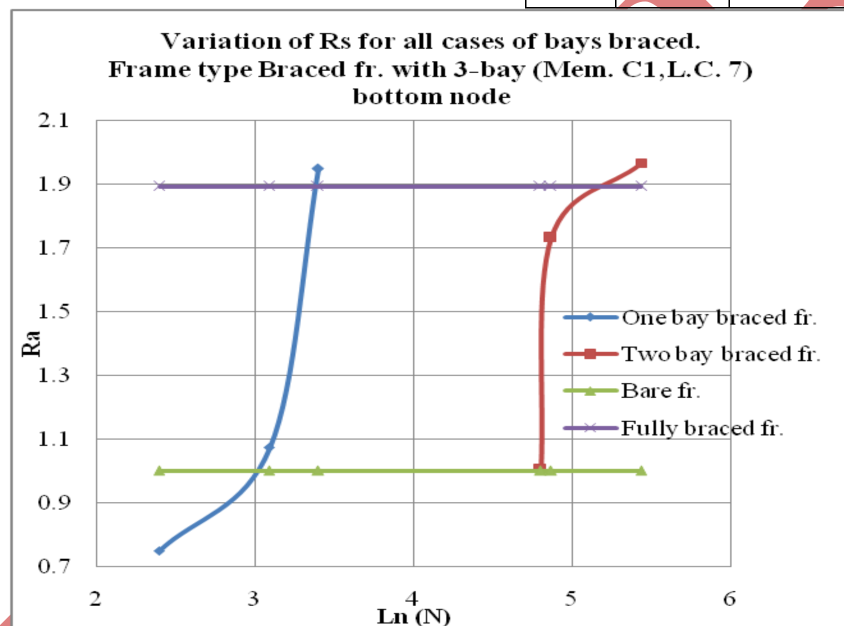


Figure 4. Variation of Rs for all cases of bays braced and Frame type braced fr. with 3-bay (Mem. C1, L.C.7) bottom node

Table 6: Variation of Bending moment in member C_1 in partially braced frames

Ln	R_m for one bay braced at a time	Ln	R_m for two bays braced at a time	Ln	Bare Frame	Fully braced fr.
2.398	0.4514	4.804	0.3780	2.398	1	0.4873
3.091	0.4749	4.868	0.5114	3.091	1	0.4873
3.401	0.6143	5.438	0.5179	3.401	1	0.4873
				4.804	1	0.4873
				4.868	1	0.4873
				5.438	1	0.4873

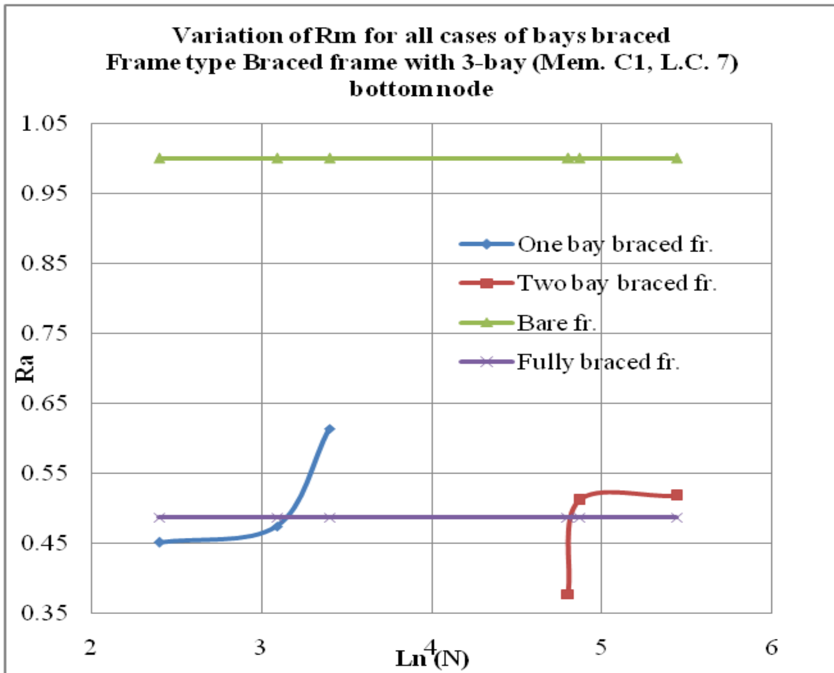


Figure 5. Variation of Rm for all cases of bays braced and Frame type braced fr. with 3-bay (Mem. C1, L.C.7) bottom node

Table 7, 8 and 9 shows variation of axial force, Ra, shear force, Rs and bending moment, Rm respectively in member C_1 in partially braced frames with 4-bay (Mem. C1, L.C.7) bottom node

Table 7: Variation of Axial force in member C_1 in partially braced frames

Ln	R_a for one bay braced at a time	Ln	R_a for two bays braced at a time	Ln	R_a for three bays braced at a time
2.485	0.952	4.796	0.924	7.115	0.915
2.996	0.936	4.89	0.937	7.124	1.171
3.466	0.944	4.949	1.251	7.203	1.182
3.689	1.302	5.438	0.916	7.759	1.106
		5.489	1.189		
		5.838	1.168		

For each abscissa that is for logarithm of reference number pertaining to above cases

For bare frame, $R_a = 1$

For fully braced frame, $R_a = 1.122$

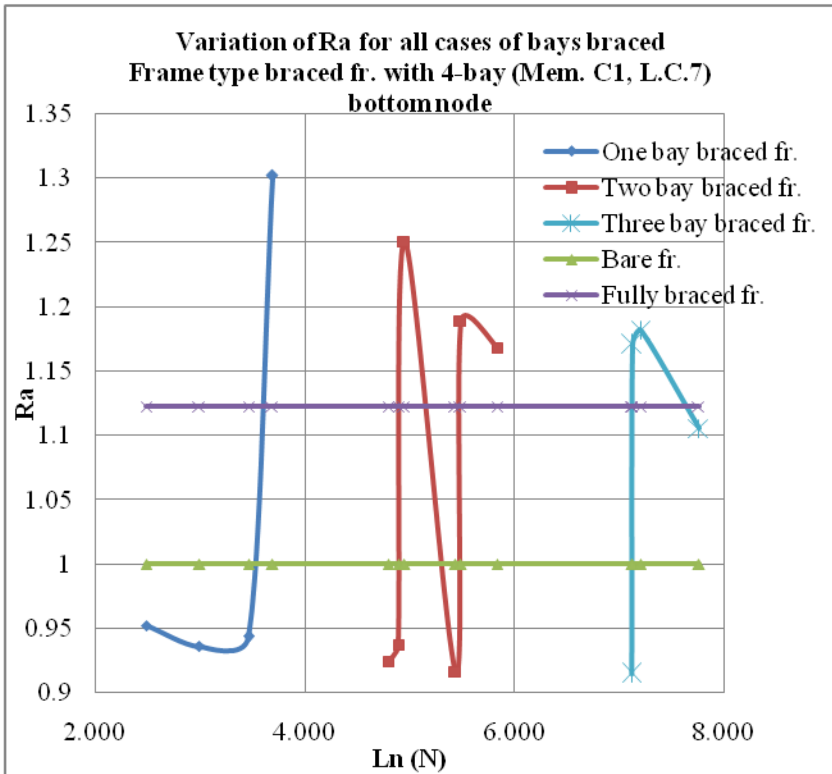


Figure 6. Variation of Ra for all cases of bays braced and Frame type braced fr. with 4-bay (Mem. C1, L.C.7) bottom node

Table 8: Variation of Shear force in member C_1 in partially braced frames

Ln	R_s for one bay braced at a time	Ln	R_s for two bays braced at a time	Ln	R_s for three bays braced at a time
2.485	0.689	4.796	0.733	7.115	1.046
2.996	0.818	4.89	1.006	7.124	1.718
3.466	1.163	4.949	1.793	7.203	2.006
3.689	2.114	5.438	1.111	7.759	2.038
		5.489	1.857		
		5.838	2.137		

For each abscissa that is for logarithm of reference number pertaining to above cases

For bare frame, $R_s = 1$

For fully braced frame, $R_s = 1.976$

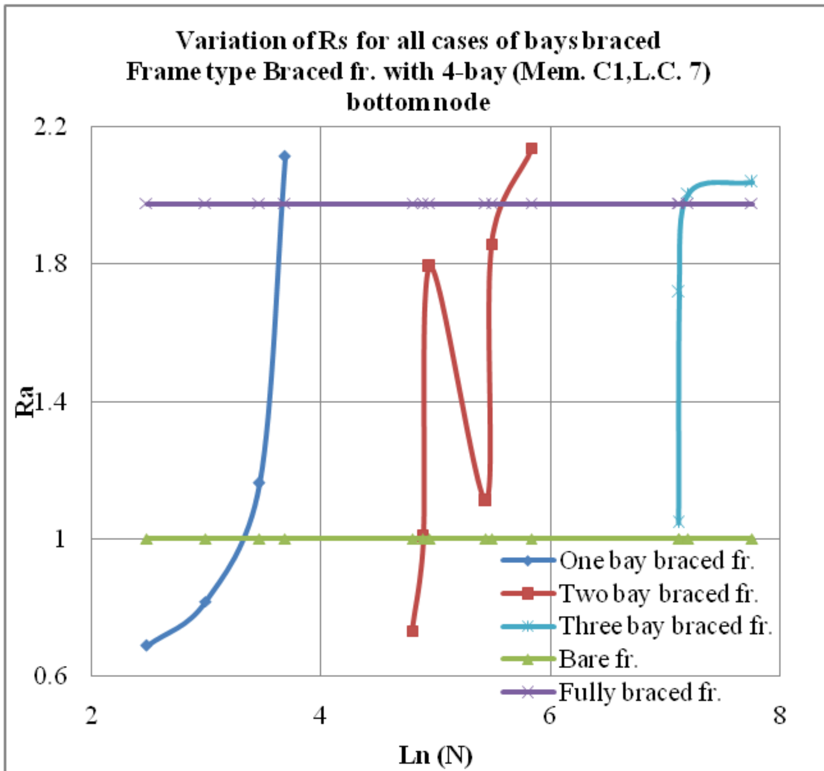


Figure 7. Variation of Rs for all cases of bays braced and Frame type braced fr. with 4-bay (Mem. C1, L.C.7) bottom node

Table 9: Variation of Bending moment in member C_1 in partially braced frames

Ln	R_m for one bay braced at a time	Ln	R_m for two bays braced at a time	Ln	R_m for three bays braced at a time
2.485	0.479	4.796	0.354	7.115	0.368
2.996	0.471	4.89	0.427	7.124	0.498
3.466	0.541	4.949	0.565	7.203	0.547
3.689	0.705	5.438	0.411	7.759	0.535
		5.489	0.558		
		5.838	0.593		

For each abscissa that is for logarithm of reference number pertaining to above cases

For bare frame, $R_m = 1$

For fully braced frame, $R_m = 0.514$

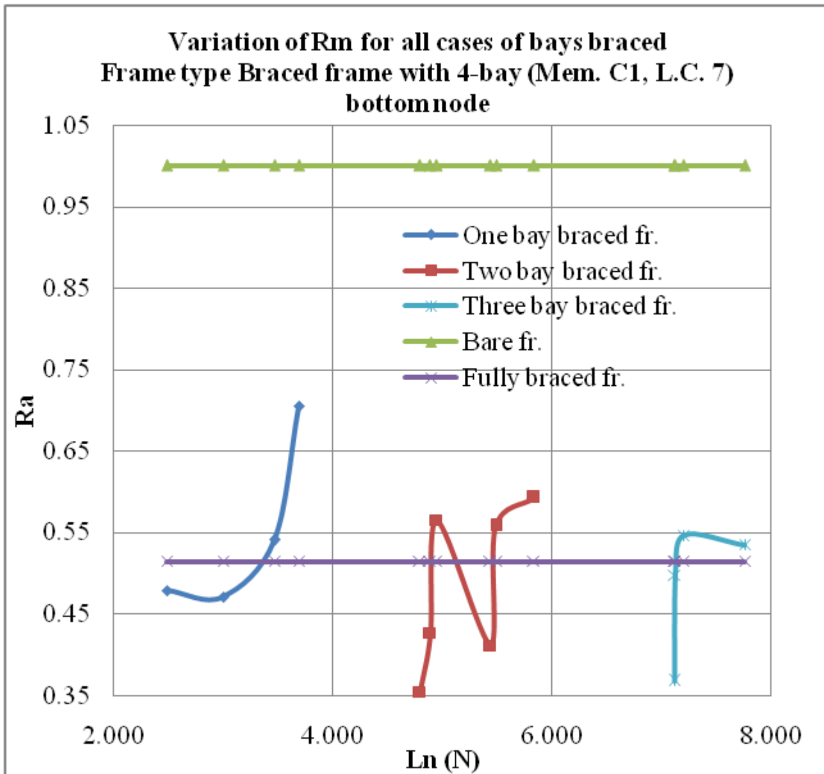


Figure 8. Variation of Rm for all cases of bays braced and Frame type braced fr. with 4-bay (Mem. C1, L.C.7) bottom node

IV CONCLUSIONS

4.1 About Bare Frame

i. For a bare frame irrespective of number of bays C_1 is found to attract about 6.5 to 8% additional axial force as the beam depth increases from 350 mm to 600 mm.

ii. Shear force marginally reduces as the beam depth increases. Percent reduction in the shear for 600mm beam depth was found to be 2.24 for 3 bay and 2.83 for 4 bay frame.

iii. The bending moment is found to reduce about 47.5 to 48% for 3 and 4 bay structures for beam depth 600mm

4.2 About Fully Braced Frame

i. When compared with bare frames, it is found that axial force attracted by column segment at all levels remains almost same, shear force increases and bending moment reduces substantially.

ii. All frames exhibit a continuous rise in the axial force as the depth of beam increases.

iii. Shear force reduces as the depth of beam increases. This reduction was found to be 2.06 to 2.5% for 600mm beam depth for 3 bay and 4 bay structures respectively.

iv. Braces are subject prominently to axial compression and carry negligibly small shear and bending moment

Following table reveals the reduction in moment in worst loaded column segment C_1 in fully braced frames in comparison with bare frame.

No of Bays	% Reduction in moment for worst loaded column C1 (G+11)
3	51.27
4	48.56

4.3 About Partially Braced Frames

A) Bay Wise Bracing

Percent saving in material cost and corresponding optimally located bracing pattern for 12 storeyed structure is found as given below.

No. of	No. of bays	Optimum bracing	%
3	One	2(central)	10.72
4	Two	2+3(central)	11.00

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