Cost Comparison of RCC Columns in Identical Buildings Based on Number of Story and Seismic Zone

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Abstract: ***The cost of construction of columns of a building covering certain plinth area varies for a combination of story and seismic zone. For a particular seismic zone, the relationship between the costs of columns over a wide range of story is not necessarily linear. Similarly, the difference in cost for a particular story over a range of seismic zone factors has to depend on the number of story as well. This study is an attempt to make such a comparison possible based on structural analysis and design of various buildings having same plinth area but different number of story and different seismic zone factors. Results illustrate that the cost trend for identical buildings over a range of building height, is same for two different seismic zones, but is not necessarily linear for a particular seismic zone.***

Keywords: cost of columns, plinth area, seismic zone, structural analysis and design, seismic zone factors

1. Introduction

The increase in the number of story of a building and/or the increase in the seismic zone factor of the site increases the total cost of RCC columns of the building. However, the relationship between these factors may not be linear. The difference in the cost of all columns of a regular six-story building designed for a site defined as seismic zone III and an identical building designed for a site defined as seismic zone V is not necessary to match the difference in the cost of similar buildings but having different number of stories.

Such a comparison, though difficult to carry out due to various factors involved, can be possible through some assumptions. The shape and plinth area of the building are assumed to be constantly fixed throughout the analysis. The costs of all RCC columns for a particular building were determined by computing the amount of PCC (M20) and steel (HYSD) required for the construction and using their prevalent cost rates. The amount of construction materials for columns was determined for 4, 6, 8 and 10 story buildings of identical nature for seismic zones III and V by using SAP2000 analysis and design.

2. Modeling of buildings in SAP2000

Each span in the plan was arbitrarily taken as 5 meters which consequently resulted in each floor area of 225 square meters. The size of beam was 500 X 300 mm in all cases whereas the size of column was varied to ensure no column fails and also almost no column has the minimum longitudinal steel reinforcement of 0.8%. Design was done using SAP2000 following IS456:2000 [1].

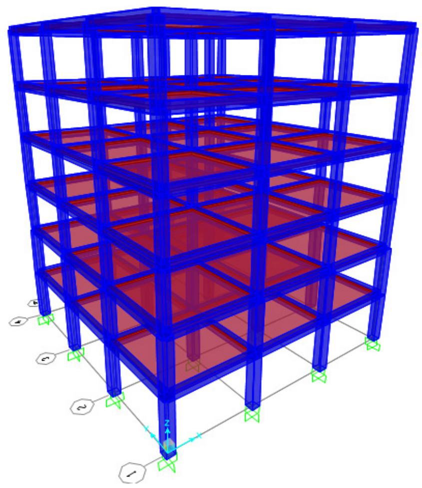

Figure 1: Typical 3D model

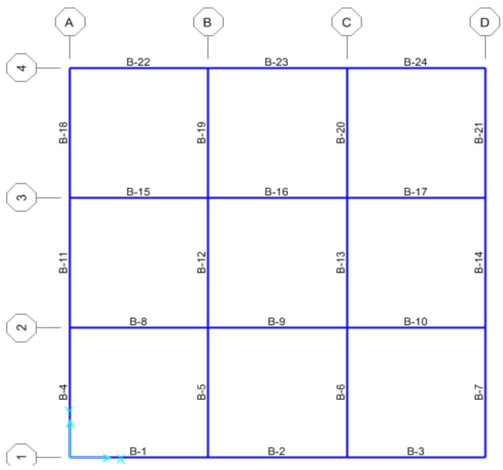

Figure 1: Typical floor plan

3. Structural Analysis and Design

<u>Typical dimensions:</u>
Beams = 500 mm X 300 mm
Slabs = 150 mm
Density of concrete = 25 KN/m3

Floor finish = 1 KN/m2
External wall thickness = 230 mm
Percentage of openings = 25%
Parapet wall thickness = 230 mm
Height of parapet wall = 1 m
Density of brick = 20 KN/m3
Typical material property:
Concrete grade = M20
Reinforcement steel = HYSD (Fe415)

Typical load calculation:

Table 1: Typical dead and live load

Dead load and Live load		
Beam	auto-assigned by SAP2000	all beams
Column	auto-assigned by SAP2000	all columns
Slab DL	4.75 KN/m^2 two way slab	all slabs
Slab LL	3 KN/m^2 two way slab	all slabs
Wall load	story 1 to 5 = 11.04 KN/m on beams	external 12 beams
	story 6 = 4.6 KN/m on beams	

Seismic load calculation for 6 story building in zone V:
The seismic load calculation was done based on IS1893 (Part 1): 2002 [2]. The calculation table and seismic load distribution diagram for a 6 story building in seismic zone V is given below [3]-[5].

Table 2: Base shear distribution for 6-storyed building in seismic zone V

Seismic zone factor Z	0.36	
Importance factor I	1.00	
Response reduction factor R	5.00	
Height of the building h	19.20	m
Soil	Medium	
Time period of the building T	0.69	sec
Basic seismic coefficient S_a/g	1.98	
Design horizontal seismic coefficient A_h	0.07	
Seismic weight of the building W	13875	KN
Base shear V_b	988	KN

Story	h_i (m)	W_i (KN)	$W_i*h_i*h_i$	Q_i (KN)
1	3.2	2350	24063	11
2	6.4	2350	96252	45
3	9.6	2350	216567	101
4	12.8	2350	385008	180
5	16.0	2350	601574	282
6	19.2	2126	783710	367
		13875	2107174	**988**

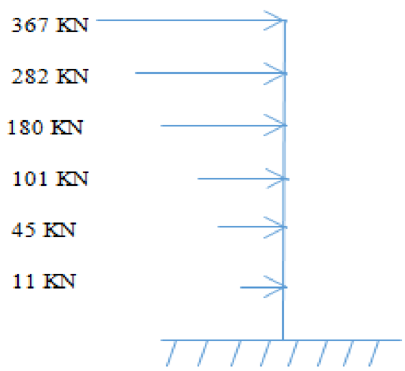

Figure 3: Lateral earthquake load on each floor for 6-storyed building in seismic zone V

4. Design Summary

The design output from SAP2000 was used to determine the area of longitudinal reinforcement bars required for each column in a particular building. Individual area of steel was added to obtain the total. The volume of concrete was calculated in gross without reducing the space occupied by steel bars. The design summary for 4, 6, 8 and 10 story buildings at seismic zone III and V is shown in tables 3-6 [6],[7].

Table 3: Design summary for 4-storyed building

Zone V			Zone III		
Column size	No. of stories		Column size	No. of stories	
0.4*0.4	4		0.3*0.3	4	
Total PCC	**32.77**	m^3	Total PCC	**18.43**	m^3
Total A_{st}	162701	mm^2	Total A_{st}	154071	mm^2
Story height	3.2	m	Story height	3.2	m
Total steel	0.521	m^3	Total steel	0.493	m^3
	4061	kg		**3846**	kg
	4.06	tons		3.85	tons

Table 4: Design summary for 6-storyed building

Zone V			Zone III		
Column size	No. of stories		Column size	No. of stories	
0.4*0.4	6		0.4*0.4	2	
			0.3*0.3	4	
Total PCC	**49.15**	m^3	Total PCC	**34.82**	m^3
Total A_{st}	333317	mm^2	Total A_{st}	235901	mm^2
Story height	3.2	m	Story height	3.2	m
Total steel	1.067	m^3	Total steel	0.755	m^3
	8320	kg		**5888**	kg
	8.32	tons		5.89	tons

Table 5: Design summary for 8-storyed building

Zone V			Zone III		
Column size	No. of stories		Column size	No. of stories	
0.4*0.4	8		0.4*0.4	4	
			0.3*0.3	4	
Total PCC	**65.54**	m^3	Total PCC	**51.20**	m^3
Total A_{st}	547091	mm^2	Total A_{st}	345578	mm^2
Story height	3.2	m	Story height	3.2	m
Total steel	1.751	m^3	Total steel	1.106	m^3
	13655	kg		**8626**	kg
	13.66	tons		8.63	tons

Table 6: Design summary for 10-storyed building

Zone V			Zone III		
Column size	No. of stories		Column size	No. of stories	
0.5*0.5	2		0.4*0.4	6	
0.4*0.4	8		0.3*0.3	4	
Total PCC	**91.14**	m^3	Total PCC	**67.58**	m^3
Total A_{st}	722726	mm^2	Total A_{st}	516629	mm^2
Story height	3.2	m	Story height	3.2	m
Total steel	2.313	m^3	Total steel	1.653	m^3
	18039	kg		**12895**	kg
	18.04	tons		12.90	tons

5. Rate analysis of Steel and PCC

The rate analysis included the material cost, labor cost and contractor's overhead and profit [8]. The rate of steel re-bars and PCC is given below in Nepali Rupees. Detail calculations are not included.

Rate of PCC M20 (1:1.5:3) per m3 = Rs 12189
Rate of structural steel reinforcement per kg = Rs 109

6. Result

Table 7: Summary of column costs for different cases

Story	Zone					
	III			V		
	PCC	Steel	Cost (NRs)	PCC	Steel	Cost
4	18.43	3846	647889	32.77	4061	846481
6	27.65	5888	984986	34.82	8320	1339910
8	65.54	8626	1748358	51.20	13655	2126734
10	91.14	12895	2530317	67.58	18039	2808843

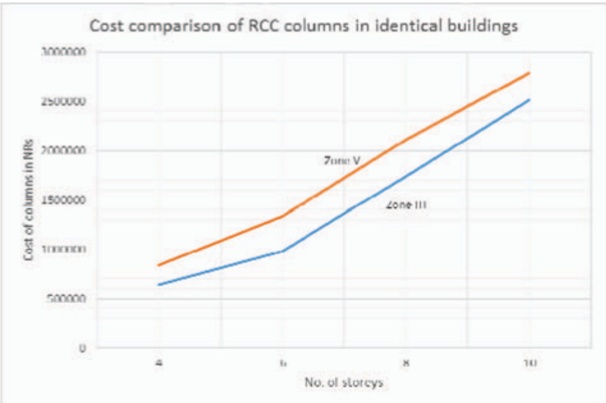

Figure 4: Cost comparison of columns as a function of number of story and seismic zone

7. Conclusion

The slope of the two lines in the graph beyond the 6 story is more or less uniform. It suggests that there is a direct relationship between the cost of columns and seismic zone factor for regular buildings 6 story or taller, i.e., 20m or higher. If the cost of columns is representative of the cost of the entire building, the difference in constructing an 8 story building at zone III and an identical 8 story building at zone V would amount to equal value as would be yielded by the difference in constructing a 9 story building at zone III and an identical 9 story building at zone V. However, it is not adequate to make such a statement in case of buildings lesser than 6 story. The two lines in Figure 4 are not parallel to each other when the number of story is lesser than 6.

The two lines below the 6 story mark are also evidently milder in slope compared to the two lines above the 6 story mark. This encourages concluding that two buildings of 5 story each covering certain floor area would be cheaper than one building of 10 story covering the same floor area. Obviously the cost of land and foundation for two separate buildings would render such conclusion unsound.

Another note-worthy conclusion is that the cost of columns for a building 5 story tall at zone III would be cheaper than the cost of the same for a building 4 story tall at zone V. The case would however not be the same if a 7 story building was compared to a 6 story building.

References

[1] IS 456:2000 – Plain and Reinforced Concrete- Code of Practice
[2] IS 1893 (Part 1): 2002 – Criteria for Earthquake Resistant Design of Structures
[3] National Society for Earthquake Technology – Nepal (2012). "Participant workbook –Module M4"
[4] Chopra A.K. (1995). "Dynamics of Structure," Prentice Hall, Eaglewood Cliffs, New Jersey.
[5] Kramer S.L. (1996). "Geotechnical Earthquake Engineering," Prentice Hall, Eaglewood Cliffs, New Jersey.
[6] Bhavikatti S.S (2005). "Design of R.C.C. Structural Elements," New Age International Limited, Ansari Road, Daryaganj, New Delhi.
[7] Jain A.K. (2012). "Reinforced Concrete Limit State Design," Nem Chand & Bros, Civil Lines, Roorkee.
[8] Chakraborti M. (2012). "Estimating, Costing, Specification and Valuation in Civil Engineering," Self-published, Bhabananda Road, Kolkata

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Samyog Shrestha received B.E. degree in Civil Engineering from Institute of Engineering- Pulchowk Campus in 2013.