

COMPARISON OF PERCENTAGE STEEL AND CONCRETE QUANTITIES OF A R.C BUILDING IN DIFFERENT SEISMIC ZONES

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Abstract

This paper addresses the performance and variation of percentage steel and concrete quantities of R.C.C framed structure in different seismic zones. One of the most frightening and destructive phenomena of a nature is a severe earthquake and it terrible after effect. It is highly impossible to prevent an earth quake from occurring, but the damage to the buildings can be controlled through proper design and detailing. Hence it is mandatory to do the seismic analysis and design to structures against collapse. Designing a structure in such a way that reducing damage during an earthquake makes the structure quite uneconomical, as the earth quake might or might not occur in its life time and is a rare phenomenon. The present IS code 1893:2002 doesn't provide information about the variation of concrete and percentage of steel from zone to zone. This study mainly focus on the comparison of percentage steel and concrete quantities when the building is designed for gravity loads as per IS 456:2000 and when the building is designed for earthquake forces in different seismic zones as per IS 1893:2002.

Keywords: Earthquakes, Reinforcement, Ductility, Damageability, STAAD-Pro.

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1. INTRODUCTION:

When planning a building against natural hazards like earthquakes, we can design it to behave in one of the following three limit states depending on the importance of the structure:

- Serviceability limit state: In this case, the structure will undergo little or no structural damage. Important buildings such as hospitals, places of assembly, atomic power plants, which are structures affecting a community, should be designed for elastic behaviour under expected earthquake forces. These structures should be serviceable even after the earthquake has taken place.
- Damage controlled (Damageability) limit state (Damage threshold level): In this case, if an earthquake occurs there can be some damage to the structure but it can be repaired after the event and the structure can again put to use. Most of the permanent buildings should come under this category. For this purpose, the structure should be designed for limited ductile response only.
- Survival(Collapse threshold level) Limit state: In this case, the structure may be allowed to be damaged in the event of an earthquake, but the supports should stand and be able to carry the permanent loads fully so that in all cases there should be no caving in of the structure and no loss of life.

Earthquakes produce large magnitude forces of short duration that must be resisted by a structure without causing collapse and preferably without significant damage to the structural element. The lateral forces due to earthquakes have a major impact on structural integrity. Lessons from past earthquakes and research have provided technical solution that will minimize loss of life and property damage associated with earthquake. Special detailing is required, and for materials without inherent ductility, such as concrete and masonry, a critical part of the solution is to incorporate reinforcement in the design and construction to assure a ductile responds to lateral forces. The ductility of the building can be increased by increasing the reinforcement in the structure. In the case of Earthquake design, ductility is an essential attribute of a structure that must respond to strong ground motions (Andreas, 2001). So, the ductility is related to the control of whether the structure is able to dissipate the given amount of seismic energy considered in structural analysis (Pankaj Agarwal, 2006). Ductility serves as the shock absorber in building, for it reduces the transmitted force to one that is sustainable. But the reinforcement plays an important role in the economy of the structure. The present IS code 1893: 2002 provides information regarding the excess amount of reinforcement to be used in the earthquake design but it does not provide the information about the percentage of the steel that should be increased in the earthquake resistant design when compared with the normal design as per IS:456-2000. This study mainly focus on the comparison of percentage steel and concrete quantities when the building is designed for gravity loads as per IS: 456-2000 and when the building is

designed for earthquake forces in different earthquake zones as per IS 1893:2002. This gives the approximate percentage in the economy compared with normal design (H J Shah, 2008).

2. METHODOLOGY

Seismic analysis of the structures is carried out on the basis of lateral force assumed to act along with the gravity loads. The base shear which is the total horizontal force on the structure is calculated on the basis of structure mass and fundamental period of vibration and corresponding mode of shape. The base shear is distributed along the height of the structure in terms of lateral forces according to codal provisions (Kazuhiro, 1987). In this study, a five (G+4) storied RC building has been analyzed using the equivalent static method in STAAD-Pro. The plan and elevation of the building taken for analysis is shown in Fig.1 and Fig.2. The nomenclature of columns is shown in Fig.3. Three Dimensional view of the whole structure is shown in Fig.4. Fig.5 is showing the structure subjected to the vertical loading and Fig.6 & Fig.7 are showing the structure subjected to loading of earthquake in “+X” and “+Z” directions.

In the earthquake analysis along with earthquake loads, vertical loads are also applied. For the earthquake analysis, IS 1893-2002 code was used. The total design seismic base shear (Vb) along any principal direction shall be determined by multiplying the design horizontal acceleration in the considered direction of vibration (Ah) and the seismic weight of the building.

The Design base shear

$$(V_b) = A_h * W$$

Ah = design horizontal acceleration in the considered direction of vibration

$$= (Z/2) * (I/R) * (S_a / g)$$

W = total seismic value of the building

The design base shear (Vb) computed shall be distributed along the height of the building as per the following expression (BIS1893: 2000)

$$Q_i = V_b * (W_i * h_i^2 / \sum W_i * h_i^2)$$

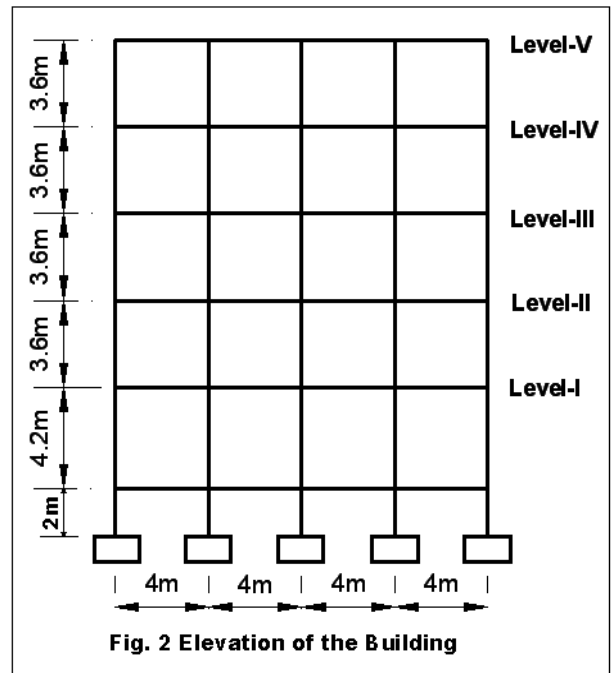
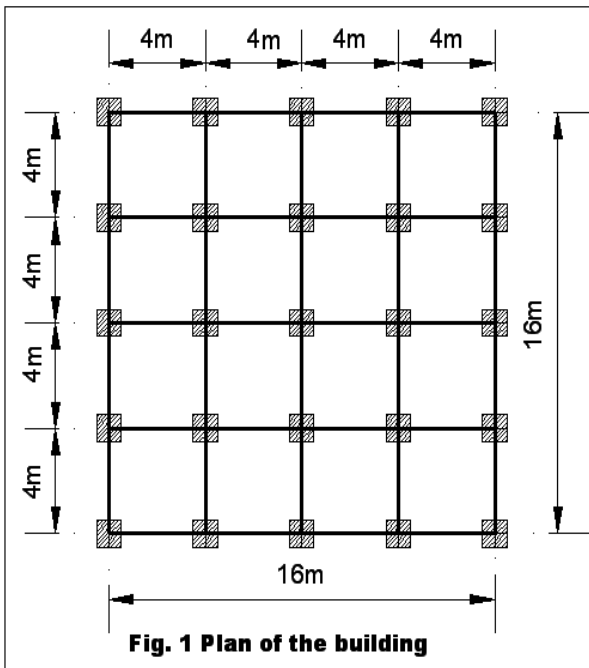
Where,

Qi is the design lateral forces at floor i,

Wi is the seismic weights of the floor i, and

hi is the height of the floor i, measured from base

The lateral force on each storey is again distributed based on the deflection and stiffness of the frame. The total lateral load in proportion to the stiffness of each frame in all the four zones (H M Salem, 2011). The distributed lateral forces shown in the Fig.6 and Fig.7.



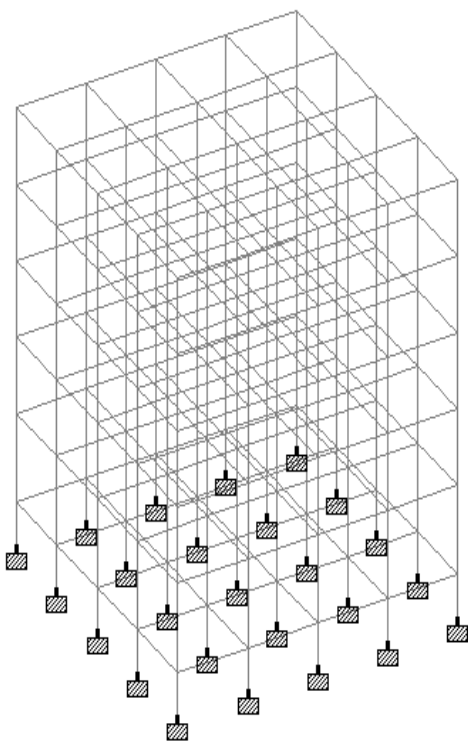
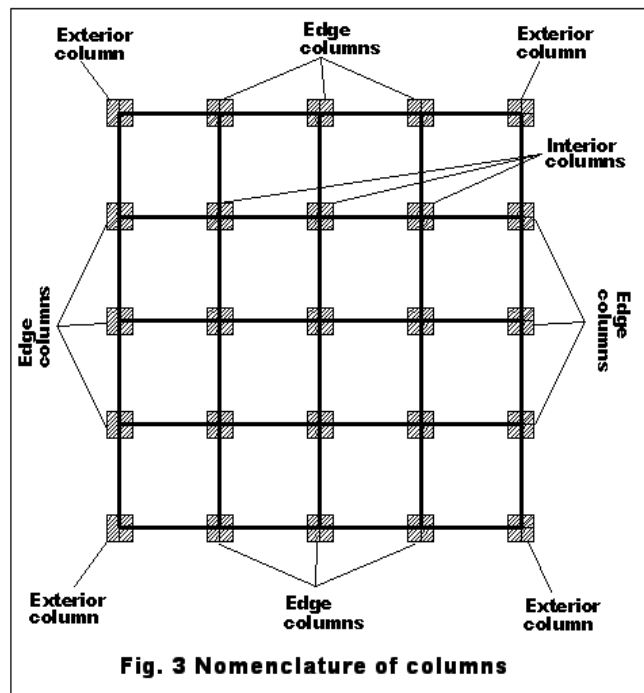


Fig. 4 3D view of the whole structure

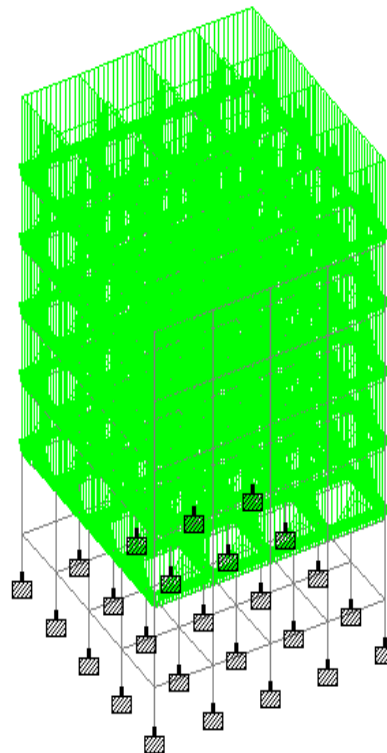


Fig. 5 Whole structure subjected to vertical loading

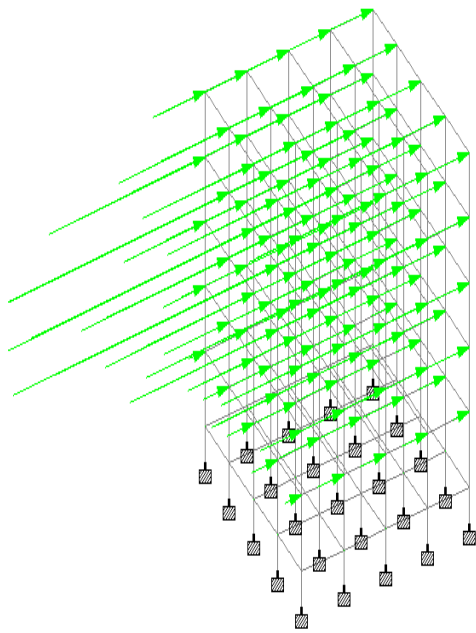


Fig.6 Structure subjected to Earthquake loading in +X direction

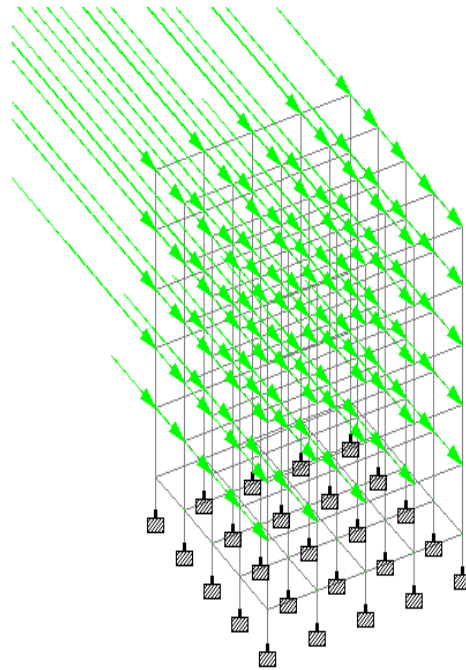


Fig. 7 Structure subjected to Earthquake loading in +Z direction

2.1 Preliminary Data for the Problem Taken:

Table 1: Preliminary Data of the structure considered for seismic analysis

Type of the structure	RCC Framed structure
Number of stories	G+4
floor to floor height	3.6 m
Plinth height	0.6 m
Walls thickness	230 mm
Grade of concrete	M 25
Grade of steel	Fe 415
Earthquake load	As per IS1893 (Part 1) : 2002
Size of the columns	0.4mx0.4m and 0.45mx0.45m
Size of the beams	0.23mx0.4m
Slab thickness	0.13m
SBC of soil taken	200kN/m ²
Type of soil	Hard rocky soil
Live load	3kN/m ²
Floor finishes	1kN/m ²
Seismic zones considered	II,III,IV,V
Type of wall	Brick masonry

1.2 Loading Data:

1.2.1 Dead Load (DL)

- 1. Self weight of slab = $0.13 \times 25 = 3.25 \text{ kN/m}^2$
 - 2. Floor finishes = 1.00 kN/m^2
- Total DL = 4.25 kN/m^2

(Assume 130mm total depth of slab)

- 3. Weight of walls = $0.23 \times 19 \times 3.6 = 15.73 \text{ kN/m}$

1.2.2 Live Load (LL)

Live Load on each slab = 3.00 kN/m^2

1.2.3 Earth quake Load (EQL)

As per IS-1893 (Part 1): 2002

1.3 Load Combinations:

The following load combinations are used in the seismic analysis, as mentioned in the code IS 1893(Part-1): 2002, Clause no. 6.3.1.2.

- 1. 1.5(DL+LL)
- 2. 1.2(DL+LL+EQX)
- 3. 1.2(DL+LL- EQX)
- 4. 1.2(DL+LL+ EQZ)
- 5. 1.2(DL+LL- EQZ)

- 6. 1.5(DL+ EQX)
- 7. 1.5(DL- EQX)
- 8. 1.5(DL+ EQZ)
- 9. 1.5(DL-EQZ)
- 10. 0.9DL+ 1.5EQX
- 11. 0.9DL- 1.5EQX
- 12. 0.9DL+ 1.5EQZ
- 13. 0.9DL-1.5EQZ

Earthquake load was considered in +X,-X, +Z and -Z directions. Thus a total of 13 load combinations are taken for analysis. Since large amount of data is difficult to handle manually (M.H. Arslan, 2007), all the load combinations are analyzed using software STAAD Pro. All the load combinations are mentioned above.

2. RESULTS:

The variation of support reactions at each location of the columns and the percentage difference in different seismic zones with respect to gravity loads is represented in the in Table 2 and Fig.8. It is observed that in edge columns, variations are 17.72, 28.35, 42.53, and 63.7% between gravity load to seismic zones II, III, IV and V respectively. In exterior columns, the variations are 11.59, 18.54, 27.81, and 41.71% between gravity load to seismic zones II, III, IV and V respectively. The variation is very small in interior columns.

Table 2 Comparison of support reactions in different seismic zones

LOCATION OF THE COLUMNS	Support Reaction in kN					Percentage difference between			
	DUE TO GRAVITY LOAD (GL)	IN SEISMIC ZONE- II	IN SEISMIC ZONE- III	IN SEISMIC ZONE- IV	IN SEISMIC ZONE- V	GL& ZONE- II	GL& ZONE- III	GL& ZONE- IV	GL& ZONE- V
EDGE COLUMNS	543.40	640.20	698.04	775.13	890.78	17.72%	28.35%	42.53%	63.7%
EXTERIOR COLUMNS	867.94	968.50	1028.84	1109.24	1129.97	11.59%	18.54%	27.81%	41.71%
INTERIOR COLUMNS	1295.68	1309.92	1318.46	1329.84	1346.92	1.10%	1.76%	2.64%	3.95%

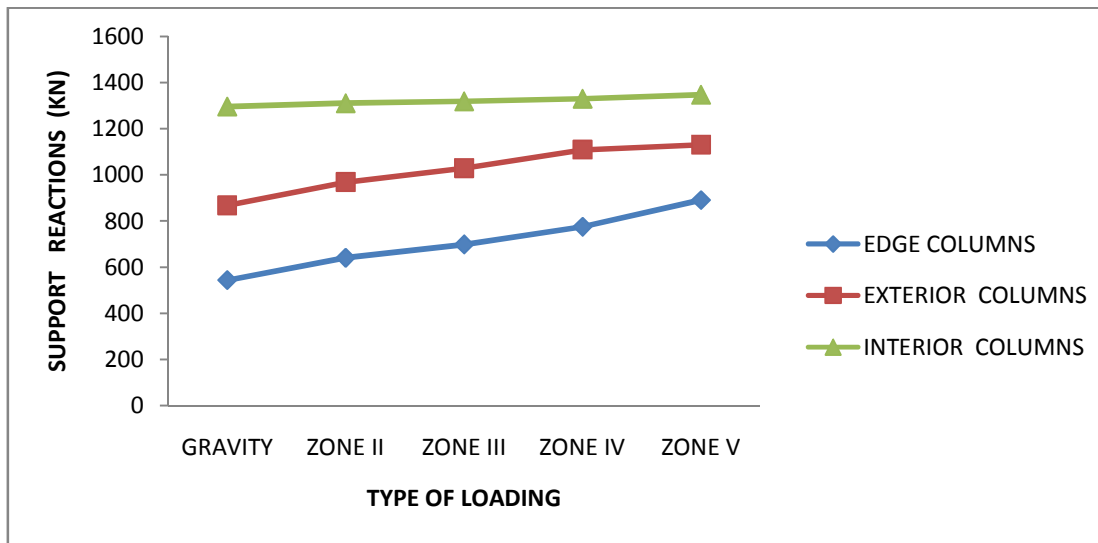


Fig. 8 Variation of support reactions in different seismic zones

The variation of volume of concrete at each location of the column footing and the increase in percentage difference in different seismic zones with respect to gravity loads is represented in the in Table 3 and Fig.9. It is observed that in edge column footings, variations are 17.75, 17.75, 27.17 and 42.0% between gravity load to seismic zones II, III, IV and V respectively. In exterior column footings, the variations are

21.51, 21.51, 45.15 and 57.77% between gravity load to seismic zones II, III, IV and V respectively. Therefore, the volume of concrete in footings is increasing in seismic zones III, IV and V due to increase of support reactions due to lateral forces. However the variation is very small in interior column footings.

Table 3 Comparison of volume of concrete in footings in different seismic zones

LOCATION OF THE COLUMN FOOTING	Volume of concrete in footings (cu m)					Percentage difference between			
	DUE TO GRAVITY LOAD (GL)	IN SEISMIC ZONE-II	IN SEISMIC ZONE-III	IN SEISMIC ZONE-IV	IN SEISMIC ZONE-V	GL& ZONE-II	GL& ZONE-III	GL& ZONE-IV	GL& ZONE-V
EDGE COLUMN FOOTING	2.186	2.574	2.574	2.78	3.1042	17.75%	17.75%	27.17%	42.00%
EXTERIOR COLUMN FOOTING	1.506	1.83	1.83	2.186	2.376	21.51%	21.51%	45.15%	57.77%
INTERIOR COLUMN FOOTING	3.291	3.291	3.291	3.40	3.40	0.00	0.00	3.51%	3.51%

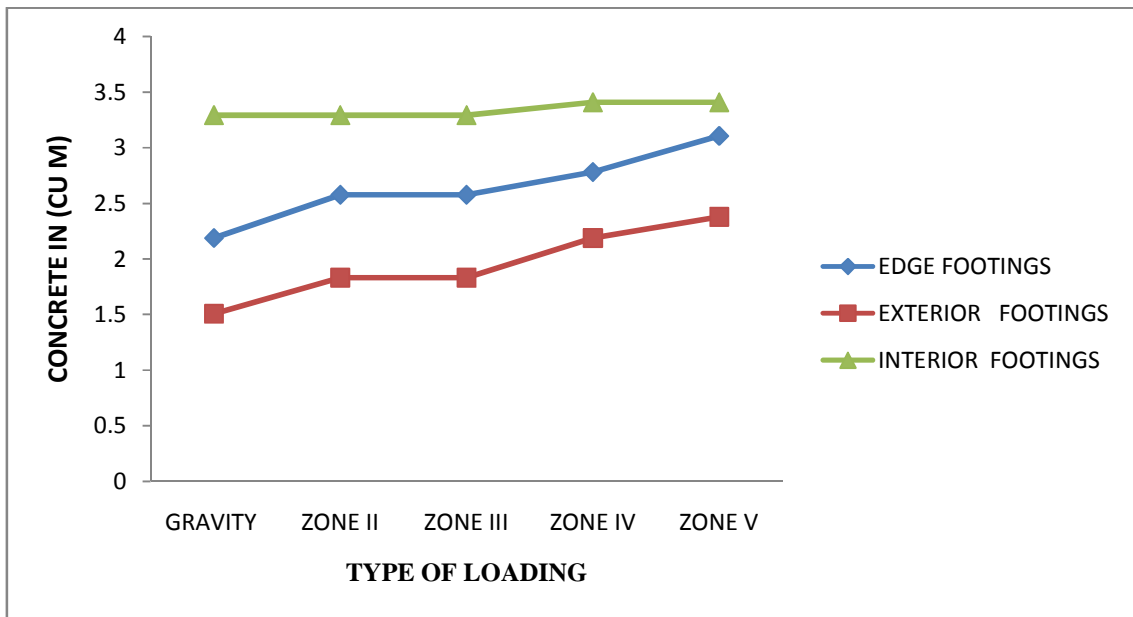


Fig.9 Variation of volume of concrete in footings in different seismic zones

The variation of weight of steel at each location of the column footing and the percentage difference in different seismic zones with respect to gravity loads is represented in the in Table 4 and Fig.10. It is observed that in edge column footings, variations are 0.0, 23.61, 47.92, and 98.96% between gravity load to seismic zones II, III, IV and V

respectively. In exterior column footings, the variations are 38.17, 54.88, 70.79 and 91.04% between gravity loads to seismic zones II, III, IV and V respectively. In the interior columns footings, the variations are 22.07, 42.44, 56.03 and 67.91% between gravity loads to seismic zones II, III, IV and V respectively.

Table 4 Comparison of weight of the steel in footings in different seismic zones

LOCATION OF THE COLUMN FOOTING	Weight of steel in footings(kg's)					Percentage difference between			
	DUE TO GRAVITY LOAD (GL)	IN SEISMIC ZONE-II	IN SEISMIC ZONE-III	IN SEISMIC ZONE-IV	IN SEISMIC ZONE-V	GL& ZONE-II	GL& ZONE-III	GL& ZONE-IV	GL& ZONE-V
EDGE COLUMN FOOTING	28.80	28.80	35.60	42.60	57.30	0.00	23.61%	47.92%	98.96%
EXTERIOR COLUMN FOOTING	46.90	64.8	72.64	80.10	89.60	38.17%	54.88%	70.79%	91.04%
INTERIOR COLUMN FOOTING	58.90	71.9	83.9	91.9	98.9	22.07%	42.44%	56.03%	67.91%

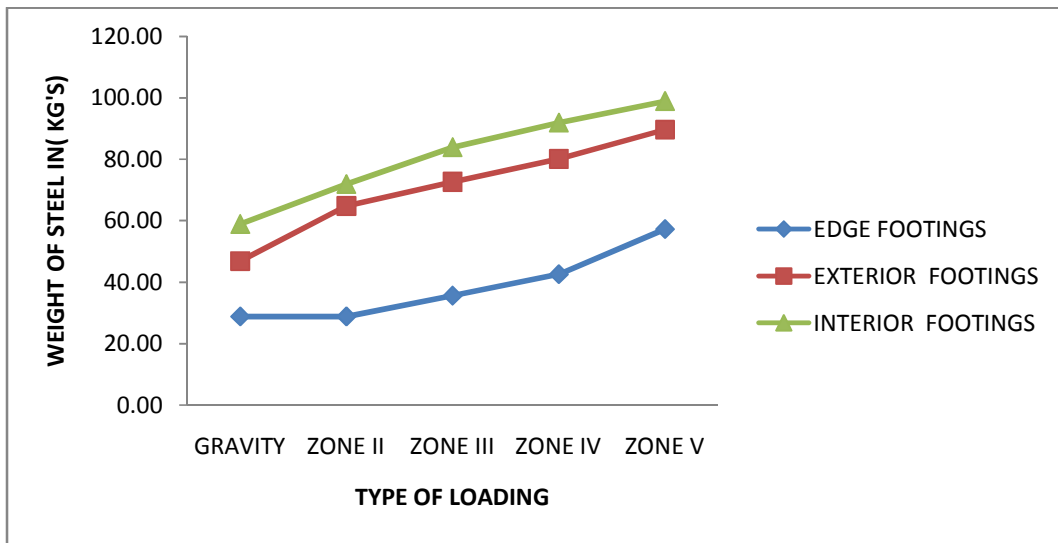


Fig. 10 Variation of weight of steel in footings in different seismic zones

The variation of percentage of steel at each location of the column in different seismic zones with respect to gravity loads is represented in the in Table 5 and Fig.11. The variation of percentage of steel in edge columns vary from 0.8% to 3%, exterior columns varying from 0.8% to 3.9% and

interior columns varying from 1.1% to 3.7% between gravity loads to zone V. For the comparison purpose at each location, the cross sectional dimension of column was kept same in all the zones.

Table 5 Comparison of percentage of the steel in columns in different seismic zones

LOCATION OF THE COLUMN	% of the steel reinforcement in columns				
	DUE TO GRAVITY LOAD	IN SEISMIC ZONE-II	IN SEISMIC ZONE-III	IN SEISMIC ZONE-IV	IN SEISMIC ZONE-V
EDGE COLUMN	0.8	0.9	1	1.5	3
EXTERIOR COLUMN	0.8	0.9	1.5	2.3	3.9
INTERIOR COLUMN	1.1	1.3	1.8	2.4	3.7

Note: For the comparison purpose at each location, the cross sectional dimension of column was kept same in all the zones.

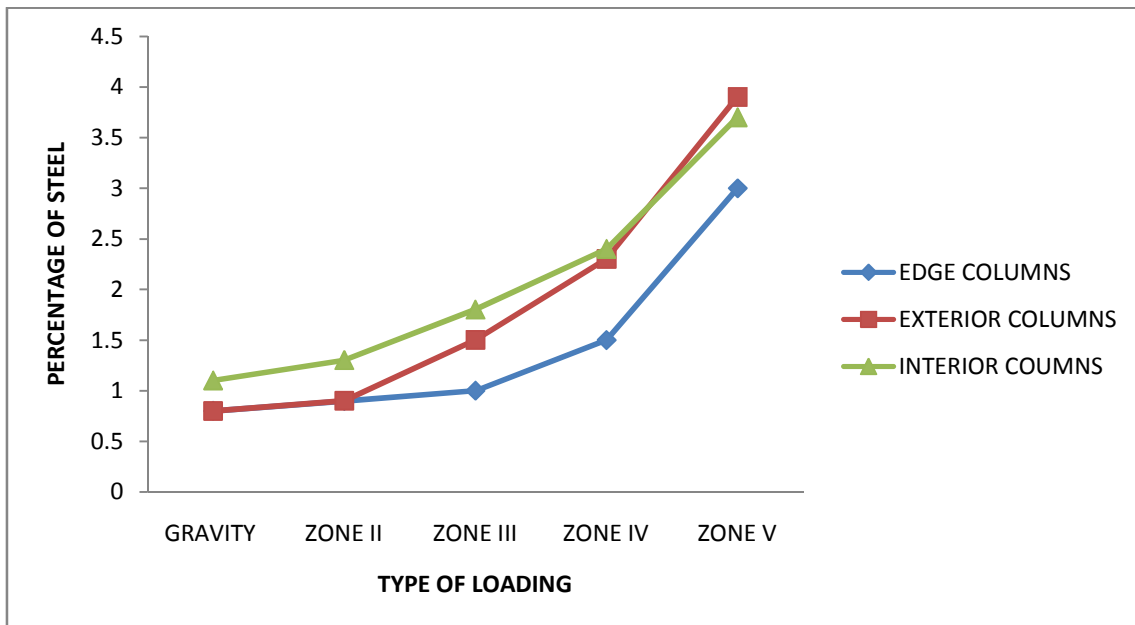


Fig. 11 Variation of percentage of steel in columns in different seismic zones

The variation of percentage of steel in beams in different seismic zones with respect to gravity loads is represented in the in Table 6 and Fig.12. The variation of percentage of steel at supports, in external beams 0.54% to 1.23% and in internal

beams 0.78% to 1.4% varying from gravity loads to zone V. At mid span locations of external and internal beams, the percentage of reinforcement is same in all the zones.

Table 6 Comparison of percentage of the steel in beams in different seismic zones

LOCATION	BEAMS	% of the steel reinforcement in beams				
		GRAVITY LOAD (G L)	IN SEISMIC ZONE-II	IN SEISMIC ZONE-III	IN SEISMIC ZONE-IV	IN SEISMIC ZONE-V
AT SUPPORTS	EXTERNAL BEAMS	0.54	0.64	0.75	0.93	1.23
	INTERNAL BEAMS	0.78	0.83	0.97	1.18	1.4
AT MID SPAN	EXTERNAL BEAMS	0.32	0.32	0.32	0.32	0.32
	INTERNAL BEAMS	0.42	0.42	0.42	0.42	0.42

Note: For the comparison purpose at each location, the cross sectional dimension of beams was kept same in all the zones.

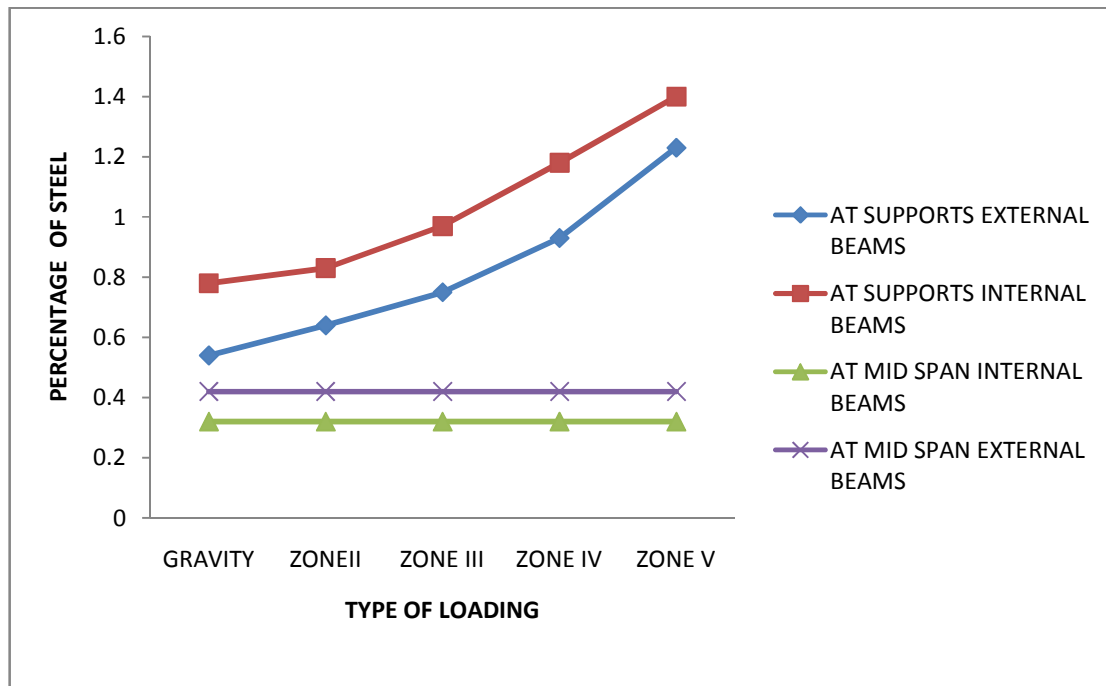


Fig. 12 Percentage of steel in beams in different seismic zones

The variation of weight of steel at each location of the beams and the percentage difference in different seismic zones with respect to gravity loads is represented in the in Table 7 and Fig.13. It is observed that in external beams, variations are 4.38, 13.8, 31.3, and 49.6% between gravity loads to seismic

zones II, III, IV and V respectively. In the internal beams, the variations are 3.07, 15.3, 20.2 and 53.3% between gravity loads to seismic zones II, III, IV and V respectively.

Table 7 Comparison of weight of the steel in beams in different seismic zones

BEAMS	Weight of the steel (kg's)					% difference of weight of steel in beams between			
	GRAVITY LOAD (G L)	ZONE II	ZONE III	ZONE IV	ZONE V	GL& ZONE-II	GL& ZONE-III	GL& ZONE-IV	GL& ZONE-V
EXTERNAL BEAMS	137	143	156	180	205	4.38	13.8	31.3	49.6
INTERNAL BEAMS	163	168	188	196	250	3.07	15.3	20.2	53.3

Note: For the comparison purpose at each location, the cross sectional dimension of beams was kept same in all the zones.

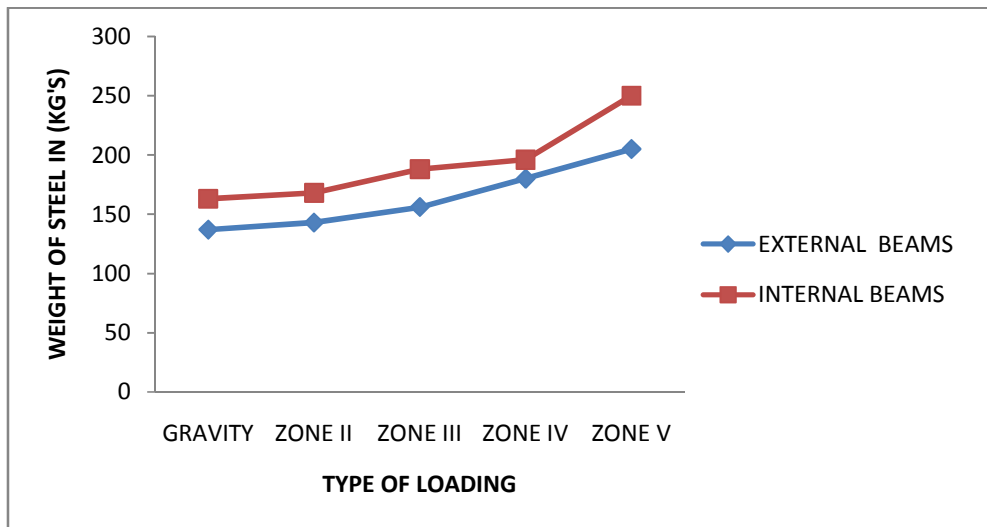


Fig. 13 Variation of weight of steel in beams in different seismic zones

CONCLUSIONS

The following conclusions can be made based on the analysis and design of RC school building designed for gravity loads and earthquake forces in all the zones.

1. The variation of support reactions in exterior columns increasing from 11.59% to 41.71% and in edge columns increasing from 17.72% to 63.7% in seismic Zones II to V. However the variation of support reactions are very small in interior columns.
2. The volume of concrete in exterior and edge column footings is increasing in seismic zones III, IV and V due to increase of support reactions with the effect of lateral forces. However the variation is very small in interior column footings.
3. The variation of percentage of steel at support sections in external beams is 0.54% to 1.23% and in internal beams is 0.78% to 1.4%.
4. In the external and internal beams, the percentage of bottom middle reinforcement is almost the same for both earthquake and non earthquake designs.

REFERENCES:

- [1] Andreas J. Kappos, Alireza Manafpour (2001), "Seismic Design of R/C Buildings with the Aid of Advanced Analytical Techniques", Engineering Structures, Elsevier, 23, 319-332.
- [2] 2. BIS: 1893 (PART 1)-2002 "Criteria For Earthquake Design Of Structures: General provisions and buildings"(Fifth revision), Bureau of Indian Standards , New Delhi
- [3] 3. IS 456(2000), "Plain and Reinforced Concrete-Code of Practice", Bureau of Indian standards, New Delhi.
- [4] 4. Design Aids for Reinforced concrete to IS: 456-1978(SP-16), Bureau of Indian standards, New Delhi.
- [5] 5. H. M. Salem, A. K. El-Fouly, H.S. Tagel-Din (2011), "Toward an Economic Design of Reinforced Concrete Structures Against Progressive Collapse", Engineering Structures, Elsevier, 33,3341-3350.
- [6] 6. H.J. Shah and Sudhir K. Jain (2008), "Final Report: A -Earthquake Codes IITK-GSDMA Project on Building Codes (Design Example of a Six Storey Building)", IITK-GSDMA-EQ26-V3.0
- [7] 7. Kazuhiro Kitayama, Shunsuke Otani and Hiroyuki Aoyama (1987), "Earthquake Resistant Design Criteria for Reinforced Concrete Interior Beam-column Joints", Published in the Proceedings, Pacific Conference on Earthquake Engineering, Wairakei, New Zealand, August, 5-8, 1,315-326.
- [8] 8. M.H. Arslan, H.H. Korkmaz (2007), "What is to be Learned from Damage and Failure of Reinforced Concrete Structures during Recent Earthquakes in Turkey?", Engineering Failure Analysis, Elsevier, 14,1-22.
- [9] 9. Pankaj Agrawal and Manish Shrikhande (2006), "Earthquake Resistance Design Of Structures", ISBN 978- 81-203-3892-1, PHI Learning Private Limited.