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Comparison of Low-Rise Open Ground Storey Framed Building in Different Earthquake Zones

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Abstract – The principle objective of this project is to analyze 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.

Key Words: open ground storey (OGS), STAAD.Pro, seismic analysis, low rise building.

1. INTRODUCTION

The word earthquake is used to describe any seismic event whether natural or caused by humans that generates seismic waves. Earthquakes are caused mostly by rupture of geological faults, but also by other events such as volcanic activity, landslides, mine blasts, and nuclear tests. An earthquake (also known as a quake, tremor or temblor) is the result of a sudden release of energy in the Earth's crust that creates seismic waves. The seismicity or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time. Earthquakes are measured using observations from seismometers. The moment magnitude is the most common scale on which earthquakes larger than approximately 5 are reported for the entire globe. The more numerous earthquakes smaller than magnitude 5 reported by national seismological observatories are measured mostly on the local magnitude scale, also referred to as the Richter scale.

There are many buildings that have primary structural system, which do not meet the current seismic requirements and suffer extensive damage during the earthquake. The buildings were designed by primary structural system and the reason behind this is lies in ZONE II, ZONE III, ZONE IV, and ZONE V of Seismic

Zone Map of 2002 i.e. according to Seismic Zoning Map of IS: 1893-2002, which says the region, is least probable for earth quakes. The institute building is a four story building designed without considering the design factors of IS: 1893-2002. At present time the methods for seismic evaluation of seismically deficient or earthquake damaged structures are not yet fully developed.

The buildings which do not fulfill the requirements of seismic design, may suffer extensive damage or collapse if shaken by a severe ground motion. The seismic evaluation reflects the seismic capacity of earthquake vulnerable buildings for the future use. According to the Seismic Zoning Map of IS: 1893-2002, India is divided into four zones on the basis of seismic activities. They are Zone II, Zone III, Zone IV and Zone V.

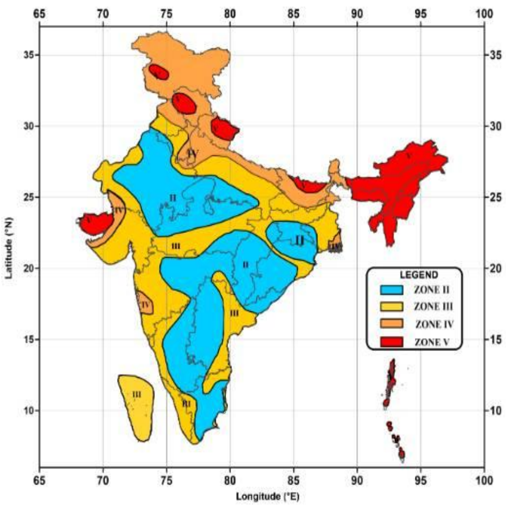

Figure 1 Seismic Zoning Map of India 2002

1.1 AIMS AND OBJECTIVE OF MY WORK

i) To study the effect of infill strength and stiffness in the seismic analysis of OGS buildings.

ii) Comparison of low- rise open ground storey framed building in different earthquake zones with the help of STAAD.Pro V8i Software.

1.2 METHODOLOGY

The methodology worked out to achieve the above-mentioned objectives is as follows:

i) Review the existing literature and Indian design code provision for designing the OGS buildings.

ii) Select an existing building model for the case study.

iii) The analysis is being done in zone II, III, IV, V.

iv) Preparing of model of G+3 residential building in 'STAAD.Pro'.

v) The static analysis and seismic analysis of the building is carried out in STAAD.Pro and the results obtained are compared.

vi) Observations of results and discussions.

2. REVIEW OF LITERATURE

[1] Choubey and Sinha (1994) evaluated the influence of several parameters on infilled frames under cyclic loading, including separation of infill wall from frame, plastic deformation, stiffness, and energy dissipation. Arlekar et al. investigated the behavior of RC-framed OGS buildings when subjected to seismic loads (1997). Equivalent Static Analysis and Response Spectrum Analysis were used to determine the forces and displacements of a four-story OGS building. This research demonstrates that the OGS frame behaves differently from the bare frame.

[2] Scarlet (1997) looked into the qualification of seismic forces in OGS structures. For OGS building, a multiplication factor for base shear was proposed. The stiffness of the infill walls must be modeled in the analysis for this technique to work. As the number of storeys increases from six to twenty, this study offered a multiplication factor ranging from 1.8 to 3.28.

[3] M. I. Adiyanto (2008) analyzed a 3storey hospital building using STAAD Pro. Seismic loads were applied to the building. The dead loads and live loads are taken from BS6399:1997 and seismic loads intensity is based on equivalent static force procedure in UBC1994. Result showed that the building can withstand any intensity of earthquake. It means that the buildings are suitable to be built in any area located near the epicenter of the earthquake.

[4] Kim and Elnashai (2009) observed that buildings for which seismic design was done using contemporary codes survived the earthquake loads. However the vertical motion significantly reduced the shear capacity in vertical members.

[5] Abu Lego (2010) Site Response Spectra was used to study the response of buildings due to earthquake loading. According to the Indian standard for Earthquake resistant design (IS: 1893), the seismic force or base shear depends on the zone factor (Z) and the average response acceleration coefficient (Sa/g) of the soil types at thirty meter depth with suitable modification depending upon the depth of foundation. In the present study an attempt has been made to generate response spectra using site specific soil parameters for some sites in Arunachal Pradesh and Meghalay in seismic zone V and the generated response spectra is used to analyze some structures using the design software STAAD Pro.

[6] Saptadip Sarkar (2010) by using STAAD Pro he studied the design of earthquake resistant RC buildings on sloping ground by changing the number of bays and floor heights. From the analysis results various graphs were drawn between the maximum axial force, maximum shear force, maximum bending moment, maximum tensile force and maximum compressive stress being developed for the frames on plane ground and sloping ground. From the studies the "Short column effects" were carefully studied. It was concluded that the software STAAD is a good tool in studying static linear behavior of the buildings.

[7] Mr.Ankur Agrawal (2012) did seismic evaluation of institute building. There are many buildings which do not meet the current seismic requirement and suffer extensive damage during the earthquake. In 1960 when the institute building of NIT Rourkela was constructed, the seismic loading was not considered. The building is only deigned to take the dead and live loads. Evaluating the building for seismic conditions gives an idea whether the building is able to resist the earthquake load or not. Mr.Ankur Agrawal carried out the Demand Capacity Ratio (DCR) for beams and columns in order to evaluate the

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member for seismic loads. Since He did not find the reinforcement details of the building as it was more than 50 years old He have prepared Design-1 applying only DEAD and LIVE loads according to IS 456:2000 to estimate the reinforcement present in the building and assuming that this much reinforcement is present. In Design-2 seismic loads are applied and for this demand obtained from design-2 and capacity from design -1 the DCR is calculated. If demand is more than capacity member fails and vice versa.

[8] Aslam analysed (2014) did (G+5) storey Hospital building in Agartala one the projects undertaken by L&T. The seismic analysis of the proposed building was done in the software ETABS, version-9.7, which is one of the most advanced software in the structural design field. The loads applied on the structure was based on IS: 875 (part I) 1987[dead load] IS: 875 (Part II)-1987[live load], IS: 875(part III)-1987[wind load], IS: 1893-2002 [Earthquake load]. Scale factor is calculated from the design base shear. (Vb) to the base shear calculated using fundamental time period (Ta).Once the analysis was completed all the structural components were designed according to Indian standard code IS: 456-2000. This included footings, columns, beams, slabs, staircases and shear walls.

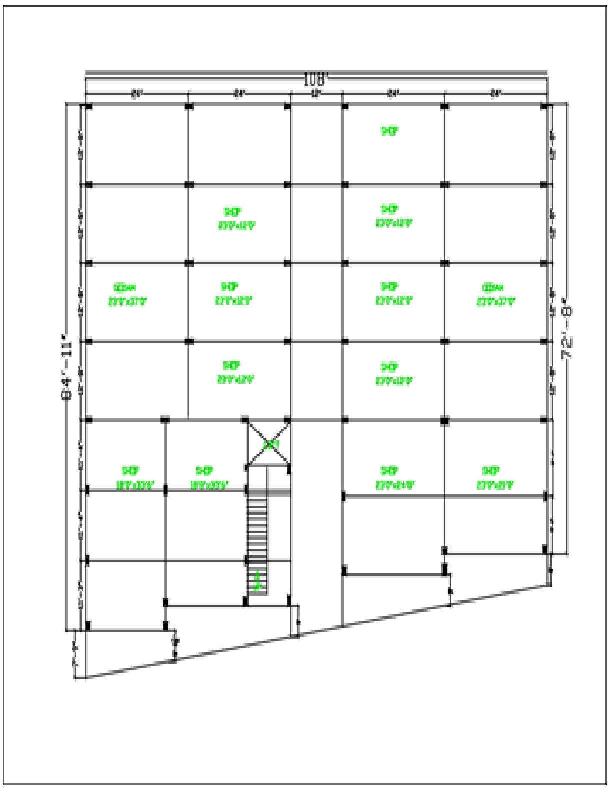

Figure 2 Building Model Plan

3. STRUCTURAL MODELLING

It is very important to develop a computational model on which analysis is performed. In this regard, STAAD.Pro V8i software has been considered as tool to perform. Hence we will discuss the parameters defining the computational models, the basic assumptions and the geometry of the selected building considered for this study. A detailed description on the modeling of RC building frames is discussed.

An OGS framed building located at India (Seismic Zone II, III, IV, and V) is selected for the present study. The building is fairly symmetric in plan and in elevation.

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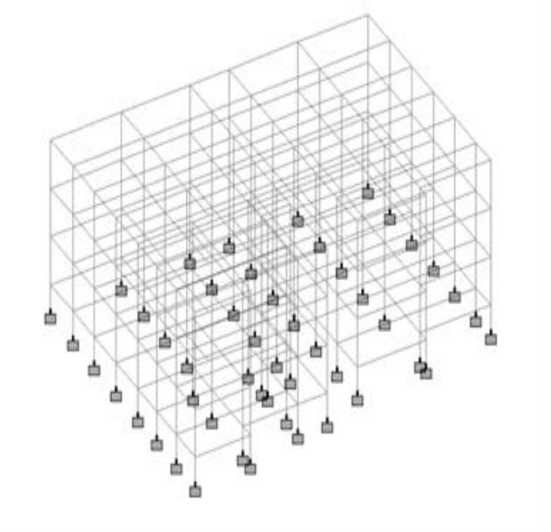

Figure 3 STAAD.Pro Model of Structure

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+3
Floor to floor height	3.6 m
Plinth height	0.6 m
Walls thickness	0.23 m
Grade of concrete	M 25
Grade of steel	Fe 415
Earthquake load	As per IS 1893 (Part 1) : 2002
Size of the columns	0.2 m x 0.4 m, 0.2 m x 0.5 m, 0.3 m x 0.5 m, 0.4 m x 0.2 m, 0.2 m x 0.20 m, 0.4 m x 0.3 m, 0.5 m x 0.3 m (cover = 0.04 m)
Size of the beams	0.3 m x 0.6 m, 0.3 m x 0.4 m (cover = 0.025 m)
Slab thickness	0.13 m
SBC of soil taken	200 KN/m2
Type of soil	Medium soil
Live load	4 KN/m2
Floor finishes	1 KN/m2
Seismic zones considered	II, III, IV, V
Type of wall	Brick masonry
Response Reduction factor	5
Importance Factor	1
Damping of structure	0.05
Passion ratio	0.2
Density	24.0261 KN/m3
Reinforcement factor	4

LOADING COMBINATION:

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. X Direction
2. Z Direction
3. Dead Load
4. Live Load
5. 1.5 (DL+LL)
6. 1.2 (DL+LL+EQX)
7. 1.2(DL+LL-EQX)
8. 1.2 (DL+LL+EQZ)
9. 1.2 (DL+LL-EQZ)
10. 1.5(DL+EQX)
11. 1.5(DL-EQX)
12. 1.5(DL+EQZ)
13. 1.5 (DL-EQZ)

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4. 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 Table 2. 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.

	Support Reaction in kN					Percentage difference between			
LOCATION OF THE COLUMNS	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%

Table 2 Comparison of support reactions in different seismic

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The variation of percentage of steel at each location of the column in different seismic zones with respect to gravity loads is represented in Table 3. 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 3 Comparison of percentage of the steel in columns in different seismic zones

	% of the steel reinforcement in columns				
LOCATION OF THE COLUMN	DUE TO GRAVITY LOAD	IN SEISMIC ZONE- II	IN SEISMIC ZONE- III	IN SEISMICZONE- 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.					

The variation of percentage of steel in beams in different seismic zones with respect to gravity loads is represented in Table 4. 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 4 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

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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.						

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 Table 5. 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 5 Comparison of weight of the steel in beams in different seismic zones

	Weight of the steel (kg's)					% difference of weight of steel in beams between			
BEAMS	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.									

5. CONCLUSIONS

The following conclusions can be made based on the analysis and design of industrial 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 variations of support reactions are very small in interior columns.
2. 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%.
3. In the external and internal beams, the percentage of bottom middle reinforcement is almost the same for both earthquake and non earthquake designs.

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