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Compartive Analysis of G + 9 Structure with Shear Wall at Corners, Central Bays and Alternate Bays

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Abstract*: Need of multi-storey buildings are increasing now-a-days because of rapidly growing population. But when natural calamities like earthquakes occur, there will be great loss to these structures, not only in terms of property but also in terms of causalities. In this paper, an attempt is being made to minimize the loss caused by lateral loads during earthquakes. Shear walls are the one of the most commonly used strategies for resisting the lateral loads. But placing a shear wall at every location is not economical. In this paper, comparison is made among multi-storied structure in different seismic zones by placing shear wall at different locations. Four different configurations viz.., a bay Frame without shear wall, a bay Frame with shear walls at corners, a bay Frame with shear walls at central exterior bays and a bay Frame with shear walls at alternate bays. These Frames are analyzed and results are compared in terms of deflection, bending moments and base shear. Based on the results best configuration is suggested. Analysis of these structures are carried out using STAAD. Pro V8i conforming to Indian codes i.e., IS456:2000, IS1893:2002, IS875 (PART1), IS875 (PART2), IS1343.

Keywords: Multi-storey building, Earthquakes, Seismic zones, lateral loads, shear wall configurations, deflection, bending moment, base shear.

I. INTRODUCTION

The Earthquakes are natural disasters which occur without any warning. These are sudden movements of earth and they cause heavy damages within very short period of time. About 90% of earthquakes causes due to tectonic events mainly from the movements of the faults. Remaining 10% may result from volcanoes, man-made activities and many other consequences. Damage will be more if earthquakes are occurred in urban centres with more population densities. In view of the intense activity in construction all over the country, there is a need to study the past Indian Earthquakes and collect the seismic data to use it in future. Bureau of Indian standards made several attempts in studying seismic data and finally adopted the Indian Standard code IS1893, PART1 for General provisions in buildings in 1962.Many revisions had been made and the latest revision is IS1893 (Part1):2016.The standard incorporated seismic zone factors on a rational basis in its third revision. Fifth revision comes out with only four zones(Zone I and Zone II are combined and together called as ZoneII)Seismic zoning is done to classify the regions with similar probable intensity of earthquake. From the zoning data, lateral loads applied on structure can be found and there by structure which can withstand earthquake is designed. So seismic zoning is also helpful in town planning.

Occurrence of earthquakes results in large amount of lateral forces. It is necessary to provide ductility in the structure so as to resist the lateral loads. Ductility is a property which arises from inelastic behaviour and detailing of reinforcement should be done in a way by which the brittle nature is avoided. It is possible to get more stable structure by using the same quantity of material but by just changing the placements of the structural members. The gap between the actual and design forces can be reduced by providing shear walls.

II. OBJECTIVES

- To study the seismic performance of the structure in different seismic zones.
- To design a structure, that can resist the lateral loads occurring from an earthquake with safety and minimum damage.
- To find the best possible configuration of shear walls to make the structure economically feasible.

III. RESEARCH SIGNIFICANCE

Akash panchal and Ravi Dwivedi [1] carried out analysis on G+6 RCC Modeld structure by equivalent static method in different seismic zones and concluded by comparing shear force, bending moment and deflection variations. Anjali B.U. , Godisiddappa [2] studied the effect of positioning on seismic response of RC building on hilly and plain terrain and found that straight shape shear wall configuration gives better results. Mohd Atif [3] compared multi-storey building with bracing and shear wall, he has shown results that shear wall elements are very much efficient than braced Model and plane Model. Sachin.P.Dyavappanavar [5] studied a 20 storey building in Zone IV and analysed the structure by changing the position of shear walls and concluded that building with shear wall at corner is better location compared to internal core.

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In this study a structure is compared with shear walls at corners, at external central bays, at alternate bays and structure without shear wall.

IV. METHODOLOGY

In this paper attempts are made to determine the lateral force by Equivalent Static procedure. In this Equivalent Static method is used to find the magnitude of lateral forces is based on the natural period and on the distribution of forces. To determine the basic components like deflection, bending moments, support reactions and beam end forces using STAAD.Pro V8i software and compare the results obtained. The analysis is carried out using Equivalent Static Method. The Models are modelled with different seismic configuration to increase the seismic response to the structure.

4.1 Building modelling

In this building RC model multi-storeyed structure with 10 floors is modelled. The height of each storey is 3m and foundation depth is 2m.Four different configurations are modelled, i.e, a bay Model without shear wall,a bay Model with shear walls at corners, a bay Model with shear walls at central exterior bays and a bay Model with shear walls at alternate bays. The structure is in rectangular shape with 21.5m in X-axis and 10m in Z-axis.

The plans for all the four different configurations which are compared are given below:

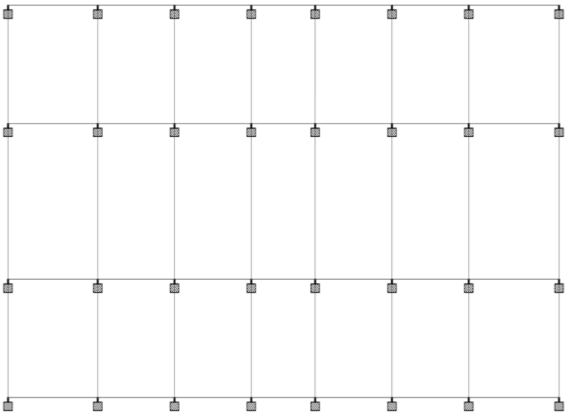

Figure 1

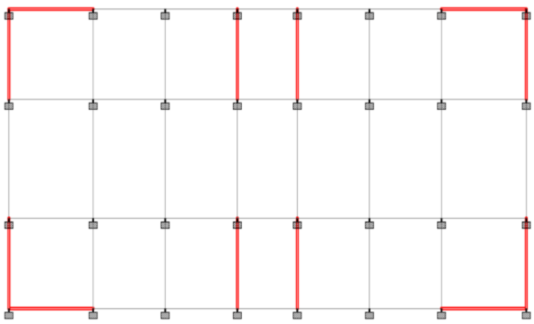

Figure 2

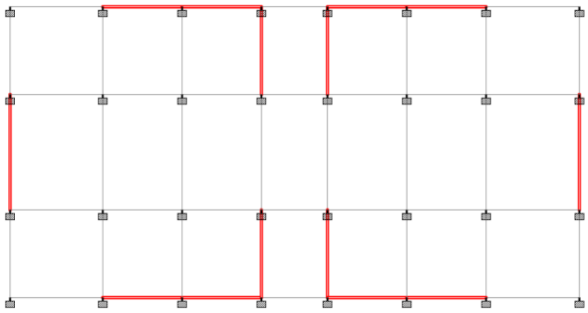

Figure 3

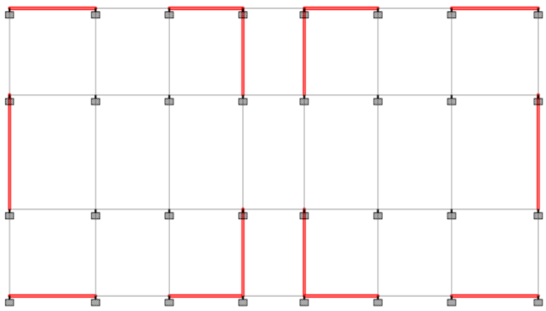

Figure 4

4.2 Specifications

Building modelling is carried out by giving the plan dimensions mentioned below for all the 16 models.

Table 1. Dimensions of the Structural elements and type of materials.

S. No	Parameters	Dimensions/Type
1.	Plan dimension	10m x 21.5m
2.	Number of storeys	G + 9
3.	Total height of the building	30m
4.	Height of each storey	3m
5.	Exterior column dimension	0.6m x 0.6m
6.	Interior column dimension	0.45m x 0.45m
7.	Beam size	0.3m x 0.45m
8.	Model type	SMRF
9.	Type of Soil	Medium soil
10.	Inner wall thickness	0.2m
11.	Outer wall thickness	0.3m
12.	Slab thickness	150mm
13.	Shear wall thickness	250mm
14.	Unit weight of concrete	$25KN/m^3$
15.	Unit weight of brick	$20KN/m^3$

4.3Material Properties

Material properties of the models are taken as the same for all the models and the values given below are used for analysis.

Table 2. Material properties of concrete and steel

Material properties	
Grade of concrete	M25
Elastic modulus of concrete	25000 N/mm^2
Poisson's ratio of concrete	0.15
Grade of reinforcing steel	Fe415
Elastic modulus of steel	2 x10^5 N/mm^2
Poisson's ratio of steel	0.286

4.4Load calculations

Loads taken are confirmed to IS875 (Part1) for dead loads and (Part2) for imposed loads. Seismic loads are taken using IS1893-2002 for seismic load (Part1).

4.4.1Dead loads

Self-weight of slab = 0.15 x 25 = 3.75KN/m^2

Load due to exterior wall =0.35 x2.85 x 20 = 19.95Kn/m

Load due to interior partition wall = 0.2 x 2.85 x 20 =11.4Kn/m

Load due to partition wall = 0.2 x1.5 x 20 =6Kn/m

Load due to plaster on two faces = 0.02 x 2.85 x 1 x 18 x 2 = 2Kn/m

4.4.2Live loads

Live load on every floor (except roof) = 4KN/m^2

Live load on roof = 2KN/m^2

4.4.3Seismic loads

From IS 1893(Part1):2002

Loads are calculated based on Equivalent Static Method.

Seismic base shear along any direction is given as

$V_b = A_h \times W$

$$A_h = \frac{ZIS_a}{2Rg}$$

The values of Z, I, R and Sa/g can be obtained from the code.

I is taken as 1 for residential building

R is taken from code by taking damping percentage ad 5%

Sa/g is found out from the inputs given by Staad software.

Table 3. Seismic Parameters

Seismic zone	ZoneII	ZoneIII	ZoneIV	ZoneV
Intensity of earthquake	Low	Moderate	Severe	Very Severe
Zone factor (Z)	0.1	0.16	0.24	0.36

The natural period of vibration is given in seconds approximately as

$$T_a = \frac{0.09h}{\sqrt{d}}$$

By calculating, $T_x = \frac{0.09*30}{\sqrt{21.5}} = 0.621\ sec$

$$T_z = \frac{0.09*30}{\sqrt{17}} = 0.911\ sec$$

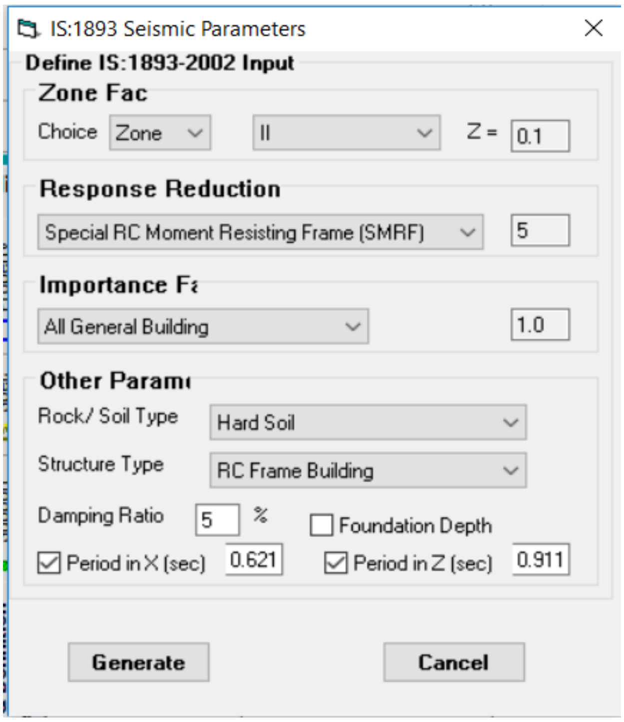

Fig. 5. Seismic input in STAAD-pro.

4.6. Load combinations

Load combinations used in the analysis of Models are given below:

1.5×(D.L+L.L)

1.2× (D.L + L.L ± EQX)

1.2× (D.L + L.L ± EQZ)

1.5× (D.L ± EQX)

1.5× (D.L ± EQZ)

0.9D.L ± 1.5 EQX

0.9D.L ± 1.5 EQZ

These load combinations are given as Staad inputs and the structure is analysed based on these loads for the limit state of design of reinforced concrete.

V.RESULTS AND DISCUSSIONS

The structures with all the four configurations are modelled, analysed and the results obtained from STAAD-PRO are compared in the four seismic zones. The results are compared for

Displacements

Bending moments

Base Shear

5.1 Displacements

Maximum displacement in the direction of X in the structure is due to the load combination 13 i.e., 1.5(D.L + EQX). The permissible limit of deflection from IS 1893 is obtained as 120mm. In Zone-V, Model-1 gave a displacement of 211.66mm whereas Model-3 gave least displacement of 18.043mm which causes a reduction of 89.27% in displacement.

Table 4. Displacements in the direction of X for four Models in different seismic zones

ZONE	Displacements in the direction of X(in mm)				
	Model-I	Model-II	Model-III	Model-IV	Permissible limit
Zone II	58.863	11.318	5.074	14.026	120
Zone III	94.124	18.014	8.067	22.384	120
Zone IV	141.138	26.942	12.057	33.528	120
Zone V	211.66	39.599	18.043	50.295	120

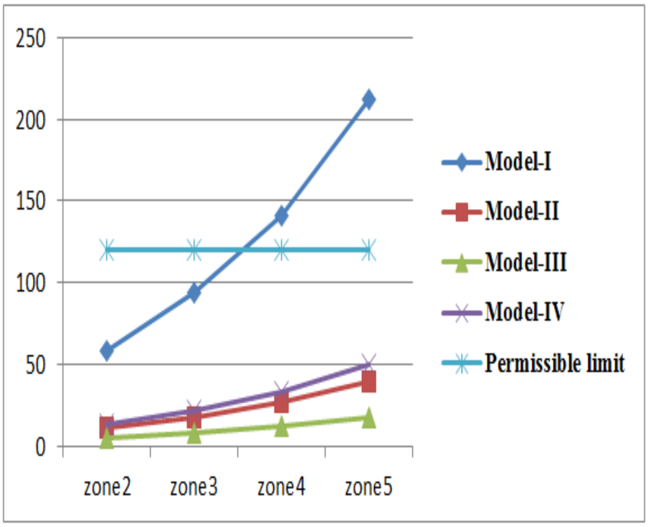

Fig. 6. Displacements in different zones for four Models in the direction of X

Maximum displacement in the direction of Z in the structure is due to the load combination 14 i.e., 1.5(D.L + EQZ). The permissible limit of deflection from IS 1893 is obtained as 120mm. In Zone-V, Model-1 gave a displacement of 186.71mm whereas Model-3 gave least displacement of 29.668mm which causes a reduction of 84.1% in displacement.

Table 5. Displacements in the direction of Z for four Models in different seismic zones

Zone	Displacements in the direction of Z(in mm)				
	Model-I	Model-II	Model-III	Model-IV	Permissible limit
Zone II	51.908	9.315	8.382	13.97	120
Zone III	83.016	14.874	13.364	22.305	120
Zone IV	124.494	22.286	20.005	33.42	120
Zone V	186.71	30.926	29.968	50.091	120

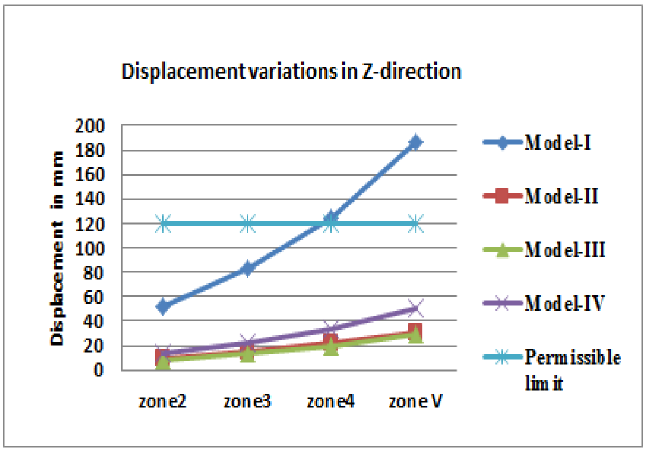

Fig. 7. Displacements in different zones for the four Models Z-direction

5.2Bending moment

Bending moment was maxima for MODEL-I with 783.704Kn-m and by placing shear wall at exterior bays centrally; it is reduced to 76.872Kn-m. So the change in bending moment is nearly 90.19%.

Table 6. Bending moment in the direction of Z for four Models in different seismic zones

ZONE	Bending moment in the direction of Z(in KN-m)			
	Model-I	Model-II	Model-III	Model-IV
Zone II	220.403	35.848	20.752	47.051
Zone III	349.433	48.82	33.703	45.416
Zone IV	523.147	72.556	50.97	103.517
Zone V	783.704	106.88	76.872	151.916

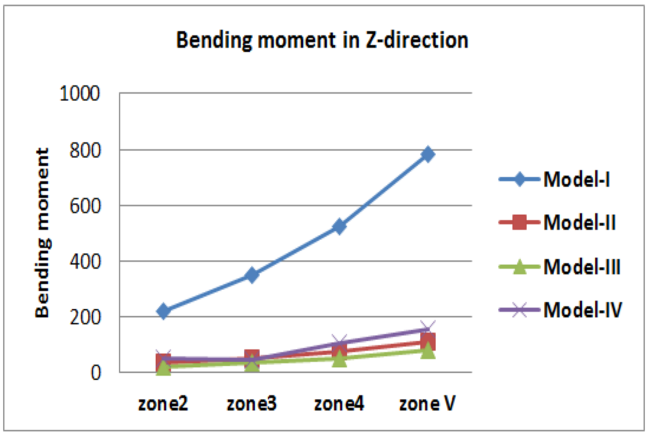

Fig. 8. Bending moment in different zones for four Models in the direction of Z

Bending moment in the direction of X was maxima for MODEL-I with 603.43Kn-m and by placing shear wall at exterior bays centrally; it is reduced to 70.872Kn-m. So the change in bending moment is nearly 88.23%.

Table 7. Bending moment in the direction of X for four Models in different seismic zones

ZONE	Bending moment in the direction of X(in KN-m)			
	Model-I	Model-II	Model-III	Model-IV
Zone II	172.089	28.995	31.521	44.838
Zone III	271.629	39.654	44.355	65.666
Zone IV	404.349	53.866	61.468	93.436
Zone V	603.43	70.981	87.137	135.092

5.3Base shear

Base shear in the direction of X was maximum for MODEL-I with 4439.051KN in Zone-V and by placing the MODEL-II, base shear was reduced to 2599.591KN.Change in base shear is approximately 42%.

Table 8. Base Shear in the direction of X for four Models in different seismic zones

ZONE	Base shear due to EQ_X(in KN)			
	Model-I	Model-II	Model-III	Model-IV
Zone II	1233.7	712.942	776.53	1010.486
Zone III	1972.912	1140.707	1242.46	1526.44
Zone IV	2959.368	1711.06	1863.69	2500.778
Zone V	4439.051	2566.591	2795.538	3001.167

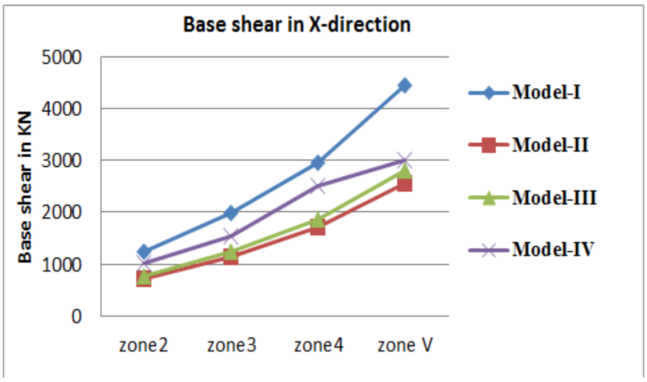

Fig. 9. Base shear in the direction of X in different seismic zones for four Models

Base shear in the direction of Z was maximum for MODEL-I with 3025.961KN in Zone-V and by placing the MODEL-II, base shear was reduced to 1749.564KN.Change in base shear is approximately 42.18%.

Table 9. Base shear in the direction of Z for four Models in different seismic zones

ZONE	Base shear due to EQ_Z(in KN)			
	Model-I	Model-II	Model-III	Model-IV
Zone II	840.545	485.99	529.341	724.10
Zone III	1344.872	777.584	846.945	1121.5
Zone IV	2017.307	1166.376	1270.418	1864.56
Zone V	3025.961	1749.564	1905.628	2045.801

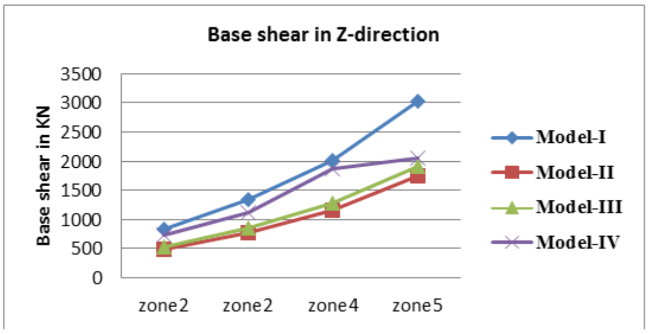

Fig. 10. Base shear in the direction of Z in different zones for four Models

VI. CONCLUSIONS

Four Models in four seismic zones are analysed, so a total of sixteen models were studied and the results among them are compared.

Shear wall thickness, beam and column dimensions are taken same for all the sixteen models in all the four seismic zones.

Out of all the load cases, 1.5(D.L+EQX) and 1.5(D.L+EQZ) has given maximum affect on the structure.

Presence of shear wall greatly reduces the displacement, bending moment and base shear in all the seismic zones.

From limit state of serviceability criteria, deflection is minimized for MODEL-III i.e., structure with shear wall at central external bays which causes a reduction of 84.1% with respect to displacement of MODEL-I

Structures in Zone-II and Zone-III have deflections less than the permissible limit without the shear walls, so structures in those Zones can resist earthquake without shear walls also.

It is evident from the obtained results that the bending moment is greatly reduced for Model-III.

Base shear is reduced for MODEL-II i.e., structure with shear wall at exterior corners.

Displacement in Zone V is increased by 72.18% approximately for bare Model when compared with Zone II.

MODEL-II satisfies better than other Models in economy point of view because it needs less number of shear walls for the same thickness.

It can be concluded that MODEL-II and MODEL-III have shown better performance in all the zones by satisfying displacement, bending moment and base shear criteria when compared to the results of MODEL-I and MODEL-IV.

Nomenclatures	
A_h	Design horizontal acceleration spectrum value
d	Base dimension of the building at the plinth level in Metres
D.L	Dead load
EQ_X	Seismic load in the direction of X
EQ_Z	Seismic load in the direction of Z
Model-I	Structure without shear wall

Model-II	Structure with shear walls at corners
Model-III	Structure with shear wall at central external bays
Model-IV	Structure with shear wall at alternate bays
h	Height of the building in metres
I	Importance Factor based on the structural functionality
L.L	Live load
R	Response reduction factor based on the ascertained seismic response of the building.
S_a/g	Average response acceleration coefficient
T_a	Approximate fundamental natural period of vibration is given in seconds
T_X	Natural period of vibration in the direction of X
T_Z	Natural period of vibration in the direction of Z
V_b	Design seismic base shear along any principal direction
W	Seismic weight of the building
Z	Zone Factor for Maximum Considered Earthquake

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