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ANALYSIS OF RC BUILDINGS DESIGN FOR INDIAN SEISMIC ZONES

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ABSTRACT:

Reinforced concrete (RC) buildings are routinely designed and detailed to have somewhat higher strengths than those required for actual service load conditions. Generally, the members are provided with larger sizes and greater material strengths than the minimum design requirements a stipulated in the building design codes. The present design procedures for seismic design also results in greater strengths. Moreover, the redundancy in the structure on account of in redistribution of stresses will also lead to increased overall strength. This study deals with the comparison of percentage longitudinal steel, reinforcement detailing and design base shear of three RC framed buildings with varying storey heights in different Indian seismic zones. Moreover, it also comprises of performance based analysis of the buildings taken under consideration and designed as per Indian codal provisions in terms of their over-strength factor using computer-based push-over analysis.

KEYWORDS:

SEISMIC ZONES, SEISMIC DESIGN, BASE SHEAR CURVES, PUSHOVER ANALYSIS

I. INTRODUCTION

1.1 SEISMIC DESIGN CONCEPTS

A severe earthquake is one of the most harmful incident of nature. It is not possible to predict and nullify an earthquake , but we can reduce the amount of damage by designing the proper structure. Hence it is prudent to do the seismic analysis and design to prevent structures against any catastrophe. There are many factor for severity of the damage such as- earthquake magnitude, proximity to epicenter, and the local geological conditions, which affect the seismic wave propagation. The lateral forces due to earthquake cause the maximum problem for structures.

Earthquake resistant design is thereby primarily concerned with limiting the seismic risk associated with man-made structures to socio-economically acceptable levels. It aims to foresee the potential consequences of an earthquake on civil infrastructure and to ensure the design & construction of buildings complies with design codes in order to maintain a reasonable level of performance with some accepted level of damage during an earthquake exposure .The ductility of a structure acts like a shock absorber and helps in dissipating a certain amount of seismic energy

1..2 PUSHOVER ANALYSIS

This is a non-linear structural analysis technique in which a progressive lateral load is applied to the structure under consideration. The sequential progress of crack formation, plastification, inter-storey drift and yielding can be aptly monitored through this method. It is an iterative process and continues till the design fulfills some pre-defined criterion such as target roof displacement. Roof displacement is often taken as the failure criteria because of the ease associated with its estimation. Pushover analysis has become a broadly used means for the purpose of seismic analysis and design of new as well as existing buildings .

II. VARIOUS SEISMIC DESIGN AND THEIR COMPARISONS

To fulfill the aim of this work, a building geometry with varying number of stories is designed as per different Indian seismic zones can be explain by a comparison of the design and detailing is presented in the part.

2.1 DESIGN CONSIDERATIONS AND BUILDING GEOMETRY

The plan of the building frame considered the present study is shown in Fig 2.1. The building with the plan shown in this figure is considered for three different number of storeys five, seven and nine. Each of the building with their specific height are designed for all the seismic zones. The building designations with the seismic zone considered are shown in Fig 2.2. The designation, 'G4ZII' represents G+4 building designed for seismic zone II.

All the buildings are designed as per IS 1893 (2002) considering medium soil conditions.. The buildings in this study have column 3m , slab thickness 125mm and plinth level as 0.6m as observed from the study of typical existing residential buildings. Considering unit weight of concrete as 25Kn/m3 and weight of floor finishes to be 1Kn/m2,the slab dead load comes out to be 4.125kN/m2. Taking the Live Load intensity as 3Kn/m2 for floor slabs and 1.5kN/m2 for roof slabs into account, and the earthquake loads as per IS 1893(part-1); all the thirteen load combinations have been considered for analysis (as in the code IS 1893(part-1). Buildings in zone II are designed considering them as OMRF and detailed according to IS:456, whereas Buildings in zone III,IV and V are designed considering them as SMRF and detailed according to IS:13920. The characteristic strength of concrete and steel are taken as 25MPa and 415MPa respectively

In order to study the design and detailing of the buildings selected, structural analysis is carried out for vertical and lateral loads. The comparison of design base shear, percentage of longitudinal steel in columns and beams are presented in the following sections. For all the three RC buildings, the following assumptions are made in this work-

- There is a common plan for all the buildings of dimensions 19 m x 10 m located on medium soil.
- The effect of finite size of joint width (e.g., rigid offsets at member ends) is not considered in the analysis.
- The floor diaphragms are assumed to be rigid.
- For analysis and design the Centre-line dimensions are considered.

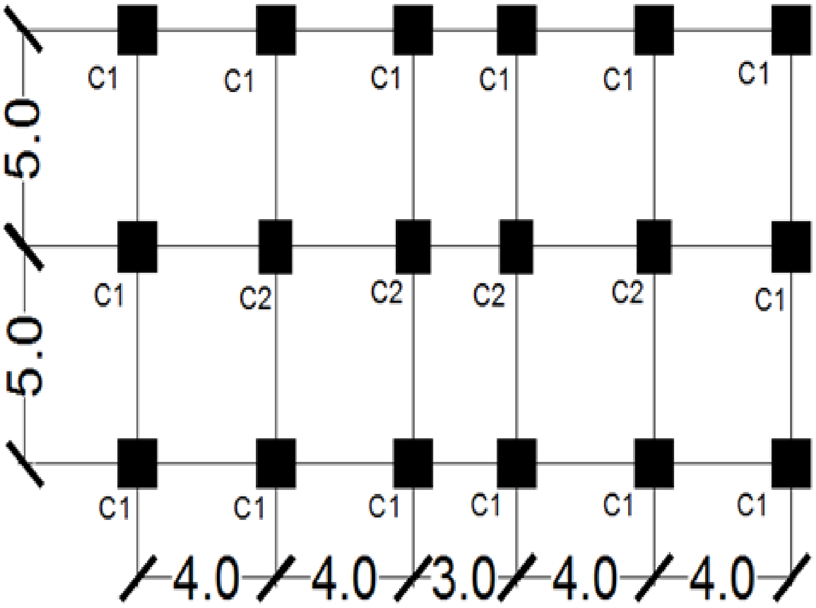
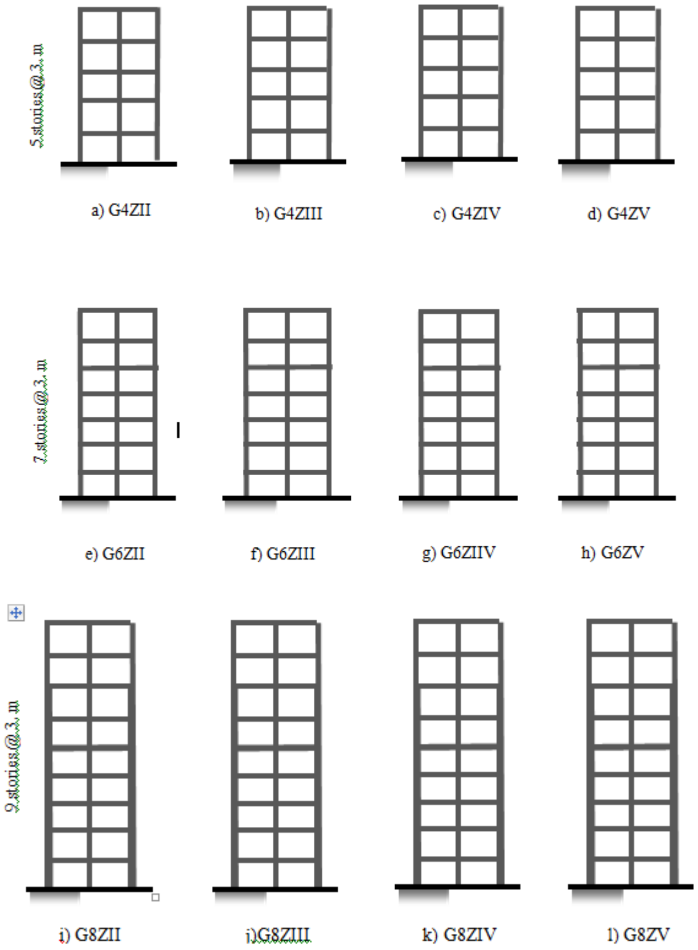


Fig 2.1: Plan of building.(all dimension in meters)



a) G4ZII b) G4ZIII c) G4ZIV d) G4ZV

e) G6ZII f) G6ZIII g) G6ZIIV h) G6ZV

i) G8ZII j)G8ZIII k) G8ZIV l) G8ZV

Fig 2.2 : Elevation of the selected frames

2.2 DESIGN BASE SHEAR AND COMPARISON

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Calculations of base shear depend on:

- soil conditions
- proximity to sources of seismic activity (such as geological faults)
- probability of significant seismic ground motion

- the level of ductility and over-strength associated with various structural configurations and the total weight of the structure
- the fundamental (natural) period of vibration of the structure.

The design base shear is calculated for all the different cases of varying storey heights and seismic zones as per equivalent static method (IS 1893, 2002) and is shown in table 2.1.From the design base shear results, it can be clearly observed that there is a significant increase inbase shear as we move from zone II to zone V, indicating the increase in severity of earthquakes occurring in these regions. Moreover, from the Fig 2.3, it is evident that magnitude of design Base Shear increases with the increase in height of a building.

Table 2.1: Design Base shear values for the designed frames

Frame identity	Design Base Shear(kN)
G4ZII	858
G4ZIII	921
G4ZIV	1125
G4ZV	1340
G6ZII	1190
G6ZIII	1272
G6ZIV	1723
G6ZV	2170
G8ZII	1851
G8ZIII	1920
G8ZIV	2362
G8ZV	2814

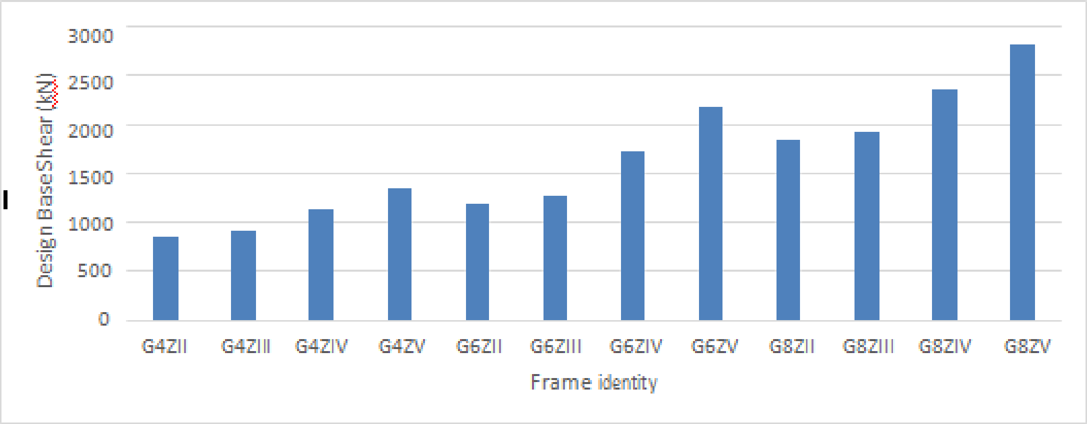


Figure 2.3 : Comparison of Design Base shear values

2.3 COMPARISON OF PERCENTAGE OF LONGITUDINAL STEEL IN COLUMNS

The percentage steel in both exterior as well as interior columns was calculated. The variation of percentage of longitudinal rebars of the column in different seismic zones is depicted in the in Table 2.3. The variation of percentage of steel in exterior columns is from 0.9% to 3% and interior columns varying from 1.1% to 3.1% as one moves from zone II to zone V. In addition to this. It is evident that as we move to higher seismic zone, the steel reinforcement requirements increase.

Table 2.3: Comparison of percentage of longitudinal steel in columns

Frame identity	percentage of longitudinal steel in columns	
	Exterior columns	Interior columns
G4ZII	.91	1.2
G4ZIII	1.3	1.8
G4ZIV	1.9	2.3
G4ZV	2.4	3.0
G6ZII	.97	1.32
G6ZIII	1.57	1.91

G6ZIV	2.1	2.5
G6ZV	2.7	3.1
G8ZII	1.13	1.39
G8ZIII	1.51	1.97
G8ZIV	2.2	2.6
G8ZV	2.7	2.89

2.4 COMPARISON OF PERCENTAGE LONGITUDINAL STEEL IN BEAMS

A beam is a member that is capable of withstanding loads primarily by resisting flexure. The bending force induced into the material of the beam as a result of the external loads, own weight and external reactions to these loads is called as bending moment. In RCC, Beams are characterized by their profile (shape of cross-section), their length, and the amount of steel provided. The percentage longitudnal steel in both exterior as well as interior beams was calculated both at supports as well as midspan and has been tabulated below table 2.4 as shown. The variation of percentage of steel at support sections in external beams is approximately 0.54% to 1.23% and in internal beams is 0.78% to 1.4%. In the external and internal beams, the percentage of bottom midspan reinforcement underwent comparatively lesser increment to about 15-20% for different earthquake zones. It is evident that as we move to higher seismic zone, the steel reinforcement requirements increase.

Table 2.4: Comparison of percentage of longitudinal steel in beams

	percentage of longitudinal steel in beams			
	Exterior beams		Interior beams	
	At supports	At midspan	At supports	At midspan
G4ZII	.66	.38	.81	.41
G4ZIII	.76	.42	.96	.57
G4ZIV	.87	.56	1.2	.65
G4ZV	1.2	.65	1.41	.76
G6ZII	.77	.48	.89	.51

G6ZIII	.89	.52	1.07	.67
G6ZIV	.98	.63	1.23	.78
G6ZV	1.3	.71	1.51	.86
G8ZII	.8	.58	.93	.61
G8ZIII	.93	.62	1.05	.67
G8ZIV	1.02	1.02	1.27	.75
G8ZV	1.4	1.4	1.57	.81

III. PUSHOVER ANALYSIS

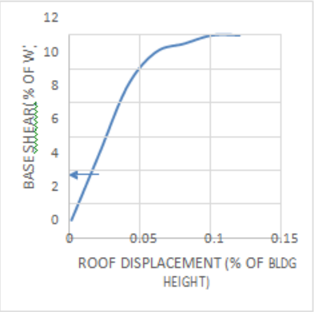
Pushover analysis is a non-linear, structural analysis procedure, which is widely used to explain structural behavior due to various types of loads resulting from an earthquake. In this study, over-strength factor obtained from the pushover curve of the buildings was used as the parameter to assess this amount of reserve strength when the buildings have been designed as per the Indian seismic codal provisions.

3.1 PUSHOVER ANALYSIS AND MODELLING

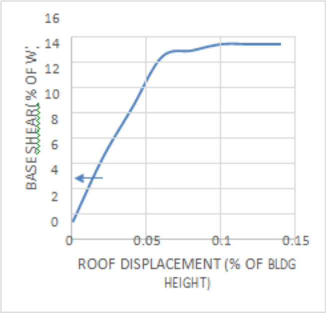
In order to perform the pushover analysis, the buildings were modelled with all the appropriate previously determined member sizes and reinforcements. Then non-linear hinges were defined with appropriate non-linear properties (force-displacement or moment-rotation diagrams) in a structure model. Thereafter, hinges were assigned to all the beams and columns. This was followed by assigning each floor slab a rigid diaphragm. A set of lateral forces was defined subsequently, and the nature of force was taken to be non-linear and displacement controlled. Finally, all other parameters of the non-linear analysis were defined. After completion of the analysis, the Over-strength factor was determined from the respective Pushover curves.

3.2 DESIGNED BUILDINGS AND THEIR PUSHOVER CURVES

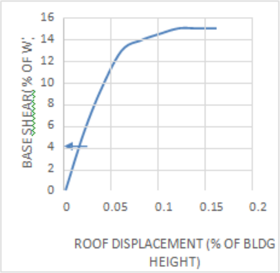
The pushover curves obtained have been made dimension-free by dividing the roof displacement with height of the building (abscissa) and base shear with the building’s seismic weight (ordinate).Fig 3.1 depicts the non-dimensional pushover curves obtained for all the three buildings in the various seismic zones (the arrowheads indicate the amount of Base shear for which the building has been designed).Pushover curves have been shown below for the all the RCC framed buildings considered. The first set of curves is for G+4 building, followed by G+6 and G+8 building respectively .It is found that after zone III there is a significant increase in the base shear which can be seen from the pushover curves for zone IV and zone V



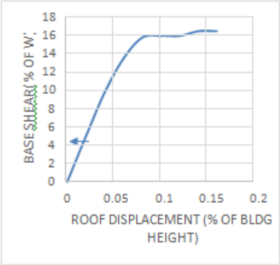
a) Pushover curve for G4ZII



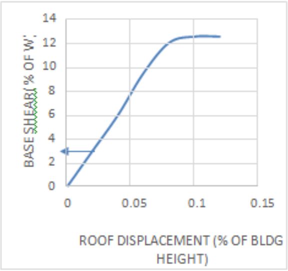
b) Pushover curve for G4ZIII

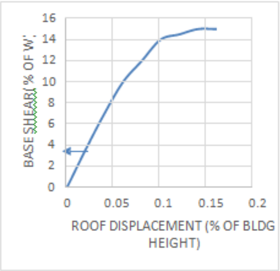


c) Pushover curve for G4ZIV



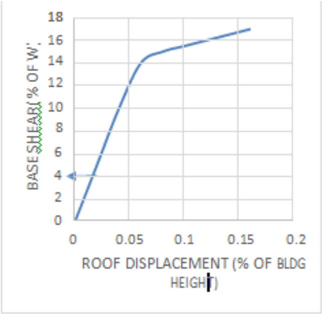
d) Pushover curve for G4ZV

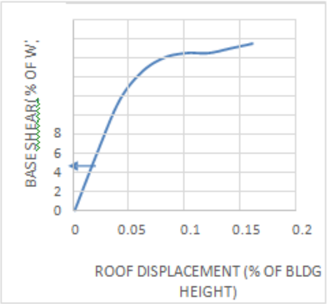




e) Pushover curve for G6ZII

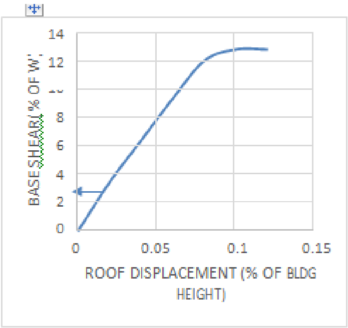
f) Pushover curve for G6ZIII

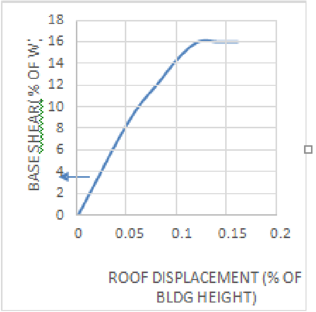




g) Pushover curve for G6ZIV

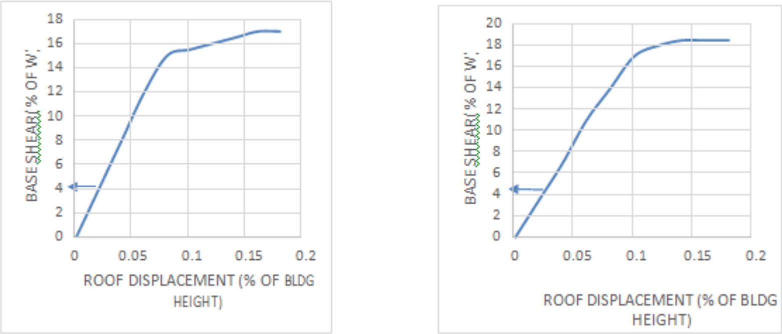
h) Pushover curve for G6ZV





i) Pushover curve for G8ZII

j) Pushover curve for G8ZIII



k) Pushover curve for G8ZIV

l) Pushover curve for G8ZV

Fig 4.1: Non-dimensional Pushover curves

3.3 COMPARISON OF OVER-STRENGTH FACTOR

From the obtained pushover curves, over-strength factors were calculated for the buildings table 3.1. From the analysis of over-strength factor ,we find that it tends to decrease with increase in height of the building. The over-strength factors for all the buildings for the various seismic zones can be listed as follows-

Table 3.1: Over-strength factor comparison

Building	Over-Strength Factor			
	ZONE II	ZONE III	ZONE IV	ZONE V
G+4	2.3	2.73	3.21	3.77
G+6	2.16	2.51	3.1	3.41
G+8	2.03	2.28	2.92	3.23

SUMMARY AND CONCLUSIONS

Study of several past numerous seismic earth quick have shown that building structures have the capacity to manage without any harm. For the seismic design of structures most codes, indeed, indicate just a solitary configuration tremor which the building and its segments are required to maintain without breakdown. The building is expected to experience some basic and nonstructural damage amongst the configuration earthquake. Furthermore, it is expected that the building outlined in this way will consequently meet the objective of no harm in a moderate intensity earthquake. Along these lines, a large number of the seismic design codes have a tendency of downsizing the design forces to record for reserve strength parameter which is crucial and simplifies the analysis as well .Pushover Analysis will help us to demonstrate that how progressive failure in buildings really occurs, and identify the mode of final failure. In this analysis, over-strength factor obtained from the pushover curve of the buildings was used as the parameter to assess this amount of reserve strength when the buildings have been designed as per the Indian seismic codal provisions. In addition to it, several other entities such as percentage steel and base shear were also compared to get an idea on the variation of these quantities with varying building heights and seismic zones. The conclusions obtained from the study and the future scopes of this research are quoted in this chapter.

CONCLUSIONS

The following are the major conclusions that make a basic concept on present work based upon the three RC buildings with different heights designed for earthquake forces in all the seismic zones-

1. There is significant increase in base shear as we move from zone II to zone V, indicating the increase in severity of earthquakes occurring in these regions.
2. Moreover, from the Base Shear curves, it is evident that magnitude of Base Shear increases with the increase in height of a building.
3. As far as steel requirement in columns is concerned, it almost increased to 43%(for exterior as well as interior columns) on average when we move from zone II to Zone V.
4. The variation of percentage of longitudinal steel at support sections in external beams is approximately 0.54% to 1.23% and in internal beams is 0.78% to 1.4%.
5. In the external and internal beams, the percentage of bottom middle reinforcement underwent comparatively lesser increment to about 15-20% for different earthquake zones.

6. There has been a steady rise in overall steel requirements in the building to about 35%,as we move from zone III to zone V.
7. From the analysis of over-strength factor, we find that it tends to decrease with increase in height of the building.

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