STUDY ON DESIGN AND PERFORMANCE COMPARISON OF RC BUILDINGS DESIGNED FOR VARIOUS INDIAN SEISMIC ZONES

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The main objective of this research is to evaluate effect of change of seismic zones on the design, detailing andperformance of the building. The work includes comparison of base shear, percentage steel incolumns and beams, and detailing of selected members. Moreover, it includes a performance comparison of the designed buildings on the basis of over-strength factors obtained from pushover analysis of the buildings.

Key words: Base Shear , Over Strength Factor, Pushover analysis.

INTRODUCTION

A severe earthquake is one of the most destructive phenomena of nature. It is quiteimpossible to precisely predict and prevent an earthquake , but the damage to a structure canbe reduced by its proper design. Hence it is prudent to do the seismic analysis and design toprevent structures against any catastrophe. The severity of the damage depends on the combination of several factors such as- earthquake magnitude, proximity to epicenter, and the local geological conditions, which affect the seismic wave propagation. The lateral forcesdue 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 thedesign & 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.

The seismic design philosophy may be explained as follows:

- Under minor but frequent shaking, the main members of the building that carry vertical and horizontal forces should not be damaged, however building parts that do not carry load may sustain repairable damage.
- Under moderate but occasional shaking, the main members may sustain repairable damage, while the other parts of the building may be damaged such that they may even have to be replaced after the earthquake.
- Under strong but are shaking, the main members may sustain severe (even irreparable) damage, but the building should not collapse

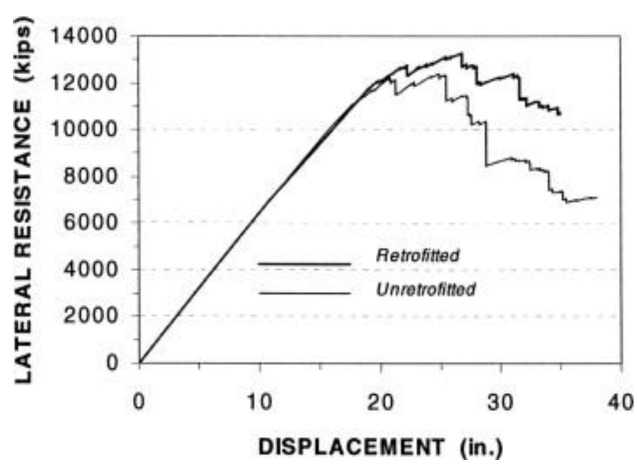


Fig.1.1

PUSHOVER ANALYSIS

Pushover analysis is a static procedure that uses a simplified nonlinear technique to estimate seismic structural deformations. Structures redesign themselves during earthquakes. As individual components of a structure yield or fail, the dynamic forces on the building are shifted to other components. A pushover analysis simulates this phenomenon by applying loads until the weak link in the structure is found and then revising the model to incorporate the changes in the structure caused by the weak link. A second iteration indicates how the loads are redistributed. The structure is "pushed" again until the second weak link is discovered. This process continues until a yield pattern for the whole structure under seismic loading is identified.

Pushover analysis is commonly used to evaluate the seismic capacity of existing structures and appears in several recent guidelines for retrofit seismic design. It can also be useful for performance-based design of new buildings that rely on ductility or redundancies to resist earthquake forces.

Pushover analysis is a static analysis used to investigate how far into the inelastic range a building can go before it is on the verge of a total or a partial collapse. A model for the building is assembled on a computer, with all load-resisting elements together with their force–deformation relationships both before and after yielding and with dead loads plus average live loads. Then a small set of horizontal forces is applied so as to simulate the effects of ground motions, and deformations are calculated. The forces are then increased in steps so as to develop a plot of base motion versus deformation. Examination of this plot reveals the largest base motion that the building can resist.

This approach was developed to permit analysis of existing buildings and to study the effectiveness of schemes for strengthening these buildings and giving them greater ductility. Figure 1.1 shows typical plots for an existing building both before and after it is remediated. The existing building begins to lose resistance rapidly once its peak resistance is exceeded, and it would likely collapse during a very strong shaking. The strengthened building exhibits some ductility that will make collapse much less likely. Pushover analysis is now also used frequently to evaluate the expected performance of designs for new buildings.

It is a non-linear structural analysis technique in which an incremental lateral load is appliedto 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 astarget roof displacement. Roof displacement is often taken as the failure criteria because of the ease associated with its estimation. This has become a widely used tool for the purpose of seismic analysis and design of new as well as existing buildings **.**

What is Pushover Analysis ?

I. It is a non-linear **analysis** to assess the structural capacity under static horizontal loads growing until the collapse of the structure. The results of the **pushover** analyses are some capacity curves identified by the variation of the base shear in function of the displacement of a control point on the structure.

II. Is a method to note the sequence of cracks, yielding, plastic hinge formation and local/global failures in which a structure modeled with non-linear properties and permanent gravity loads is subjected to an incremental lateral load (of certain shape)

III. Is also called static nonlinear **analysis**; because it is a method in which, the action is static, but the structure behavior is nonlinear.

BACKGROUND AND MOTIVATION OF THE PRESENT STUDY

The present work in its utmost sense, tries to delineate that what will be the changes in the structural design of buildings with variation in the seismic zones. It helps in giving a generalized sense of design and detailing differences that will be taking place with the increment in probable severity of ground motions. Thereby, aiding in developing a general perception about the design of regular RC buildings particularly in India. Jain *et al*. (2008), has done the detailing comparison for some selected members of a six-storey building, considering it once as an OMRF and once as an SMRF. The similar idea has been used in thiswork as well, the buildings in zone II have been considered OMRF and detailed as per IS 456,and those in higher seismic zones have been considered as SMRF and detailed as per IS 13920. This study moreover, attempts to do a comparison of the base shear, percentage reinforcement in beams and columns for all the various zones.so as to give further insights into the design aspects. Kumar *et al.* (2013) has carried out such comparison for all components of a G+4 building .This work in addition to all such comparison, includes pushover analysis of the designed buildings followed by comparison of the obtained over-strength factors

METHODOLOGY

The present study comprises of two stages-

Comparison of design and detailing requirement of an RC building for all the four earthquake zones(II,III,IV, and V),i.e, as in India. This will be done for 3 buildings with varying heights of five, seven and nine storey respectively. For every building, It will consist of the following steps-

I. Modelling of the building with all the requisite parameters .
II. Designing the building for all the four earthquake zones(as in India)
III. Comparing of design and detailing for different earthquake zones.
IV. A comparison of performance of designed buildings for various seismic zones and detailing provisions using computer based "PUSH-OVER" analysis

STRUCTURAL MODELING AND DESIGN:-

1. **B. Gireesh** Studied the structural and seismic analysis of G+7 structure using the Stadd.Pro software. In this study the design was based on the following Indian standard codes: IS 1893 (Part 1) – 2007, for the design of base shear. IS 1893:2002 for the earthquake resistant criteria which stated the different analysis criteria based on Zone of area, the height of building and Importance of the building. After starting the project various dead load, live load, wind load, snow load and earthquake load was imposed for which the analysis will run. The building was designed for Heydrabad area whose zone was II. From the analysis, it was concluded that the steel quantity was increased by 1.517% compared to the conventional concrete design. The earthquake load was more dominant than wind load in the selected area but still, there was no need for a shear wall and braced column as the base drift at every storey is 0.0 hence the structure was safe under the drift condition.

2. **Aman et.al** The analysis and design of C+G+5 residential cum commercial building based on the criteria defined by the IS codes on Stadd.Pro software. The load imposed were only dead and live load hence the load combination generated was 1.5(D.L. + L.L.) after which the analysis of the building was done for the Frame and the resulting Bending moments and shear forces were studied. The detail of all the building members was represented along with the functions of slab, beam, column, footing and staircase. From which it was concluded that the horizontal deflections were within 20mm and the structure was safe and economical. And not much difference was obtained between the results from Kani's method and Stadd.Pro

3. **Mahesh et.al** This study was focused on the analysis of the structure in the effect of wind load on the sloping ground by the software Stadd.Pro. The design of wind was based on the Indian standard code IS 875 part- III. The study stated that as the height increases the Bending moment, shear force and joint displacement all show an approx directly proportional relationship with the height.

LITERATURE REVIEW

PUSHOVER ANALYSIS

In the literature, **1) Goel et al.** have implemented modal pushover analysis (MPA) for unsymmetrical buildings in plan. In the MPA procedure, the seismic demand due to individual terms in the modal expansion of the effective earthquake forces is determined by nonlinear static analysis using the inertia force distribution for each mode, which for unsymmetrical buildings includes two lateral forces and torque at each floor level.

2) Fredrick et al. have performed pushover analysis for a five-story building. The buildings were modelled as soft story with varying bottom story heights. is found that primary concern in vertical irregularities is the localization of seismic demand.

3) Cimellaro et al. has proposed bidirectional pushover analysis on models with irregular in shape. The extended N2 method and Proposed Bidirectional pushover analysis were analyzedto the irregular models and the results were compared with nonlinear response history analysis (NRHA) in terms of interstory drift and floor rotations, proves acceptable.

4)Cavdar et al. have conducted pushover analysis and nonlinear dynamic analysis for a building which was collapsed in Turkey earthquake in 2003. Their objective was to perform the pushover analysis and NDA for different earthquakes to test the reliability and usability of performance levels.

5)Grigorios E. Manoukas has evaluated multimode pushover analysis for mass irregular in elevation for RC buildings. In this study two types of models were considered they are inverted pendulum system (ips) and abrupt mass change (amc).

Summary

An extensive review of previous research papers related to the present work and existing seismic design guidelines was done so that a proper methodology could be planned in order to do the design, comparisons and subsequent pushover analysis of the three buildings with varying storey heights as proposed in this present work.

SEISMIC DESIGN AND COMPARISONS

All the aforementioned buildings were designed appropriately as per their respective zones and then detailed accordingly. The results were carefully evaluated. It can be clearly seen that there issignificant increase in base shear as we move from zone II to zone V, indicating the increase in severity of earthquakes occurring in these regions. In addition to this, from the base shear variation,it is evident that magnitude of Base Shear increases with the increase in height of a building. It canbe concluded that 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. The detailings were meticulously drawn so as to give a clear picture of the differences in codal provisions with seismic zones. In the next chapter, pushover analysis of all these buildings has been done to determine their over-strength factors.

PUSHOVER ANALYSIS

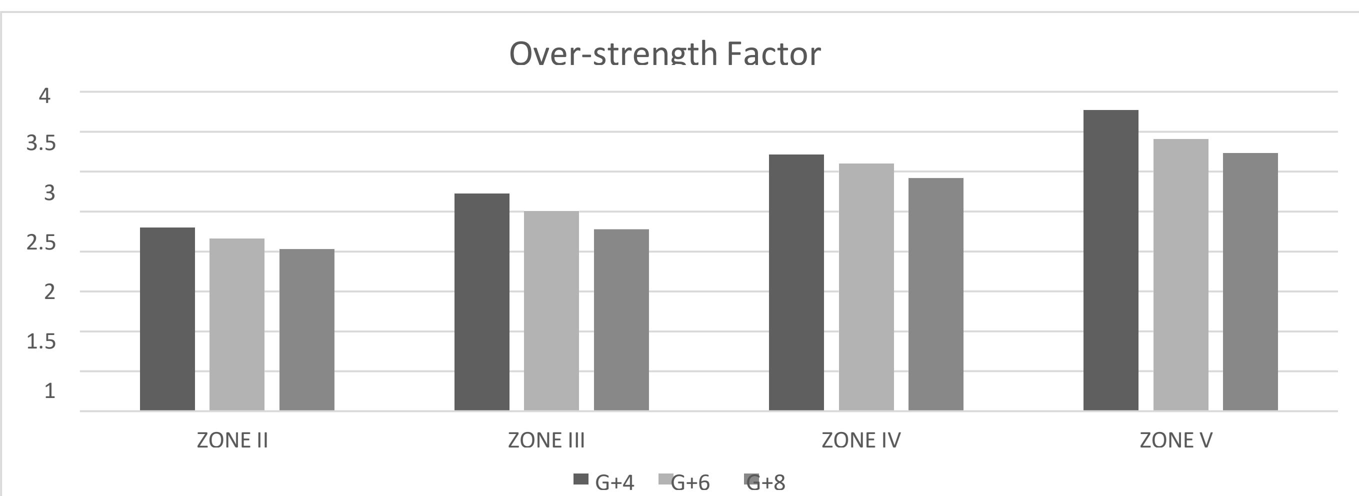
GENERAL

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 theparameter to assess this amount of reserve strength when the buildings have been designed as per the Indian seismic codal provisions.

PUSHOVER CURVES FOR ALL THE DESIGNED BUILDINGS

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 seismicweight (ordinate).Fig 4.1 depicts the non-dimensional pushover curves obtained for all the three buildings in the various seismic zones (the arrowheads indicate the amount of Base shearfor which the building has been designed).Pushover curves have been shown below for the allthe RCC framed buildings considered. The first set of curves is for G+4 building, followed byG+6 and G+8 building respectively .It is found that after zone III there is a significant increasein the base shear which can be seen from the pushover curves for zone IV and zone V respectively, indicating the increase in severity of earthquakes occurring in these regions.

over-strength factor obtained from the pushover curve of the buildings was used as the parameterto assess this amount of reserve strength when the buildings have been designed as per the Indianseismic codal provisions. A total of twelve pushover curves were made, four for each building corresponding to the four Indian seismic zones. From the analysis of over-strength factor, we findthat it tends to decrease with increase in height of the building. There is significant increase in baseshear as we move from zone II to zone V, indicating the increase in severity of earthquakes occurring in these regions. Moreover, from the Base Shear curves, it is evident that magnitude ofBase Shear increases with the increase in height of a building.



RESULTS AND CONCLUSIONS

RESULTS

Analysis of several past numerous seismic tremors have demonstrated that building structures have the capacity to manage without any harm the seismic constraints bigger than those they were intended for during design. For the seismic design of structures most codes, indeed, indicate just asolitary 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 amid theconfiguration 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 downsizihe

CONCLUSIONS

The following are the major conclusions that can be made based on present work carried upon thethree RC buildings with different heights designed for earthquake forces in all the seismic zones-

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.
Moreover, from the Base Shear curves, it is evident that magnitude of Base Shear increaseswith the increase in height of a building.
As far as steel requirement in columns is concerned, it almost increased to 43%(for exterioras well as interior columns) on average when we move from zone II to Zone V.
The variation of percentage of longitudinal steel at support sections in external beams isapproximately 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 middle reinforcement underwent comparatively lesser increment to about 15-20% for different earthquake zones.
There has been a steady rise in overall steel requirements in the building to about 35%,aswe move from zone III to zone V.
From the analysis of over-strength factor, we find that it tends to decrease with increase inheight of the building

SCOPE OF FUTURE WORK

On the basis of the present work done, the scope for future study is identified on the following aspects-

In the present study, seismic design of buildings is carried out using Equivalent Static analysis.

Similar studies may be taken up with other methods such Response-spectrum Analysis, Time-History Analysis.
In this work, only the Indian Seismic design codes have been taken into account, the work can be further extended by incorporation of British, American and other design codes as well.
The present study considers only the over-strength factor obtained from the Pushover Analysis output. Several other parameters such as- Capacity spectrum, hinge-backbone results, etc., canalso be augmented to it.
Efforts may be made to take the soil-structure interaction into account as well.

The present study is carried out on RC buildings. Similar studies may be taken up with Steel structures as well.
Efforts may be made to study the pushover analysis using different software tools or some other procedures to validate the results.

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