Structure Analysed for Maximum considered and Design Basis Earthquake in Northern India

Abdul Arafat Khan[#1], Hafsa Farooq[#2], Syed Suhaib[#3]
#1Department of Civil Engineering, Jamia Millia Islamia, New Delhi, 110025 India
#2Department of Civil Engineering, Jamia Millia Islamia, New Delhi, 110025 India.
#3 Department of Civil Engineering, A.M.U, Aligarh, U.P.202002,India

Abstract

Seismic hazard assessment is essential for carrying out safe and economic design of structures. The different zone factors corresponding to seismic hazard in different parts of India that has been mentioned in the IS code (IS 1893: 2002). The damages caused by earthquakes recently in northern India have indicated that seismic zonation may not be accurate. The uniform ratio of maximum considered earthquake (MCE) to design basis earthquake (DBE) is assumed as 2 in the IS codes, thus leading to non uniform margin of safety at MCE level ground motions. The probabilistic seismic hazard assessment based on these issues is discussed. For testing earthquake resistant building models ground motion records are necessary input in the analysis. Time history records of India for different peak ground accelerations were used in the analysis. The model analyzed using the software ETABS, Response Spectrum Analysis, Time History Analysis (linear & non-linear) were carried out for maximum considered earthquake(MCE) zone factor & design based earthquake (DBE) zone factor as per codes. In this article, analysis were performed on a 10 storey RCC building model for seismic zones IV & V (0.24g & 0.36g) for MCE and (0.12g & 0.18g) for DBE respectively. The peak ground acceleration produced for the extreme scenario by a M7.5 earthquake corresponds to the maximum PGA estimate of 0.63g.

Keywords: *Design basis earthquake; Maximum considered earthquake; PSHA; Response Spectrum analysis; Time History analysis.*

I. INTRODUCTION

Earthquake is a vibration caused in the earth's surface sometimes violent, that results in the release of energy. These vibrations are usually caused by volcanic eruptions, movement of plates or by any manmade disaster. Among these the movement of crust causes the most violent types of earthquakes. All the structures are vulnerable to earthquake vibrations. Whenever a violent earthquake occurs, the structures can get affected that is either a crack or failure can occur. Due to the very nature of release of energy, damage is evident which, however, it's not a disaster unless it strikes a populated area. The twentieth century has seen an increase in the world's population and growth in the size of villages, towns and cities across the globe. Migration processes has led to dense urban areas, surrounded by small growth of scattered settlements especially in the developing third world countries. The cities have increased in size, thus increasing the potential for massive destruction. Thus the risk of earthquake disaster is fast increasing, and is higher as compared to the past times. The main contributor for the cause of deaths in large-scale disasters is the total or partial collapse of buildings. About 75% of fatalities, however, are caused by the collapse of buildings, which primarily are weak masonry buildings or unreinforced structures that can collapse even at low intensity of ground shaking. A very large proportion of the world's building stock resides in the developing third world or the developed world. On the other hand the increasing population in the developing countries will continue to be housed in these types of structures for a long time in the future. It is therefore then the mitigation becomes utmost important.

A. Seismic Disaster Mitigation

The word mitigation may be defined as the reduction of risk. Earthquake disaster mitigation, therefore, implies that such measures may be taken which help to reduce damage caused to life, property and environment. While "earthquake disaster mitigation" usually refers primarily to strengthen the built environment, and "earthquake protection" is to include human, social and administrative aspects of reducing earthquake effects. It should, however, be noted that the reduction of earthquake hazards through prediction was considered to be the one of the most effective way. However it does not guarantee safety and even if done correctly, the damage to life and property on such a large scale guarantees the use of effects of mitigation.

II. LITERATURE REVIEW

For understanding of the seismic disaster and its management, several techniques and analysis have been taken into consideration that would lead to the conclusion.

A. Earthquake Design techniques

The objective of design codes is having structures that will behave elastically under earthquakes that can occur more than once in the life of the building. It is also expected that the structure will survive major earthquakes without collapse. To avoid collapse during a large earthquake, members must be ductile enough to absorb and dissipate energy by post-elastic deformations.

The design seismic forces acting on a structure as a result of ground shaking are usually determined by one of the following methods:

a) Static analysis is the use of equivalent seismic forces obtained from response spectra for horizontal earthquake motions.

b) Dynamic analysis, either modal response spectrum analysis or time history analysis with numerical integration using earthquake records.

B. Elements of seismic mitigation

Earthquake cannot be prevented. But certainly it is necessary to be much more concerned about the probable upcoming earthquake in order to minimize the loss of lives and property in national interest. We should remember that one earthquake of moderate intensity would kill thousands of people and destroy enormous national property. India is possibly one of the most vulnerable countries to potential earthquake threat and damage. An earthquake of even medium magnitude on Richter scale can produce huge destruction. Construction of new buildings strictly following building code or development of future controls on building construction are the activities which will be functional in future. Earthquake vulnerability of any place largely depends on its geology and topography, population density, building density and quality, and finally the strategy of its people for coping its effects. It is thus necessary to identify the scale of such variations and take necessary measurements to cope with that.

For earthquake disaster mitigation, the following measures should be taken:

- Increasing awareness about earthquakes through mass media, education (at school), training, earthquake drills, publications etc.
- Refined assessment of probable ground motion and local soil effects.
- Assessment of probable damage to various structures.
- Survey and identification of risky buildings, Updating and legal use of building code.
- Developing testing facilities and labs for research work.
- Developing low-cost techniques so that individual house owners are able to adopt them.
- Training engineers, planners, architects and construction workers for disaster management.
- Automatic safety shutdown system during a major earthquake
- Developing facilities for post-earthquake rescue and recovery.
- Urban planning of the city to lessen the earthquake effects.
- Execution of national earthquake disaster management plan

III. RESEARCH PAPERS FROM PREVIOUS YEARS

- ***C. Allin Cornell (1968). Engineering Seismic Risk[1]:*** This paper introduces a method for the evaluation of the seismic risk at the site of an engineering project. The results are in terms of a ground motion parameter (such as peak acceleration) versus average return period. The method incorporates the influence of all potential sources of earthquakes and the average activity rates assigned to them. Arbitrary geographical relationships between the site and potential point, line, or areal sources can be modeled with computational ease. In the range of interest, the derived distributions of maximum annual ground motions are in the form of Type I or Type II extreme value distributions; if the more commonly assumed magnitude distribution and attenuation laws are used.

- ***McGuire, RK (2004). Seismic Hazard and Risk Analysis[2]:*** McGuire is one of the pioneers of seismic risk analysis, and his monograph provides a general introduction to methods of seismic hazard and risk analysis. He pays particular attention to one of the most important aspects of seismic risk analysis, that is, how to deal with the associated large uncertainties.

- ***N. R. Chandak (2004) Response Spectrum Analysis of Reinforced Concrete Buildings[3]:*** In this work, a parametric study on reinforced concrete (RC) structural walls and moment resisting frames building representative of structural types using response spectrum method is carried out. The design spectra recommended by Indian Standard Code and two other well-known codes (Uniform Building Code, Euro Code 8) have been considered for comparison. The main objective of this study is to investigate the differences caused by the use of different codes in the dynamic analysis of multi-storey.

- ***Pardeshi sameer, Prof. N. G. Gore (2016) Study of seismic analysis and design of multi storey symmetrical and asymmetrical building[4]:*** This report discuss of current version IS: 1893-2002 that practically all multi storied buildings be analyzed as three-dimensional systems. This paper is concerned with the effects of various vertical irregularities on the seismic response of a structure. The objective of the project is to carry out Response spectrum analysis (RSA) of regular and irregular RC building frames and Time history Analysis (THA) of regular RC building frames and carry out the ductility based design using IS 13920 corresponding to response spectrum analysis. Comparison of the results of analysis of irregular structures with regular structure is done.

- ***N. Torunbalci & G. Ozpalanlar (2008) Evaluation of earthquake response analysis methods for low rise base isolated buildings[5]:*** This paper deals with available analysis methods determined on a comparative basis for most suitable and realistic approaches, especially for cases where the isolators are provided for the foundations of low-rise and medium-rise buildings. To this end, a brief introduction is followed by the investigations performed for different analysis methods, namely the static equivalent earthquake force analysis, linear response spectrum analysis, linear time history analysis and nonlinear time history analysis. For each analysis method, the comparisons are performed and conclusions are discussed for the total base shear forces, story shear forces at columns and absolute and relative story drifts.

Probabilistic Seismic Hazard Analysis

PSHA is composed of four steps

Step I: Identify and characterize the earthquake sources probabilistically. This involves assigning a probability of occurrence of an earthquake at a point within the source zone. Generally, a uniform probability distribution is assumed for each source zone, that is, it is assumed that the earthquake originating from each point within the source zone is equally likely.

Step II: The probability distribution of the source to site distance, considering all points in the source zone to be potential sources of an earthquake, is determined from the source geometry.

Step III: A predictive relationship is used to obtain a seismic parameter (such as the PGA) at the site for a given magnitude of earthquake and source to site distance for each source zone. The uncertainty inherent in the predictive relationship (attenuation law) is included in the PSHA analysis. Generally, the uncertainty is expressed by a log normal distribution by specifying a standard deviation for the seismic parameter and the predictive relationship is expressed for the mean value of the parameter. Cornell et al (1979) predictive relationship is used

ln PGA(gals) = 6.74 + 0.859M - 1.80ln (R+25) …….[1]

where,

R is the epicentral distance in kilometers and M is the magnitude of earthquake.

Step IV: Finally, the uncertainties in earthquake location, earthquake size, and ground motion parameter prediction are combined to obtain the probability that the ground motion parameter will be exceeded during a particular time period. [6]

IV. RESPONSE SPECTRUM ANALYSIS

Response spectrum method is the linear dynamic analysis method. In that method the peak response of structure during an earthquake is obtained directly from the earthquake response, but this is quite accurate for structural design applications [7].The response spectrum of an earthquake is considered as a very useful input for the seismic analysis of structures and is directly used for the response spectrum method of analysis of structures.

The equivalent (static) lateral force for an earthquake is obtained by carrying out a modal analysis of structures, and then a static analysis of the structure with equivalent (static) lateral force in each mode of vibration is performed to obtain the desired responses. The entire procedure is known as the response spectrum method of analysis and is developed using the following steps.

1. A modal analysis of the structure is carried out to obtain the mode shapes, frequencies, and mode participation factors for the structure.
2. An equivalent static load is derived to get the same response as the maximum response obtained in each mode vibration, using the acceleration response spectrum of the earthquake.
3. The maximum modal responses are combined to find the total maximum response of the structure.

A. Modal combination rules

A modal analysis has to be performed for determining frequencies, mode shapes, and mode participation factors for the structure. Subsequently, a static analysis of the structure under the equivalent lateral load is required to obtain the maximum response in each mode of vibration.

The maximum responses obtained in each mode of vibration are generally combined using three different types of modal combination rules, namely: (i) ABSSUM, (ii) SRSS, and (iii) CQC.

*1) **ABSSUM***

ABSSUM stands for absolute sum of maximum values of response. Thus, if x is the response quantity of interest then

$$x = \sum_{i=1}^{m} |x_i|_{max} \qquad [2]$$

where $|x_i|_{max}$ is the absolute maximum value of response in the i^{th} mode of vibration.

*2) **SRSS***

In SRSS, square root of sum of squares, the response x is given by:

$$x = \sqrt{\sum_{i=1}^{m} x_{i\,max}^2} \qquad [3]$$

*3) **3. CQC***

The CQC, complete quadratic combination rule, is a generalization of the SRSS rule and is applicable for a wider class of structures. It is specifically used for structures having closely spaced frequencies. The response x is given by:

$$x = \sqrt{\sum_{i=1}^{m} x_i^2 + \sum_{i=1}^{m} \sum_{j=1}^{m} \rho_{ij}\, x_i x_j}$$

…….[4] [6]

V. TIME HISTORY ANALYSIS (LINEAR AND NON-LINEAR ANALYSIS)

It is known as Nonlinear Dynamic Analysis. It is an important technique for structural seismic analysis especially when the evaluated structural response is nonlinear. To perform time history is required for a structure being evaluated. Time history analysis is a step-by step analysis of the dynamic response of a structure to a specified loading that may vary with time. Time history analysis is used to determine the seismic response of a structure under dynamic loading of representative earthquake [8].
In general, the methods of seismic analysis can be classified as (1) Static and (2) Dynamic. Dynamic analysis can further be classified as (i) Dynamic Characteristics based (static) Analysis and (ii) Time Domain Analysis. All of the above categories have their (a) Linear and (b) Non-linear counterparts.

A. Time Domain Analysis

1) Linear Time History Analysis (Lin.THA). [9]:

In THA, the support points of the model is oscillated back and forth in accordance to a recorded ground motion of an actually occurred earthquake (as recorded by a seismograph, and available in tabular form of time vs. acceleration).

2) Non-linear:

This is done by running a non-linear analysis on a non-linear building model. Non-linearity is incorporated in the analysis model in form of non-linear hinges.

B. Time Domain Analysis

A. Non-linear

Time History Analysis (NL-THA) [10]. This is same as the Lin.THA, but here since the structure has non-linear hinges inserted, the members can undergo and stiffness degradation, strength deterioration – in general, damage, as a real building would, during the progress of an earthquake.

Time history analysis requires time history records of any past earthquakes. Here we have used time history records of Delhi region and Indian standard codes namely IS 1893-2002.

Time history analysis has been carried out for a spectral acceleration of 0.24g & 0.36g on hard soil, with a damping of 5%. Each record is divided into 4095 steps with acceleration spaced at 0.02s. Below are the time history functions of the Delhi region for hard, medium and soft soils.

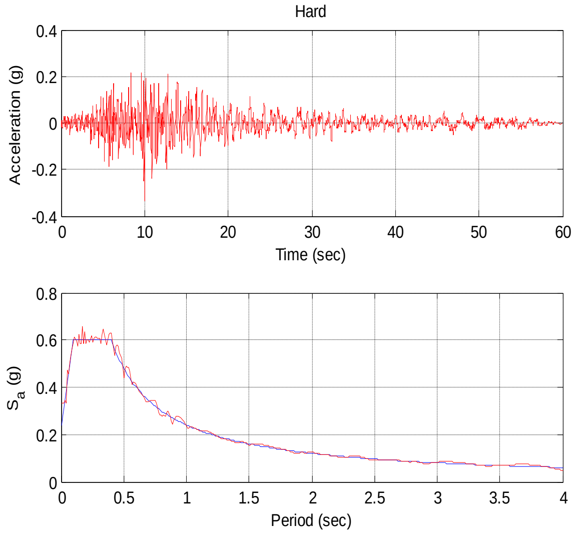

Fig 1: Time History Record of Delhi Region

VI. STRUCTURAL MODEL

Modelling is a whole process that includes assemblage of the various load carrying components of the structure.

Dimensions of Model Sr. No.	Property	Dimension
1	Plan Dimension in X Direction(3bays 6m each)	18m
2	Plan Dimension in Y Direction (3bays 6m each)	18m

Table1 Dimensions of Proposed Model

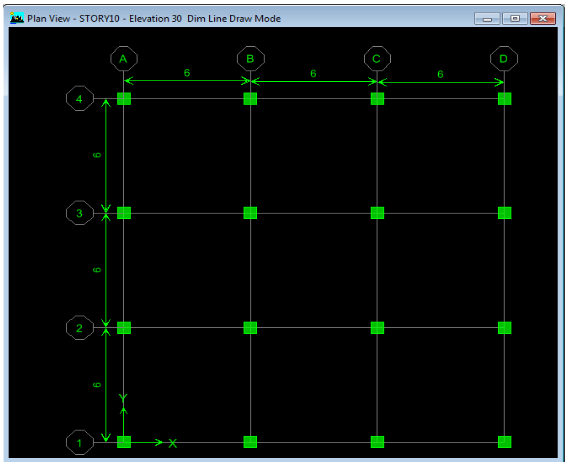

Fig 2 Plan of 10 Storey Building

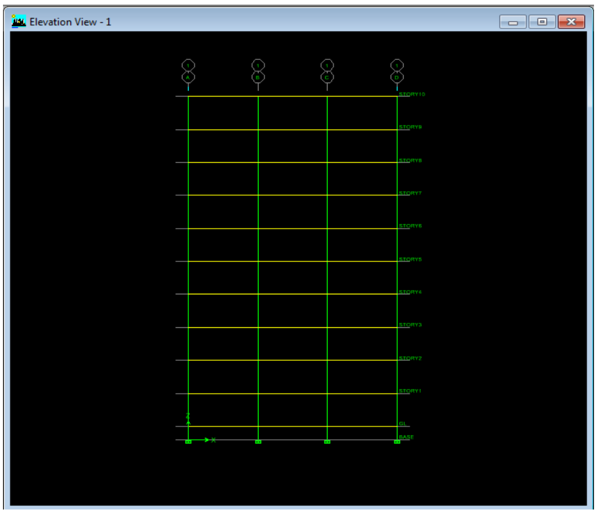

Fig 3 Elevation of 10 Storey Building

A. Loads Considered as per IS 1893 – 2002 (Part I)

1. Super Imposed Dead Load = 1.5 kN/m^2
2. Live Load = 2 kN/m^2
3. Earthquake force in X direction
4. Earthquake force in Y direction
5. Wall load inner = 6 kN/m^2
6. Wall load outer = 12 kN/m^2

B. Earthquake Parameters Based on Structure Location IS 1893:2002 (Part-1)

Sr. No.	Material Property	Values
1	Specific Weight $(\gamma)\ \frac{W}{V}$	$\frac{7850\times9.81}{1000}$ =76.93 kN/m^3
2	Density $(\rho)\ \frac{M}{V}$	7.85 kN/m^3
3	Modulus of Elasticity **E**	2×10^8 kN/m^2
4	Poisson's Ratio (μ)	0.3
5	Coefficient of Thermal Expansion (Clause 6.2.6)	$1.2\times10^{-5}\ {}^{\circ}C$
6	Shear Modulus (**G**)	76884615 kN/m^2
7	Concrete comp. Strength $(f_{ck})\ IS1786:2008$	30×10^3 kN/m^2
8	Minimum Yield Stress(f_y) $IS1786:2008$	415000 kN/mm^2
9	Minimum Tensile Strength(f_u)	415+8%=418200 kN/mm^2

Table 2 Earthquake Parameters Based On IS 1893: 2002

C. Sizes of Structural Members

Table 3 Size Of Structural Members

Sr. No.	Structural Member	Size
1	Columns	600mmX600mm
2	Beams	300mmX600mm
3	Thickness of Slab	150mm
4	Thickness of Wall	230mm
5	Grade of Concrete & Steel	M30 & Fe415

D. Material Properties of Steel (IS800:2007)

Sno	Parameters	Code Provision
1	Type of structure	RCC
2	Nature of Building	Residential
3	Damping of Concrete	5%
4	Importance Factor	1
5	Response Reduction Factor	5

Table 4 Material Properties Of Steel.

VII.RESUTS AND DISCUSSION

Response spectrum, time history, & non-linear time history analysis is done using PGA of 0.63g which is obtained after doing PSHA, PGA 0.24 & 0.36 for seismic zone IV & V for maximum considered earthquake and 0.12g & 0.18g for design based earthquake using code IS code 1893:2002 respectively are performed and time history records Indian standard code compatible are used.

A. Linear Analysis (Response Spectrum Method)

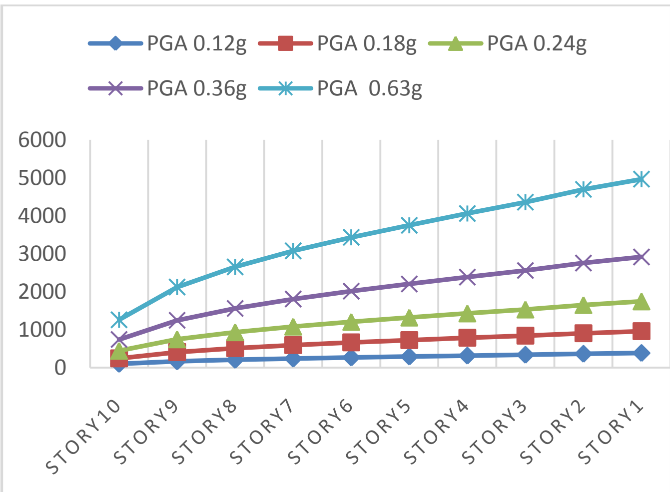

Fig 4 Storey Shear

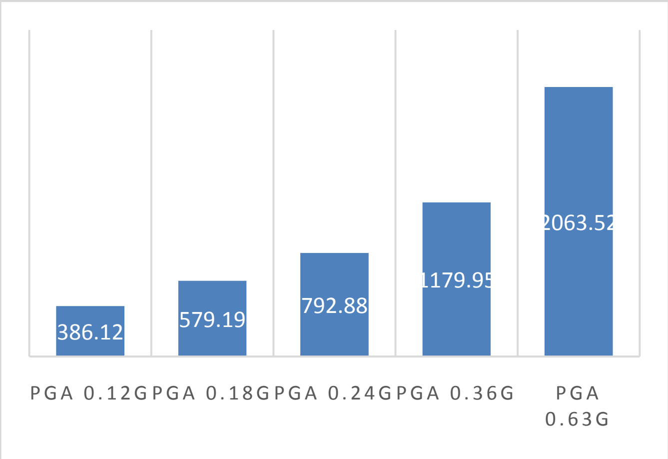

Fig 5 Base shear

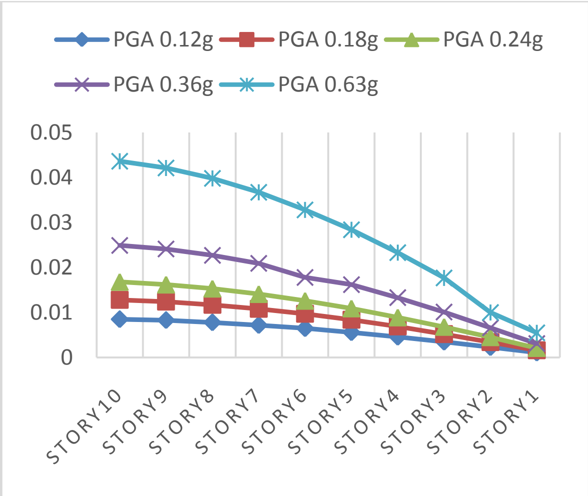

Fig 6 Displacement

6.2 Linear Time History Analysis

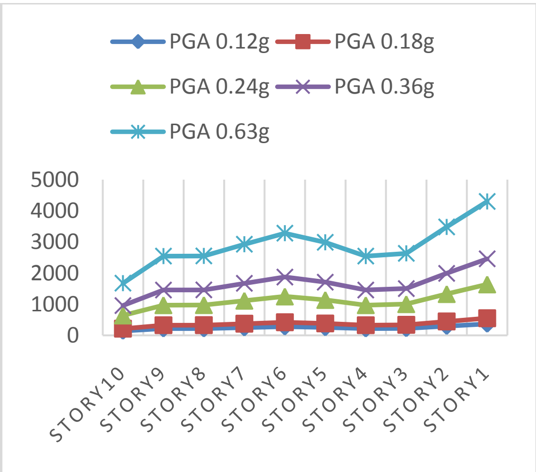

Fig 7 Storey Shear

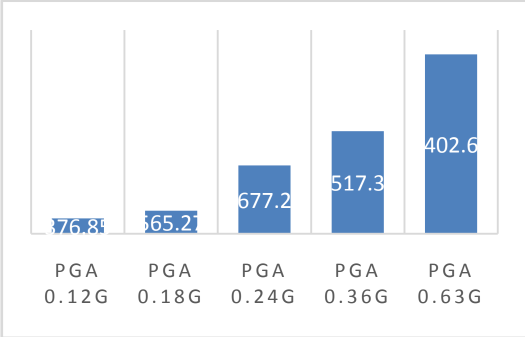

Fig 8 Base Shear

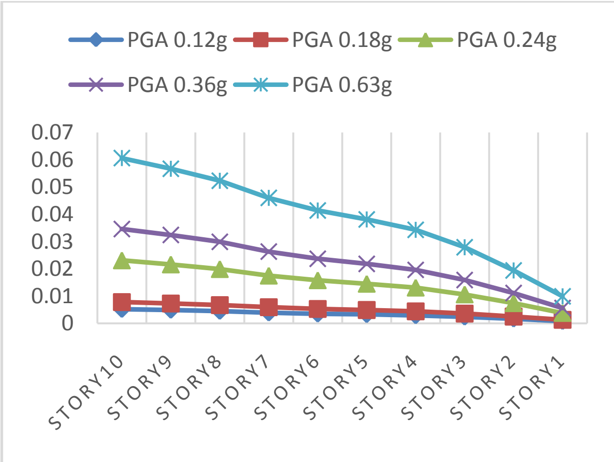

Fig 9 Displacement

6.3 Non- Linear Time History Analysis

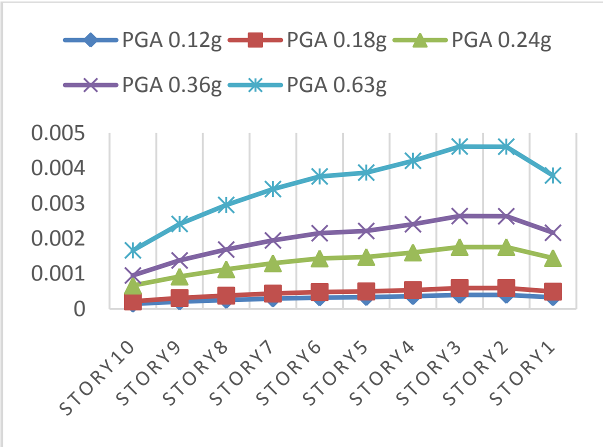

Fig 10 Storey Shear

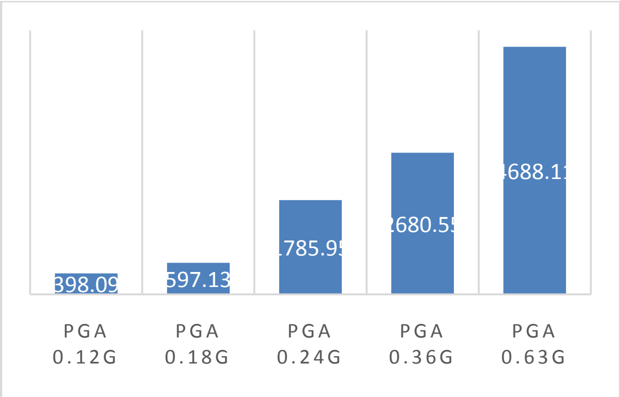

Fig 11 Base Shear

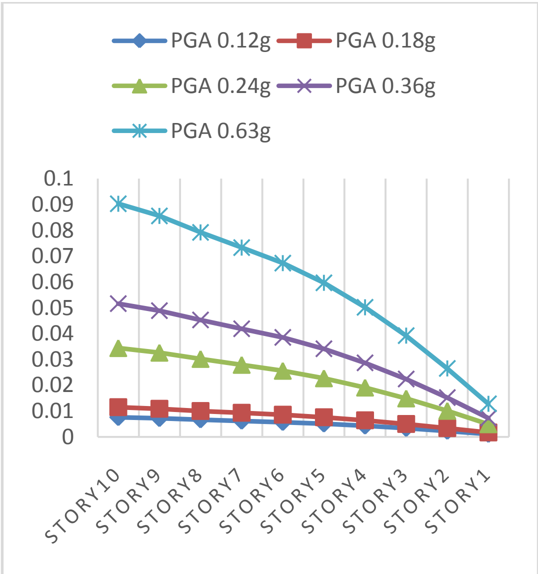

Fig 12 Displacement

VIII. CONCLUSION

We conclude that evaluating seismic risk at particular site has advantage that the risk can be estimated at the potential sites. The probabilistic seismic hazard analysis method is necessary to determine how rapidly the risk decays as resistance of the structure is increased. The method used offers the means by which the analysis are made consistent with the seismic information available.

The values of seismic responses namely base shear, storey displacement & story shear for all the Time Histories & response spectrum for different ground motion intensities are found to be increased with increasing PGA & in similar varying pattern.

The values of base shear, storey displacements, story drifts & story shear for seismic intensities 0.12g & 0.18g are found to be more by 4.5 times by 0.24g & 0.36g for maximum considered earthquake respectively for non-linear analysis.

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