Earthquake Causes Different Shaking Intensities At Different Locations And The Damage Induced In Buildings: A Review

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Abstract - For over 35 years now, field of earthquake engineering has existed in our country. There have been significant contributions to seismic safety of several important structures in our country by Indian engineers. It is also seen that due to lack of awareness amongst practicing engineers about provisions that needs to be followed in designing earthquake resistant buildings, the result has been less satisfactory for normal structures during past Earthquake in India. To prevent the buildings from earthquake excitations there are several techniques that are used nowadays such as base isolation, dampers, bracings, etc. This paper is a review on various researches carried out by various researchers and engineers on such systems. The paper consists of a short review on the tests and investigations on systems for earthquake resistance in buildings done by professors, students, etc of various universities from all over the globe and also focuses on the result they obtained.

Due to fast urbanization construction of a large number of multi-storeyed buildings, many existing RCC buildings located in seismic zones are deficient to withstand earthquakes. In order fulfil the requirement of this increased population in the limited land the height of building becomes medium to high-rise. But during Bhuj earthquake, in Ahmedabad two buildings which were designed as per IS:1893-1984 and were found to be seriously damaged due to mass irregularity as a swimming pool was located at the 10th floor. During an earthquake, failure of structure starts at points of weakness. Generally weakness is due to geometry, mass discontinuity and stiffness of structure. Hence structures fail during earthquakes due to vertical irregularity. Vertical Mass irregularity is an important factor which is to be considered while designing multi-storeyed building. In this project work seismic analysis of RCC buildings with mass irregularity at different floor level are carried out. This paper highlights the effect of mass irregularity on different floor in RCC buildings with as Response Spectrum analysis was performed on regular and various irregular buildings using Staad-Pro.

Keywords - Multi-storey building, Seismic Analysis, Vertical Irregularity, Mass Irregularity, Storey drift, Storey Shear, Story Displacement.

Introduction

Disasters have always caused huge damage to humans ever since our existence. They are unexpected, unpredictable. In counter activities, there have been several attempts to alleviate the catastrophic effects of these disasters. Since ancient times, earthquake is one of nature's greatest hazards on our planet which have caused immense damage to human life. What makes it even worse is its sudden and unexpected nature. Bringing down the damage caused due to untimely earthquake excitations is a major concern for many parts of the world. Since they are unpredictable, the only way left to prevent structures from earthquake is to design earthquakes resistant buildings. Considering this concern, there have been several attempts in this direction globally. The outcome of such attempts are motivating in developed countries while on other hand in developing countries results have been terrible including ours too. This can be proved as there were less loss of life and damage in developed countries compared to developing countries, due to earthquake excitations. Earthquake being a natural phenomenon, it cannot be stopped but all that humans can do is construction of safe structures to mitigate the death toll and damage. Only if the buildings are built earthquake resistant, just as it is made in USA and Japan, the developed countries, we will be able to bring down the damage and death toll and provide a safe environment for humans to live on and carry out their daily activities.

The structures having this discontinuity are termed as Irregular structures. These structures contain a large portion of urban infrastructure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the 'regular' building. Seismic zone map is revised with only four zones instead of five (IS: 1893- 2002). Earthquake causes different shaking intensities at different locations and the damage induced in buildings at these locations is also different. Buildings are designed as per Design Based Earthquake (DBE), but the actual forces acting on the structure is far more than that of DBE. So, in higher seismic zones Ductility based design approach is preferred as ductility of the structure narrows the gap.

The primary objective in designing earthquake resistant structures is to ensure that the building has enough ductility to withstand the earthquake forces, which it will be subjected to during an earthquake. Analyzing the structure for various Indian seismic zones and checking for multiple criteria at each level has become an essential. This paper shows the effect of different seismic zone on the performance of G+10 residential multi-storeyed RC building. The main parameters consider in this study to compare the seismic performance of base shear, storey shear and storey displacement with method of seismic analysis.

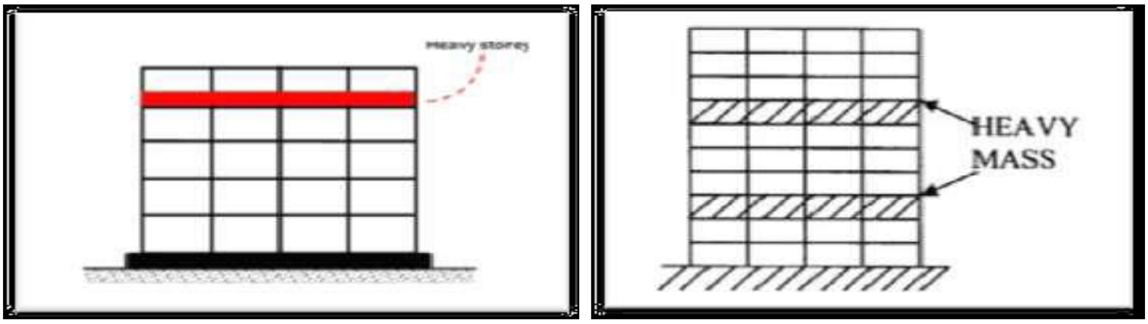

Figure 1: Mass irregularity in structure

Types of vertical irregularity have been listed below:

- Stiffness Irregularity:

a) Stiffness Irregularity - Soft Storey :A soft storey is one in which the lateral stiffness is less than 70 percent of the storey above or less than 80 percent of the average lateral stiffness of the three storey's above.

b) Stiffness Irregularity - Extreme Soft Storey : An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storey's above.

- Mass Irregularity-Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storey's. In case of roofs irregularity need not be considered.
- Vertical Geometric Irregularity- A structure is considered to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey

Literature Review

A brief review on earthquake resistant techniques by some of the researchers is given below:

Lin Su et al (1991): In this paper Lin Su, Goodarz Ahmadi and Iradj G. Tadjbakhsh, discusses about the analysis on a new combination of base isolator resulted after combination of the properties of electricity de France (EDF) base isolator and resilient base isolator(R-FB1) device, and new isolator formed i.e. sliding resilient base isolation system (SR-F). A curve is generated which is than compared with the one by EDF and RFB1 system called as Isolator Response Spectra. The outcome is then compared with fixed base isolation system. Different outcome from this different earthquake records were then compared with SR-F newly proposed isolator. Peak response of all earthquakes for EDF and R-FB1 were recorded and obtained results are compared to the SRF system. Therefore, maximum responses almost ended without large base displacement and the peak response of this isolator was also not too much serious in frequency and amplitude content.

H.W. Shenton et al (1993): In this paper, Shenton and Lin compared and analyzed relative results of fix based and base isolated structure. Referring the concrete fix base structure was designed according to the Structural Agencies Association of California (SEAOC), and comparison was done with a fixed base response. According to the SEAOC recommendation, the base shear was varying. Three various type of time history, post-earthquake record were chosen for the performance of nonlinear dynamic analysis for fixed base and base isolated structure. Comparisons of the results were done to 25% and 50% of the specified lateral force by SEAOC and the building's performance was checked for various lateral forces.

Todd W Erickson et al (2010): In this paper, Erickson and Altoontash discuss the response of the industrial structure. It is shown that the response of industrial structure was presented under seismic forces and according to the IBC code, the building was designed. The current study signifies that three industrial buildings rest on one isolation slab. All problems related to analyses, design, placement of isolator are examined comparatively.

SM Kalantari: SM Kalantari (2010): who for decreasing the base and storey shear of structure investigated effect of using two various types of seismic isolators. Four models of 2, 5, 8 and 12 stories had been created for cases of fixed base, lead rubber and friction pendulum isolator with varying stiffness. All this four models were analyzed under earthquake characteristics of Electro, Naghan, Tabas and Manjil by use of non linear finite element program. The outcome showed that use of LRB had more displacements in lower storey of building compared to fixed base model. While in most number of cases was seen that using FPS isolators didn't guarantee displacement requirement.

Franco Braga (2010): Franco Braga carried out some experimental study on series of dynamic snap back tests. The test was conducted on Potenza Basilica, a residential building in south Italy. The study aimed towards investigation of seismic behavior of low rise base isolated buildings on rubber bearings only.

Alex Y Tuan and GQ Shang (2014): In their paper "Vibration control in a 101 storey building using a TMD" an investigation was carried out on effects of TMD on structural dynamic responses of Taipei 101 tower. A detailed dynamic analysis was conducted for evaluation of structural behavior.

Mr Ashish A Mohite, Prof. G.R. Patil (2015): In his paper "Earthquake analysis of tall building with tuned mass damper", a software study on TMD was conducted. In which TMD is placed on the top of the building and storey drift, storey displacement and base shear was analyzed with and without TMD on ETAB. The analysis was done by investigating seismic behavior of 10th, 12th, 14th, 16th, 18th and 21st floor and excitations of Bhuj earthquake were applied using time history analysis. They concluded that the TMD should be placed at top floor for best control of the first mode and also proper implementation is necessary.

Balakrishna G.S et al (2014): In his paper, it is presented that by using passive energy absorbing devices, seismic response of the building in earthquake prone areas can be improved. By use of SAP2000 v14, a 6 storey building was analyzed with provision of Viscous Fluid Dampers (VFD), Tuned Mass Damper (TMD), and without any damping devices and non linear time history analysis was conducted by applying equivalent to Bhuj earthquake.

Thakur VM et al (2012): This paper comprises of explanation of use of TMD in soft storey form constructed at the top of building. A six storey building, rectangular in shape was considered and analyzed using SAP2000 software by using direct integration approach. Percentage mass of TMD used were 2% and 3%. Comparison between buildings with TMD and without TMD was done by applying three different recorded time histories of past earthquakes for analysis.

Liya Mathew (2012): Liya studied a reinforced concrete building, one with fluid viscous damper and other without it. A study was conducted to find the optimum damper properties for reinforced concrete frames. A symmetrical square building was analyzed using SAP2000 software for nonlinear time history and graphical format was used for showing comparison.

AK Sinha (2012): AK Sinha talked about the use and efficacy of fluid viscous dampers for response control of structures and to minimize the damping. In this paper, a nonlinear time history analysis was performed by him on a 3D model of 12 story RCC MRF building with help of 3D synthetic accelerogram. Two various cases of building models were analyzed one with supplemental damping and other without, it using ETABS. Absolute maximum displacement was compared and Time history response plots were also compared for various responses i.e. base shear and story shear forces, damping behavior and roof displacement and acceleration for both the models. The outcome of time history analysis was that the use of dampers improved the structural response as well as damping demand and proved to be effective.

Tomasz Falborski, Robert Jankowski (2012): The present paper is a report on outcome obtained from the experimental study of determining the effectiveness of elastomeric polymer bearings (EPB) in suppressing structural vibrations during different dynamic excitations. Analysis on single storey model one with fixed base and one with EPB was done and the response of the same was noted. It was seen that there was significant improvement in dynamic properties by use of EPB which reduces the structural vibrations.

Devesh p. soni and Bharat b. mistry (2006)1 have observed that increase in drift demand in the tower portion of set-back structures and on the increase in seismic demand for buildings with discontinuous distributions in mass, stiffness, and strength. The largest seismic demand is found for the combined-stiffness-and-strength irregularity.

Humar and Wright (1977)2 studied seismic response of steel frames with set-backs by using one ground motion. They found story drifts to be larger in the tower parts of set-back structures than those for the regular structures. On the other hand, smaller story drifts were found in the base parts of set-back structure as compared to the regular structures. They concluded that the difference in elastic and inelastic story drifts between set-back and regular structures depends on the level of story considered. Most notable observations were altered displacements and high ductility demands in the vicinity of the irregularities.

Aranda (1984)3 made a comparison of ductility demands between set-back and regular structures by using ground motions recorded on soft soil. He observed higher ductility demands for set-back structures than for the regular ones and found this increase to be more pronounced in the tower portions.

Shahrooz and Moehle (1990)4 observed based on their analytical study that damage is concentrated inthe tower portion of a setback structure due to high rotational ductilities. They also performed experimental studies and concluded that fundamental mode dominates the response in the direction parallel to the set-back.

During the experimental study on two models of set-back frames by **Wood (1992)**5, noticed thatthe response of set-back structures did not differ much from that of the regular structures.

Wong and Tso (1994)6 studied the response of set-back structures by using elastic response spectrum analysis. They observed that the modal masses of higher modes are larger for the set-back structures resulting in different seismic load distributions as compared to those from the static code procedure.

In this work Dynamic analysis of G+12 multistoried RCC building considering Koyna and Bhuj earthquake is carried out by **Mayuri D. Bhagwat (2014**)7by using time history analysis and response spectrum analysis. Seismic responses of such building are comparatively studied and modeled with the help of ETABS software. Two time histories (i.e. Koyna and Bhuj) have been used to develop different acceptable criteria (base shear, storey displacement, storey drifts).

In the study by **Himanshu Bansal (2012)**8 the storey shear force was found to be maximum for the first storey and it decreased to a minimum in the top storey in all cases. It was found that mass irregular building frames experience larger base shear than similar regular building frames. The stiffness irregular building experienced lesser base shear and has larger inter storey drifts.

In the study analyses by **B. M. Saiful Islam (2011)**9 results show that isolation system considerably reduce earthquake induced load on building. Furthermore, method of analysis has been found to have considerable effect on the response of low to medium rise buildings. Time history analysis shows significant less base shear than that from response spectrum analysis. Also, less isolator displacement is obtained from time history analysis than that from response spectrum analysis.

Seismic analysis of high rise building by **S.S. Patil (2013) :** 10 by using program in STAAD Pro. with considering different conditions of the lateral stiffness system. Analysis is carried out by response spectrum method. This analysis gives the effect of higher modes of vibration and actual distribution of force in elastic range in good way. These results include base shear, storey drift and storey deflection are presented.

Methodology

If the structure not properly designed and constructed with required quality they may cause large destruction of structures due to earthquakes. Response spectrum analysis is an useful technique for seismic analysis of structure when the structure shows linear response.

- Extensive literature survey by referring books, technical papers carried out to understand basic concept of topic.
- Selection of an appropriate plan of G+10, story building.
- Computation of loads and selection of preliminary cross-sections of various structural members.
- Geometrical modeling and structural analysis of building for various loading conditions as per IS Codal provisions.
- Interpretation of results include base shear, storey drift and storey deflection.

In the present work it is proposed to carry out seismic analysis of multi-storey RCC buildings using Response spectrum analysis method considering mass irregularity at different floor levels with the help of STAAD PRO software.

Conclusion

- Simple base isolation system in low rise structure performs better and gives better outcome which means there is no need to modify the characteristics of superstructure as modification might not have a positive impact on performance of isolators.
- By increasing damping of superstructure and allocating additional base mass, better isolation can be achieved in middle rise buildings.
- By increasing the damping and making the superstructure stiff, we can reach effective base isolation in high rise buildings.
- Although fluid viscous dampers reduces the response, it can be further reduced by proper selection and installing the fluid viscous dampers at various crucial locations.
- It was seen that base shear can be reduced by about 10-35% while storey displacement can be reduced to 10-25 % effectively by providing 3% TMD. The drift of each floor can be reduced to 1.2 % in a building frame by provision of Viscous Fluid Dampers (VFD).
- It can be understood from this research that efficiency of isolated base and fixed base structure depends primarily on the type of soil upon which the structure rests. Response is satisfactory for hard strata but acceleration increases for soft soil strata thereby decreasing the energy dissipation of the structure and increase in frequency.
- The efficiency of isolators varies with varying height of buildings. For buildings with low to medium height efficiency of isolators is good. The response of the structure is different because of the different types of changes due to the changes in physical properties of an isolator.
- Recently, the seismic control systems have been used widely what is important is selecting best suitable damper and its installation in buildings

for minimizing the structural vibrations when subjected to seismic loading. As passive control systems doesn't require any external power and are reliable, TMD is used as it is one of the best passive dampers.

- On testing the structure using shake table there was seen significant decrease in structure with EPB. There was 58% reduction during sine sweep test and 40% reduction in peak lateral acceleration during dynamic tests. As it can be seen from the result, free vibration test showed considerable increase in damping of structure. The use of EPB was effective in reducing the structural vibrations.
- Going through all these research paper we conclude that earthquake vulnerability can be greatly reduced by application of earthquake resistant techniques thereby providing safe living conditions and safer environment too. The success of such techniques is largely attributed to the development of such devices and proper planning.

Many of the studies have shown seismic analysis of the RCC structures with different irregularities such as mass irregularity, stiffness and vertical geometry irregularity. Whenever a structure having different irregularity, it is necessary to analyse the building in various earthquake zones. From many past studies it is clear that effect of earthquake on structure can be minimize byproviding shear wall, base isolation etc.

The lateral displacement of the building is reduced as the percentage of irregularity increase. As the percentage of vertical irregularity increases, the story drift reduces and go on within permissible limit as clause no. 7.11.1 of IS 1893-2002 (Part I). It was found that mass irregular building frames experience larger base shear than similar regular building frames.

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