A Study of Seismic Strengthening of Multi Storey Building

Aakash Pathak, Rahul Satbhaiya

M.Tech Scholar Dept. Of Civil Engineering, Infinity Management & Engineering College Sagar, M.P. India
Head of Dept. Of Civil Engineering, Infinity Management & Engineering College, Sagar, M.P. India

---***---

Abstract - *Earthquakes, even though they occur rarely, induce inertia force which is dynamic and complex. Moreover, they are sometimes so devastating that it is worth going into the depth of understanding them. The current work is one step towards understanding the complex effects of this dynamic force particularly on low rise RC structures which are found in almost all parts of the world. During 2001 Bhuj earthquake of India, a major damage was observed in RC framed structures at Ahemdabad which were in the range of G+3 to G+7 storey. Most of the buildings were having a normal grid of 3m x 3m column spacing with a storey height of 3m. Hence the present work, which is expected to act as a guide line for Civil and Structural Engineers in smaller towns and cities where expert advice may not be easily available, is devoted to RC framed structures ranging from G+3 to G+ 7 storeys.*

Key Words: Earthquake, Seismic Analysis, RCC structures, Hybrid.

1. INTRODUCTION

Earthquakes have occurred in every part of the globe. It is one of the natural phenomena which has a long lasting and a devastating effect on the human society at large. Although some of the regions are identified as earthquake prone zones, the risk of earthquake has been a major cause of worry for the human race. It is generally felt that the occurrence of earthquakes in the recent times has increased. But the fact is that the awareness and instrumentation has increased throughout the world. This has led to the fact that if one just sees the USGS website which is one of the major online source of earthquake data occurring throughout the world in real time, one can see that there are more than 65 significant earthquakes recorded up to October in 2010. The number of significant earthquakes is 74 for the year 2009.

Although almost all earthquakes are devastating some of the facts and figures tell us the specific reasons for caution against their effects. According to Asian Disaster Reduction Centre (ADRC), Japan, from 1991 to 2000 38% of world's disasters occurred in Asia and 5,88,000 people were killed which is 78% of world's casualty. It also states that in the same period, 1.9 billion people were affected which is 90% of people affected in the world. Economic losses amounted to 374 billion US dollars which accounts for 54% of the world's total damages. ADRC data for the period of 25 years from 1975 to 2000 states that earthquakes affected only 1% of the total people affected by natural disasters in Asia but accounted for about 50% of the total economic damage.

It is a known fact that urbanization is an ongoing process and it cannot be altered or reversed. Hence, it is clear from the facts and figures presented earlier that the earthquake risk is going to be on the upward trend. To mitigate this trend, it is proposed by earthquake engineers that the seismic risk should be predetermined and as one plans the city, it should be divided into zones as per the seismic performance of the buildings.

In the event of an earthquake, it is generally seen that different buildings behave and respond differently. For example, one building which is properly designed and detailed to resist the seismic forces remains intact whereas, an adjoining building which may be designed to perform poorly in the event of an earthquake may be rigorously damaged or may even collapse. If such, a thing happens, the building which is intact may not be approachable because of the debris of the adjoining building. Further usage of the intact building may be hampered because of the reconstruction or retrofitting of the damaged building.

In order to avoid such a scenario, it is desirable to go for performance based engineering and performance based design as far as seismic risk is concerned. Using the static pushover analysis, the structural and non-structural performance may be restricted to a predefined level say - Immediate Occupancy, Life Safety or Collapse Prevention. Hence, it is desirable to divide the newly planned city into zones having a specific seismic performance. Thus, a zone of the city may be reserved for all the buildings meeting the requirement of immediate occupancy as per push over analysis. Thus, in the event of an earthquake, all the buildings in that particular zone will be in a state of immediate occupancy. This will ensure that there is no disturbance from the adjoining buildings due to damage or collapse in the event of an earthquake. This will ensure that this particular zone will not experience any loss of man days and large corporate houses can opt for locating their offices in such zones.

Thus, the new technology and research may help in mitigating the earthquake risk to quite an extent. It is hoped that the concept of push over analysis for framed structures will become a common practice in future in order to identify the seismic performance of a building.

2. EARTHQUAKE AND THEIR ANANLYSIS

One of the major areas of research in the field of earthquake engineering has been the development of the method of evaluating the earthquake esponse of buildings under static nonlinear analysis, popularly known as the push over analysis. It was in the year 1996 that ATC 40 (Applied Technology Council document No. 40) titled as "Seismic Evaluation and Retrofit of Concrete Buildings" was published. It emphasizes the use of available simplified nonlinear static procedures like the capacity spectrum method, the displacement coefficient method and the secant method and focuses on the capacity spectrum method (CSM) which uses the intersection of the capacity (pushover) curve and a reduced response spectrum to estimate maximum displacement. This document is a comprehensive guide for implementing the Static Non Linear analysis procedure along with the other two important documents FEMA 273 and 274

In the year 1996, Moghadam and Tso were among the early researchers who attempted to develop a simple method, yet capable, to predict seismic response of irregular buildings. They applied two static pushovers combined with a dynamic analysis of a single degree of freedom system to estimate the seismic deformation and damages of elements located at the perimeter of the building. The methodology starts with a pushover analysis of a three dimensional system from which base shear - roof centre of mass displacement relationship is obtained. Such correlation is approximated by a bilinear hysteretic curve, to account for unloading. A SDOF system is developed by means of the deflection profile, of the 3D model, when the top centre of mass displacement equals to 1% of the total height. Next, a non linear dynamic analysis of the SDOF system is performed to obtain the maximum roof top displacement Ymax- Another 3D pushover analysis is then carried out to determine the state of stress and deformation of the flexible edge of the building when displacement is Ymax. The results seems to produce comparable results with those from the dynamic analysis when Ymax is evaluated but when near field motions were used it failed to predict the maximum ductility demand and inter story drift at the flexible edge.

3. SESMIC ANALYSIS

Seismic analysis is a particular case of dynamic analysis. Here, instead of a uniform forcing function being applied, the ground motion generated by earthquakes is given as acceleration in terms of g (gravitational acceleration) in the lateral direction to the building. The response of a building or a structure generated because of this dynamic force is studied and the internal forces and moments developed in the structure are evaluated.

Generally, seismic analysis involves the steps mentioned in the previous section wherein the natural frequencies are evaluated first and the mode shapes are also found out. The seismic code of practice specifies the method to be adopted in a particular country based on the past history of earthquakes and probable risk areas. The country is usually divided into various zone based on the probability of an event occurring in that region. Some countries even go for microzonation of the major earthquake zones as the effect of an earthquake can be affected by local soil conditions and other factors.

Based on the occurrences of earthquakes, the various factors are specified by the seismic codes. The response of a structure to an earthquake force depends on variety of factors such as nature of foundation soil; materials, form, size and mode of construction of structures; and the duration and characteristics of ground motion. The coded provisions provide a general guideline for converting the complex phenomenon of earthquake ground motion into a simplified formula to convert {he inertia force induced in the structure into a static force in the lateral direction which can be applied on the structure.

A. Methods of Analysis for Earthquake Forces

Seismic analysis is related to calculation of the response of a building or other structures under earthquakes. It is a part of the process of structural design which includes earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent.

During earthquake many of the buildings collapse due to lack of understanding of the inelastic behavior of structure. Elastic analysis gives only elastic capacity of the structure and indicates where the first yielding occurs. It cannot give any information about redistribution of forces and moments and failure mechanism.

For study of inelastic behavior of structure nonlinear analysis is necessary. The development of rational methodology that is applicable to the seismic design of new structures using available ground motion information and engineering knowledge, and yet is flexible enough to permit the incorporation of new technology as it becomes available has been supported for sometimes now. This is the focus of several major research and development efforts throughout the world. In majority of cases nonlinear analysis is used.

4. PERFORMANCE BASED SEISMIC EVALUATION

Various analysis methods, both elastic (linear) and inelastic (nonlinear), are available for the analysis of existing concrete buildings. Elastic analysis methods include code static lateral force procedures, code dynamic lateral force procedures and elastic procedures using demand capacity ratios. The most basic inelastic analysis method is the complete nonlinear time history analysis. Simplified nonlinear analysis methods, referred to as nonlinear static analysis procedures, include the Capacity Spectrum Method (CSM) that uses the intersection of the capacity (pushover) curve and a reduced response spectrum to estimate maximum displacement; the displacement coefficient method that uses pushover analysis and a modified version of the equal displacement approximation to estimate maximum displacement; and the secant method that uses a substitute structure and secant stiffness.

Although an elastic analysis gives a good indication of the elastic capacity of structures and indicates where first yielding will occur, it cannot predict failure mechanism and account for redistribution of forces during progressive yielding. Inelastic analysis procedures demonstrate how building really behave by identifying modes of failure and the potential for progressive collapse. The use of inelastic procedures for design and evaluation is an attempt to help engineers better understand how structures will behave when subjected to major earthquakes, where it is assumed that the elastic capacity of the structure will be exceeded. This resolves some of the uncertainties associated with code and elastic procedures.

The capacity spectrum method, a nonlinear static procedure that provides a graphical representation of the global force-displacement capacity curve of the structure and compares it to the response spectra representations of the earthquake demands, is a very useful tool in the evaluation and retrofit design of existing concrete buildings. The graphical representation provides a clear picture of how a building responds to earthquake ground motion, and, as illustrated in this chapter, it provides an immediate and clear picture of how various retrofit or safeguard strategies, such as adding stiffness or strength, will affect the building's response to earthquake demands.

5. HYBRID CONCEPT

The concept of hybrid frames which was developed in the previous chapter has been extended here to larger sized frames. The main reason for doing this is that the 2 bay frames consisting of four panels in plan was having totally nine columns out of which there is only one column which can be considered as an interior column. The eight columns located on the peripherals frame were rigidly connected to the beam elements. This results in a strong hybrid frame which behaves very similar to a rigid frame.

G+ 3 storeys to G+7 storey RC space frames having 3 bays, 4 bays and 5 bays of 3m x 3m panels in plan with columns at all points of intersection are considered for the analysis. Thus, the overall plan dimensions of the frames considered are 9m x 9m, 12m x 12m and 15m x 15m. For each of the frames, apart from the fully rigid case, hybrid and semi rigid frames with beam end flexural rigidities of 0, 7500, 100000 and 290000 kNm/rad are considered. Thus, 9 models for each frame are considered for the analysis. In all 45 models for each of the plan dimensions are analyzed using ETABS software making a total of 135 models for all the three cases.

6. CONCLUSION

1. For a G+6 storey RC frame having an overall plan dimension of 6m x 6m and a panel size of 3m x 3m, the seismic performance of frame having rectangular shaped columns is found inferior to the same frame having equivalent square columns.

2. The results of the push over analysis for G+6 storey RC space frame indicates that the storey drift for model with rectangular columns shows a much higher storey drift at first storey level as compared to the model having equivalent square columns.

3. The number and intensity of plastic hinges developed in a G+6 storey RC space frame with rectangular columns at performance point is found

much higher compared to the same model having equivalent square columns. This fact indicates a better seismic performance of the square shaped columns.

4. For an overall plan dimension of 6m x 9m for a G+6 storey building, the push over analysis indicates that the seismic performance of both rectangular and square columns is almost similar. However, the maximum storey drift for model with square columns is less than that with rectangular columns.

5. When brick infill walls are considered in the form of struts in the push over analysis, the number of plastic hinges decreases but severity of plastic hinges developed at performance point increases for both G+6 storey models having square and rectangular columns as compared to the same without considering infill walls.

6. In case of G+6 storey RC frames, looking at the effective damping and base shear at performance point, it can be stated that square columns perform better for overall square plan (3m x 3m panel) whereas rectangular columns perform better for rectangular overall plan (3m x 4.5m panel). This is true for push over analysis with infill walls modeled as struts and even without infill walls.

7. For a G+6 storey model, T shaped columns show a better seismic performance as compared to the rectangular columns in terms of plastic hinges developed at performance point as well as storey drift which is observed. It is also clear that the rectangular column show better performance when pushed in the direction of it's strong axis and inferior performance when pushed in the direction of it's weak axis as compared to T shaped columns. This behavior is found more pronounced when infill walls are considered in the form of compression struts.

8. The seismic performance of frames with rectangular columns as compared to T- shaped columns is better in one direction and inferior in the other direction push from the point of view of roof displacement and base shear observed at performance point. This is also found true when infill walls are considered for the models.

9. It is found that the effective" damping at performance point is almost the same for T and rectangular column models when infill walls are not considered but the difference is more prominent when infill walls are modeled as struts.

10. For a G+6 storey model, with an overall plan dimension of 6m x 6m, it can be concluded that equivalent T shaped columns perform better under seismic forces as compared to rectangular columns by comparing parameters like roof displacement, base shear, effective damping, plastic hinges and storey drift

REFERENCES

[1]. Applied Technology Council, "Seismic Evaluation and Retrofit of Concrete Buildings", ATC-40, Volume 1 and 2, Report No. SSC 96- 01, Seismic Safety Commission, Redwood City, CA, 1996.

[2]. FEMA-273/274, Federal Emergency Management Agency, NEHRP Guidelines and Commentary on the Guidelines for the Seismic Rehabilitation of Buildings, Washington D C, USA, 1997.

[3]. Moghadam A. S. and Tso W. K., "Damage Assessment of Eccentric Multistory Building using 3-D Pushover Analysis", Proceedings of the 11th World Conference on Earthquake Engineering, Paper 997, Acapulco, 1996.

[4]. Kiiar V. and Fajfar P., "Simplified Pushover Analysis of Building Structures", Proceedings of 11th World Conference on Earthquake Engineering, Paper 1011, Acapulco, 1996.

[5]. Faella G. and Kiiar V., "Asymmetric Multistory R/C Frame Structures: Pushover versus Non Linear Dynamic Analysis", Proceedings of 11th European Conference on Earthquake Engineering, Balkema, Rotterdam, PP- 1123-1139, 1998..

[6]. Habibullah A., and Pyle S., "Practical Three Dimensional Nonlinear Static Pushover Analysis", Structure Magazine, Winter, 1998.

[7]. De-La-Colina J., "Effects on Torsion Factors on Simple Non Linear Systems using Fully-Bidirectional Analysis", Earthquake Engineering and Structural Dynamics, No. 28, pp. 691-706, 1999.

[8]. Chopra A. K. and Goel R. K., "Capacity-Demand Diagram Methods for Estimating Seismic Deformation of Inelastic Structures: SDF Systems", Pacific Earthquake Research Center, PEER Report" - 1999/02, 1999.

[9]. Moghadam A. S. and Tso W. K., "Pushover Analysis for Asymmetric and Set-back Multistory Buildings", Proceedings of 12th World

[10]. Peckley D. C., Tanzo W. T. and Pacheco B. M., "Pushover Analysis of a Thirty Five Year Old Pre-Code RC Building", Proceedings of 1st Asia Conference on Earthquake Engineering, Manila, Phiilipines, Vol. 1, pp 137- 150, March 2004.

BIOGRAPHIES

Akash Dubey is an M.Tech Scholar & currently researching on the effect of earthquakes on the giant buildings. He is a Lecturer in Infinity Management & Engineering Sagar (M.P.)