A Study on Uncertainty in Seismic Design and Method of Analysis

Devbrat Bose[1] Prof. Suhail Qureshi[2]
[1,2]Prashanti Institute of Technology and Science, India

Abstract— An earthquake is a natural inevitable unpredictable phenomena which takes place when high stresses built in the earth crust, are suddenly released as the crust breaks with a few kilometres from the earth's surface. The destruction caused on the structure is not only the shaking of structure , but also due to the action of lateral forces on the structure which tend to bend the structure against the ground motion in order to maintain the inertia of rest. The input shaking causes the foundation of a building to oscillate back and forth in a more or less horizontal plane. The building mass has inertia and wants to remain where it is and therefore, lateral forces are exerted on the mass in order to bring it along with the foundation. For analysis purposes, this dynamic action is simplified as a group of horizontal forces that are applied to the structure in proportion to its mass and to the height of the mass above the ground.
Key words: Seismic Design, Method of Analysis

I. Introduction

Structures of civil engineering are mainly considered to resist static loads. In General, the effects of dynamic loads acting on the structure are not measured. This feature of neglecting the dynamic loads sometimes becomes the cause of disaster, particularly in case of seismic forces due to earthquake. Recently an example of this category is earthquake occurred on Jan.26, 2001 in Bhuj (Gujarat). This has produced a growing interest for earthquake resistant design of structures. Other earthquakes in asia are Indian ocean earthquake (2004), Kashmir and regions of Pakistan (2005), bihar and Nepal earthquake (1934), assam (1950) etc.

Earthquakes are catastrophic events that occur mostly at the boundaries of portions of the earth's crust called tectonic plates. When movement occurs in these regions, along faults, waves are generated at the earth's surface that can produce very destructive effects.

Aftershocks are smaller quakes that occur after all large earthquakes. They are usually most intense in size and number within the first week of the original quake. They can cause very significant re-shaking of damaged structures, which makes earthquake-induced disasters more hazardous. A number of moderate quakes (6+ magnitude on the Richter scale) have had aftershocks that were very similar in size to the original quake. Aftershocks diminish in intensity and number with time. They generally follow a pattern of being at least 1 large (within magnitude 1 on the Richter scale) aftershock, at least 10 lesser (within magnitude 2 on the Richter scale) aftershocks, 100 within magnitude 3 on the Richter scale, and so on. The Loma Prieta earthquake had many aftershocks, but the largest was only magnitude 5.0, with the original quake being magnitude 7.1.

In multistory buildings with floors of equal weight, the loading is further simplified as a group of loads, each being applied at a floor line, and each being greater than the one below in a triangular distribution .Seismically resistant structures are designed to resist these lateral forces through inelastic action and must, therefore, be detailed accordingly. These loads are often expressed in terms of a percent of gravity weight of the building and can vary from a few percent to near 50% of gravity weight. Increased compression may exceed the axial compressive capacity of columns while decreased compression may reduce the bending strength of columns.

II. Literature review

Earthquake engineering Research institute (EERI) has conducted the full survey of Bhuj earthquake or also known as Kutch earthquake. This earthquake is considered in one of the most destructive and disastrous earthquake in the last fifty years history of india. The important cities affected by the earthquake are Bhuj, Anjar, rajnagar, Gandhidham, Morbi etc. where the maximum amount of damage and casualties has taken place. It reveals the structural weakness or inefficient in the form of design and planning, improper analysis of calculation of dynamic loads which results in design deficiency and inadequate constructions.

In earthquake engineering, we deal with random variables and therefore the design must be treated differently from the orthodox design. The orthodox viewpoint maintains that the objective of design is to prevent failure; it idealizes variables as deterministic. This simple approach is still valid and applied to design under only mild uncertainty. But when confronted with the effects of earthquakes, this orthodox viewpoint seems so over trustful as to be worthless. In dealing with earthquakes, we must contend with appreciable probabilities that failure will occur in the near future. Otherwise, all the wealth of this world would prove insufficient to fill our needs: the most modest structures would be fortresses. We must also face uncertainty on a large scale while designing engineering systems—whose pertinent properties are still debated to resist future earthquakes about whose characteristics we know even

III. Factors affecting analysis and design of structure due to various behavior of structures under seismic forces

A. Building Behavior

The building is subjected to various types of forces, mostly due to vibration caused on account of earthquake forces. The foundation of structure or structural members are not damaged due to impact forces or external pressure due to winds, but due to action of inertial forces caused by various vibrations and shakening of structure of the building. The increased weight of structure has adverse effects on design of building against seismic forces. It increases the inertial forces on the structure as mass of structure get increased and secondly it results in buckling and crushing of structural members such as walls and columns when the earthquake forces tends to bend the structural members or moved out the members from its initial position .

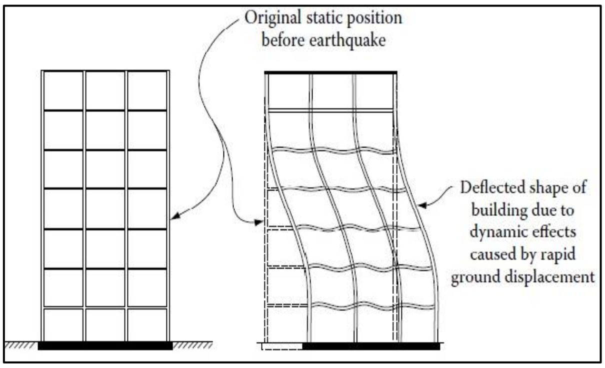

Fig. 1: showing Behavior of Building under Seismic Forces

B. *Influence of Soil*

Due to vibration of structure, which is associated with the ground motions, the amplification of acceleration and its frequency of vibration coincides with the vibrations transferred to soil. This phenomena of coinciding of frequency is called resonance. Thus it is possible for the building and the ground which it rest on it have same fundamental time period and frequency of vibrations which wake the situation more adverse during occurrence of such conditions. Thus, it is concluded from the fact that, to avoid such conditions the structure must ensures that it has different frequency and time period of vibrations to that of ground on which it rest upon.

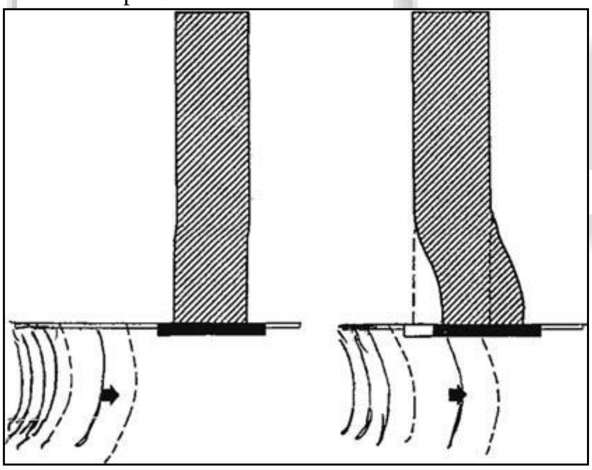

Fig. 2: Showing Action of Seismic Waves on Foundation Soil

C. *Damping*

When the vibrational characteristics of structure coincides with the vibrational characteristics of seismic waves, results in resonance which is responsible for heavy destruction of structure. But, considering the fact that resonance in building is not same as in ideal cases which we have studied, rather they are damped resononating in nature. Their damping behavior depends on the constructional material, connection type and other influence due to presence nonstructural members, which are only used to serve for architectural purposes and thus have no stiffness characteristics on the building. Damping of structure is measured with reference to critical damping in some percentage.

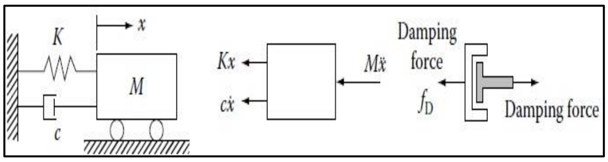

Fig. 3: Showing Concept of Damping

D. *Building Motions and Separations*

Earthquake-induced motions, even when they are more violent than those induced by wind, evoke a totally different human response—first, because earthquakes occur much less frequently than windstorms, and second, because the duration of motion caused by an earthquake is generally short. People who experience earthquakes are grateful that they have survived the trauma and are less inclined to be critical of the building motion. Earthquake-induced motions are, therefore, a safety rather than a human discomfort issue. Lateral deflections that occur during earthquakes should be limited to prevent distress in structural members and architectural components. Non load-bearing in-fills, external wall panels, and window glazing should be designed with sufficient clearance or with flexible supports to accommodate the anticipated movements.

IV. METHODS OF SEISMIC DESIGN

Based on the three criteria strength, stiffness and ductility the methods for seismic design are described below

A. *Lateral Strength Based Design*

It is one of the commonly used design method used nowadays. The concept of this method is based on providing the structure with sufficient lateral strength to resist various impacts on structure due to seismic forces, assuming the condition of structure that it will behave adequately in non-linear range. To achieve this, only simple construction details are needed to satisfied for safe structural characteristics against uneven failure

B. *Displacement Based Design*

In this method the structure is designed in such a way that , to possess sufficient strength an ductility so that it can transfer the vibrational energy by yielding and should bear the shock and shaking of structure effectively. This method operates directly with deformation quantities hence gives better insight on the expected performance of the structures. This method of design has been adopted by many countries in the form of their own design codes.

C. *Capacity Based Design*

Capacity based design is one of such techniques which is new to field of seismic design of various structures. It is based on the positioning of plastic hinges which is in predetermined positions and predetermined sequences. The main objective of this method is to avoid the brittle failure of structural member, which is achieved by transforming brittle failure members into ductile modes

D. *Energy Based Design*

This is the most capable and innovative approach of earthquake resistant design. This method is based on the concept of total energy is dissipated by the kinetic energy, the elastic strain energy and energy resisted through deformations and damping of the structural members associated with it.

V. Seismic Analysis Methods

Main features of seismic method of analysis based on Indian Standard 1893(part 1): 2002 are described as follows

A. *Equivalent Lateral Force Method*

The approach of equivalent lateral force procedure, uses a simple technique of the structures fundamental period and anticipated maximum ground acceleration, or velocity, together with relevant factors, to determine the maximum base shear. The loads acting on the structure specifically horizontal loads are then distributed to the full height of the structure .Then the structure is analyzed for static loads. Then the design forces are calculated in this static load analysis are generally less than the forces which are actually acting on the structure corresponding to the seismic forces. The design lateral forces or the design force for base shear are imposed on the structure as per the clauses stated in IS 1893

B. *Response Spectrum Analysis*

Earthquake acceleration show the irregularity of the ground motions, such as acceleration and velocity as a function of time. These ground motion characteristics provide information related to the nature of ground motions. Thus it is necessary, to have such a meaningful data which describes the criteria of design purposes. This meaningful data is provided by the method called response spectrum method. this method can be more efficiently defined as a graphic representation of maximum responses of damped single degree of freedom (SDOF), in which the mass spring system is continuously varying with natural frequencies as well as natural periods to a given ground motion characteristics.

VI. Objectives

The main objectives are as follows

- To understand the fundamentals as well as the basic terminology of the earthquake forces.
- To understand the behavior of ground motions with respect to the structural behavior on the basis of characteristics such as frequencies and time period of vibrations.
- To familiarize with the design procedure and codes adapted, according to the nature of earthquake forces.
- Discuss the various aspects and their proper evaluation of various risks occur due to earthquake.
- To adopt the method which can able to analyze, and helps in managing destruction caused due to earthquake.

VII. Problem Formulation

A. *Uncertainty or Randomness in Seismic Design*

The largest uncertainty involved in the seismic design of structure are associated with the prediction of the potential of the earthquake , that may affect a specific location on earth, any time with fixed period and their characteristics.

- Duration of earthquake
- Frequency of p-waves and s-waves
- Magnitude and intensity of earthquake
- Maximum acceleration and ground motion characteristics
- Types and nature of waves
- Location of epicenter and its focus

B. *Randomness in Capacity and Demand Uncertainity in Demand*

There are various unavoidable sources of uncertainty occurs in the expected demands on a structure. These sources of uncertainty include:

- Seismology.
- Ground motion characteristics
- Structural characteristics
- Modeling
- Structural Analysis Method

C. *Uncertainity in Capacity*

In recent years, strength of structure is calibrated in terms of capacity. However, the previous studies and research has proved that, capacity of a structure is not only a function of strength of bearing loads and forces but also to proper dissipation of energy to nearby members without failure. Thus it is however difficult to finalize or calculate the overall capacity of a building or structure against these types of forces , which overall affects the design strength and load calculation , which is going to imposed on the structure. Thus uncertainty in capacity of structure include following difficulties

- Composite action of joints
- Connection between various structural members
- Proportioning of ductile elements in structure
- Members to serve for structural behavior as well as architectural importance.

VIII. Conclusion

The structure should be well analyzed for properly resisting those forces due to earthquake without failure. There are various techniques available and documented in various design standards. But the most effective technique should be one which effectively detects the various characteristics of seismic forces associated with the ground motion characteristics and the nature of those forces when imposed on the structure. Also unconditionally they have easy constructability and feasible in cost of construction

References

[1] Kumar, S. L., Research Paper published at the PEC, 1933.
[2] 2. “ Study on Seismic Capabilities of Dhajji-Dewari Frames” M A Dar, J Raju, A.R Dar and A H Shah, (AARCV) 2012 at India (Proceedings of International Conference on Advances in Architecture and Civil Engineering (AARCV 2012, 21st -23rd June 2012, Paper ID SAM206, vol 1)) (ISBN 978-93-82338-01-7)
[3] Coull, Alex, Smith, Bryan trafford, Analysis and design, Design of tall structures.
[4] Taranath,S.B , CRC press , Taylor and francis group, design of tall structures

[5] Jain, S. K, paper published on CURRENT SCIENCE, VOL. 89, NO. 9, IIT Kanpur , Department of Civil Engineering