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Seismic Resistant Design of high rise Structures with Passive Energy Dissipation Devices by software approach

Payal S. Patel[1],Prof. Gunvant Solanki [2],

[1] *PG student of civil engineering department, CGPIT maliba college bardoli*
[2] *Prof. At civil engineering department,CGPIT maliba College bardoli*

Abstract — *Amongst the natural hazards, earthquakes have the potential for causing the greatest damages. Since earthquake forces are random in nature & unpredictable, the engineering tools needs to be sharpened for analysing structures under the action of these forces.*

In recent years, serious efforts have been undertaken to develop the concept of energy dissipation or supplemental damping into a workable technology, and a number of these devices have been installed in structures throughout the world. The seismic performance and effectiveness of the damper system could be mainly affected by the distributed locations and damping capacities. Seismic Dampers are used in place of structural elements, like diagonal braces, for controlling seismic damage in structures. It partly absorbs the seismic energy and reduces the motion of buildings.

This study investigates the influence of mechanical control on structural systems through strategically applying reliable dampers that can modulate the response of building. SAP2000 nonlinear time history analysis program was applied to investigate the effects on building such as normalized base shear, tip displacement, normalized acceleration and energy dissipation of damper element by varying different important parameters namely Earthquake time histories, location of dampers, damping coefficient, damper stiffness, no of story of building. Comparison study is also presented between building installed with dampers, building installed with diagonal bracing, combination of both and simple building to show importance of damping system for reduction of seismic quantities. Finally, the building installed with damping system is very effective and reliable solution to reduce very vital seismic quantities such as base shear, floor displacement, and floor acceleration and also mitigate architectural requirement which cannot be satisfied by shear walls.

Keywords-*Structural control system ,passive energy dissipation, dampers and bracings, SAP2000*

I. INTRODUCTION

1.1 BACKGROUND OF STUDY

Earthquakes are one of nature's greatest hazards to life on this planet and have destroyed countless cities and villages on virtually every continent. They are one of man's most feared natural phenomena due to major earthquakes producing almost instantaneous destruction of buildings and other structures. Additionally, the damage caused by earthquakes is almost entirely associated with man made structures. As in the cases of landslides, earthquakes also cause death by the damage they induce in structures such as buildings, dams, bridges and other works of man. Unfortunately many of earthquakes give very little or no warning before occurring.
The main objective of Structural engineering field is to design and construct the safe and stable structures. Various types of structural control technologies have been developed to solve the safety and functional problems for structures under the excitation of external force. With current design procedures, the structures are expected to suffer significant damage but no collapse if the earthquake scenario that was considered for its design occurs. Although this philosophy has been the standard for many decades, new design procedures and novel devices are changing the traditional approach. An example of the new procedures is the one known as performance based design. This methodology will provide the structural engineer with the tools to predetermine the amount of damage that the user is willing to tolerate and design the structure accordingly.
Structural control for seismic loads is a rapidly expanding field and the family of control systems, also known as earthquake protective systems, now embraces passive, active and hybrid systems. Applications to buildings, bridges and industrial plant have been made in many of the seismically active countries of the world. Structural control provides an alternative to conventional design methods, which are based on ductile (yielding) response. In many applications, elastic performance during large earthquake events is economically feasible and the methodology permits performance-based design criteria, now required in many modern seismic design codes, to be satisfied more readily than conventional methods.

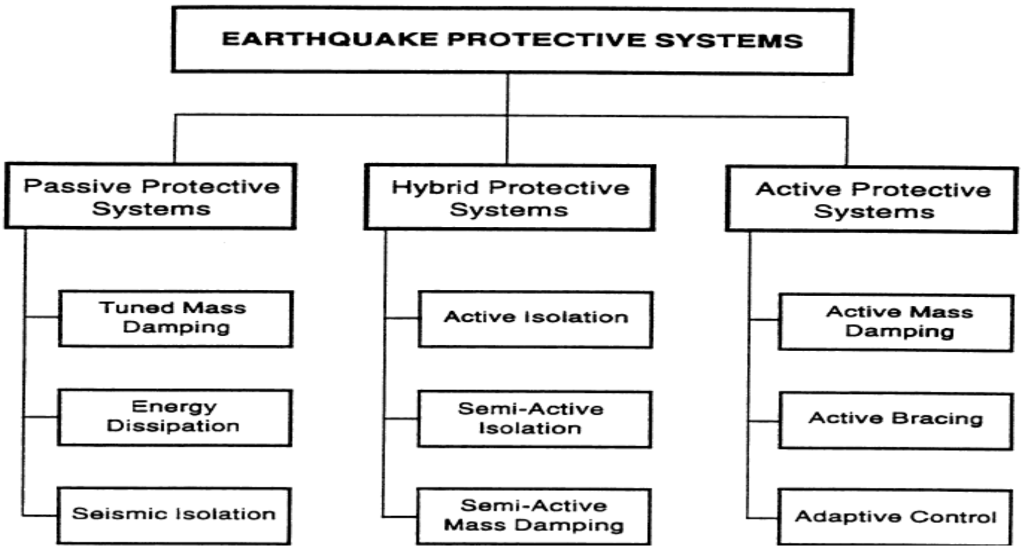

Figure 1.1 earthquake protective systems

As noted above, the family of earthquake protective systems has grown to include passive, active and hybrid (semi-active) systems as shown in Figure 1. Passive systems are perhaps the best known and these include seismic (base) isolation and passive (mechanical) energy dissipation. Certainly isolation is the most developed member of the family at the present time with continuing developments in hardware, applications, design codes and retrofit manuals. But there has also been continuing growth in the passive energy dissipation field with an increasing number of different kinds of dissipation devices being developed, accompanied by technically complex applications such as those found in near-field sites.

In order to achieve satisfactory earthquake response of a structure, three methods can be identified as being practical and efficient. These are**; isolation**, **energy absorption** at plastic hinges **and use of mechanical devices** to provide structural control.

1.2 FUNDAMENTAL OF PASSIVE STRUCTURAL CONTROL

Passive Control Systems

Figure 1.1 shows the Conventional System. The principal function of a passive energy dissipation system is to reduce the inelastic energy dissipation demand on the framing system of a structure. The result is reduced damage to the framing system. A passive control system (Figure 1.2) may be defined as a system which does not require an external power source for operation and utilizes the motion of the structure to develop the control forces. Control forces are developed as a function of the response of the structure at the location of the passive control system. The control system and the structure do not behave as independent dynamic systems but rather interact with each other.

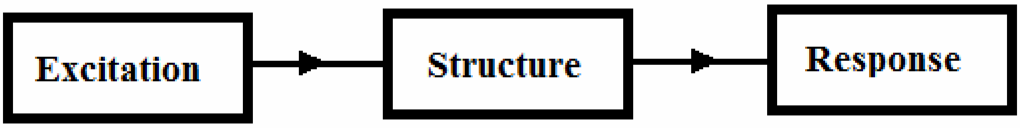

Figure 1.2 conventional system

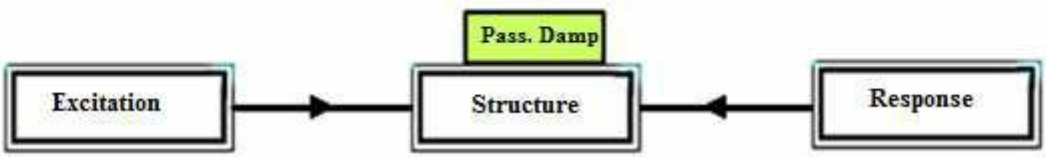

Figure 1.3 passive control system

1.3 PASSIVE ENERGY DISSIPATION SYSTEMS FOR STRUCTURAL DESIGN AND RETROFIT

Historically, a seismic design has been based upon a combination of strength and ductility. For small, frequent seismic disturbances, the structure is expected to remain in the elastic range, with all stresses well below yield levels. However, it is not reasonable to expect that a traditional structure will respond elastically when subjected to a major earthquake. Instead, the design engineer relies upon the inherent ductility of buildings to prevent catastrophic failure, while accepting a certain level of structural and nonstructural damage. This philosophy has led to the development of aseismic design codes featuring lateral force methods and, more recently, inelastic design response spectra. Ultimately, with these approaches, the structure is designed to resist an 'equivalent' static load. Results have been reasonably successful. Even an approximate accounting for lateral effects will almost certainly improve building survivability.

However, by considering the actual dynamic nature of environmental disturbances, more dramatic improvements can be realized. As a result of this dynamical point of view, new and innovative concepts of structural protection have been advanced and are at various stages of development.

Modern structural protective systems can be divided into three major groups:

- Seismic Isolation
  - i. Elastomeric Bearings
  - ii. Lead Rubber Bearings
  - iii. Combined Elastomeric and
  - iv. Sliding Bearings Sliding Friction
  - v. Pendulum Systems Sliding Bearings with Restoring Force
- Passive Energy Dissipation
  - i. Metallic Dampers
  - ii. Friction Dampers
  - iii. Viscoelastic Solid Dampers
  - iv. Viscoelastic or Viscous Fluid Dampers
  - v. Tuned Mass Dampers Tuned Liquid Dampers Preface i x
- Semi-active and Active Systems
  - i. Active Bracing Systems
  - ii. Active Mass Dampers Variable Stiffness and
  - iii. Damping Systems Smart Materials

1.4 damping system

In recent years damping devices have been developed in order to reduce effectively the seismic response of structures subjected to earthquake excitation. The usefulness of the devices is a function of where they are located in the structure, when incorporated into a structure these devices can substantially increase the costs, then optimization of number and location of dampers is convenient. However, little attention has been paid to evaluating the influence of the number and placement of dampers on dynamic response, although a significant amount of experimental and analytical research has been done regarding the applicability of damping devices.

The objective of utilizing dampers is to reduce structure responses and to mitigate damage or collapse of structures from severe earthquakes by participating energy dissipations. As a successful application, installation of dampers in an existing building structure, which does not possess sufficient lateral stiffness, enables control of the story drift within the required limitation and maintains its desired functions during an earthquake event. Since the first application of dampers in structural engineering took place in 1960s, abundant research work has been conducted to study the mechanisms of dampers and the behavior of damped structures. With the invention of different types of damping devices, improvement of modeling techniques and development of new computational methodologies, use of dampers has become a mature technology in designing of new structures and retrofitting of existing facilities.

A flexible structural element of the damping system that dissipates energy due to relative motion of each end of the device . Damping devices include all pins, bolts, gusset plates, brace extensions, and other components required to connect damping devices to the other elements of the structure. Damping devices may be classified as either displacement dependent or velocity dependent, or a combination thereof, and may be configured to act in either a linear or nonlinear manner.

1.5 STRUCTURAL PERFORMANCE OF DAMPER

Under the action of horizontal wind forces the building acts as a braced frame, with the shear force resisted by the diagonals and the overall bending by the cantilever action of the structure, the members being subjected to predominantly axial forces. (Frame action is used for gravity loads). Forces to cause joints to slip will be chosen such that slipping is improbable, and the entire system remains elastic, for the expected wind conditions, and minor earthquakes. When the ground acceleration reaches the initiating design value, slipping occurs, energy is dissipated, the building motion ceases to be elastic and the natural frequency changes, thereby eliminating the possibility of resonance. As the intensity of the ground motion increases, more joints slip and the travel in the joints increases, until the limiting design earthquake is reached, at which point the distortion of the frame is just short of that which would cause it to yield. It is to be observed that in a rigid frame relying on yielding to dissipate energy, the building must have deflected to the point where yielding occurs before damping takes effect; with friction dampers all the required energy dissipation has taken place before the frame yields. This represents the condition for the projected maximum earthquake. For more intense ground motion the rigid frame will yield, adding to the rate of energy dissipation. Collapse is difficult to predict, because the structure continues to be an effectively braced frame. The limit may be due to fracture at a yield hinge, buckling of a column, or instability due to the P-δ effect. To reach this extreme case requires that sufficient travel is allowed in the slip joints to permit the development of the fully plastic structural system, otherwise failure in a diagonal will occur due to the impact when the available slip travel is exceeded.

II. AIM AND OBJECTIVES

In conventional seismic design, acceptable performance of a structure during earthquake excitation is based on the lateral force resisting system being able to absorb and dissipate energy in a stable manner for a large number of cycles . Conventional design approach is not applicable in situations when a structure must remain functional after earthquake. In such cases, the structure must be designed with sufficient strength to minimize the inelastic deformations, however, this approach is very expensive. Furthermore, in such structures, special precautions need to be taken in safeguarding against damage of important secondary system, which are needed for continuing serviceability. Over the past couple of decades the astounding developments in alternate design strategies have been made, which incorporate, earthquake protective systems in the structure.
The main aim of this project is to generate fundamental research information on the seismic performance of building structural systems having passive damping devices installed within shear walls.

Objectives of study

Study the behavior of high rise building by providing passive energy dissipation devices.
To understand the behavior of high rise building like displacement and base shear.
Compare the result of displacement and base shear of high rise building with damper, without dampers and with bracing systems obtain by SAP2000.

III. LITERATURE RIVEW

[1]SEISMIC RESPONSE CONTROL OF A BUILDING INSTALLED WITH PASSIVE DAMPERS[1]

Seismic response control using passive dampers is most cost effective, satisfied the architectural requirement of opening and recent technique to control the vibrations of structures arising due to dynamic loading. This study investigates the influence of mechanical control on structural systems through strategically applying reliable dampers that can modulate the response of building. SAP2000 nonlinear time history analysis program was applied to investigate the effects on building such as normalized base shear, tip displacement, normalized acceleration and energy dissipation of damper element by varying different important parameters namely Earthquake time histories, location of dampers, damping coefficient, damper stiffness, no of story of building. Comparison study is also presented between building installed with dampers, building installed with diagonal bracing, combination of both and simple building to show importance of damping system for reduction of seismic quantities. Finally, the building installed with damping system is very effective and reliable solution to reduce very vital seismic quantities such as base shear, floor displacement, and floor acceleration and also mitigate architectural requirement which cannot be satisfied by shear walls.

[2] ENERGY DISSIPATION SYSTEMS FOR BUILDINGS[2]

This paper develops a detailed study of the seismic performance of a tall building when an energy dissipation system is adopted. This dissipation solution consists on several viscous dampers placed diagonally between all structure’s floors. The main purpose of this paper is to test different ways to distribute a set of dampers along the height of the building, to improve the seismic response of the structure.

[3]SEISMIC ENERGY DISSIPATION OF A BUILDING USING FRICTION DAMPER[3]

Conventional methods of seismic rehabilitation with concrete shear walls or steel bracing are not considered suitable for some buildings as upgrades with these methods would have required expensive and time consuming foundation work. Supplemental damping in conjunction with appropriate stiffness offered an innovative and attractive solution for the seismic rehabilitation of such structures extensive use of friction joints in new and retrofitted buildings has demonstrated the economic advantages of this form of device to control the amplitude of building motion due to seismic action. The paper highlights in particular the use of friction devices in conjunction with rigid structural frames, either steel or concrete. The introduction of supplemental damping provided by friction devices dramatically reduces forces on structure, amplitude of vibration and floor acceleration.

[4]SEISMIC RESISTANT DESIGN OF BUILDINGS WITH VELOCITY DEPENDENCE PASSIVE ENERGY DISSIPATION DEVICES[4]

This research collect the passive energy dissipation devices design parameters, and using case of passive energy dissipation devices in Taiwan . To use ETABS computer program to analysis the effects of seismic response control of building structure retrofit by different kind of passive energy dissipation devices, include the displacement dependent devices(LYS-Low yielding steel) the velocity dependent devices(VED-viscous elastic damper) and the velocity dependent devices(FVD-fluid viscous damper.

IV. SCOPE OF WORK

In this study high rise building of 15- storey and 20- storey is to be analyzed in software SAP2000 . The study will investigate the effects on building such as normalized base shear, tip displacement, normalized acceleration and energy dissipation of damper element by varying different important parameters namely Earthquake time histories, location of dampers, damping coefficient, damper stiffness, no of story of building. Comparison study is also presented between building installed with dampers, building installed with diagonal bracing, combination of both and simple building to show importance of damping system for reduction of seismic quantities. Finally, the building installed with damping system is very effective and reliable solution to reduce very vital seismic quantities such as base shear, floor displacement, and floor acceleration and also mitigate architectural requirement which cannot be satisfied by shear walls.

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