SEISMIC RESPONSE OF MULTI-STORIED BUILDINGS WITH DIFFERENT VIBRATION CONTROL TECHNIQUES-A REVIEW

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Abstract - *Structural vibration control has become a workable technology to protect infrastructure against wind and earthquake loads. Earthquake is the frequently occurring vibration of earth surface which results in damaging of structures and causes loss of lives. Performance-based seismic design has brought about new technological advances and introduced innovative approaches to constructing seismic-resistant buildings. To minimize the damage due to earthquake on the structures active and passive vibration control methods are there. Different passive vibration control methods adopted in practice are reviewed in this paper. Buildings with base isolators, with shear walls and tunnel form type buildings are considered.*

Key Words: Vibration control, base isolator, shear wall, tunnel form type buildings.

1. INTRODUCTION

Most of the world's population lives in seismic hazardous regions. Earthquakes are shaking of ground which is caused by rapid release of strain energy stored in the earth's crust. Earthquakes are the natural calamity which causes immense damages to the man-made structures on the earth and also causes a great loss of life. Multi-storeyed buildings, if not designed properly for lateral forces, may lead to complete collapse and hence loss of property and life. When an earthquake strikes, the structure moves laterally and vertically caused by the surface ground motion induced by the seismic waves. Typically the lateral motion is much greater than the vertical motion. The mass, size and configuration of a building or a structure indicate how the structure will respond to an earthquake event. Any structure is to be designed to hold out against the lateral forces induced on to it by the earthquake ground motion. To achieve this, the lateral load resisting systems need to resist all these lateral forces coming on to the structure during an earthquake event. To perform well during an earthquake event, a building must have the four main hallmarks that are simple-regular configuration, proper lateral strength, stiffness and ductility.

Conventional design approach is not applicable in situations when a structure must remain functional after earthquake .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 vibration control techniques can be divided in to active and passive methods.This paper describes the passive vibration control methods attempted in buildings.

2. SEISMIC CONTROL METHODS

The structural vibrations produced by earthquake or wind loads can be controlled by various fundamental means. These conceptual approaches include modifying damping, masses or shape, rigidities, and by providing passive or active counter forces. Some methods of structural control have been used successfully. In recent years, considerable attention has been paid to research and development of structural control systems. A large numbers of techniques have been tried to produce better control against wind and earthquake excitation. These can be classified into four broad categories: passive control, active control, semi-active control and hybrid control. Passive control system is one that does not require an external power source. All forces imposed by passive control devices develop as direct responses to the motion of the structure. Hence, sum of the energy of both the device and the primary system will be constant. Active control assures improved response to passive systems at the cost of energy and more complex systems. Active control system has been as any control system in which an external power source is required to provide additional forces to the structure in a prescribed manner, by the use of actuators. The signals are sent to control the actuators and determine the feedback from the sensors provided on or through the structure. Due to the presence of an external power source, the force applied may either add or dissipate energy from the structure. Semi active control performed on the benefits of active control and the reliability of passive control, which makes it a much more appealing alternative to traditional control scheme in civil structures. Semi active control systems act on the same principle of active control system but they differ in that their external energy requirement is smaller. Hybrid systems act on the combined use of passive and active control system.

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For example, a base isolated structure which is equipped with actuator which actively controls the enhancement of its performance. Earthquake on the structures is reduced by using base isolators, shear walls, dampers etc and minimize the damage of structure. Different passive vibration control methods are discussed here. They are base isolators, frames with shear wall and tunnel form type buildings.

2.1Base Isolation

The protection of building from the damaging effects of an earthquake by introducing some type of support that isolates it from the shaking ground is called Base Isolation. It is a passive control device that is installed between the base of the building and the foundation. Seismic isolation consists essentially of the installation of mechanisms which decouple the structures and their contents from potentially damaging earthquake-induced ground motions. The base isolation system introduces a layer of low lateral stiffness between the foundation and the structure. This isolation layer of the structure increases the natural period which is much longer than its fixed base natural period. This lengthening of the period can reduce the pseudo-acceleration and hence the earthquake induced forces in the structure.

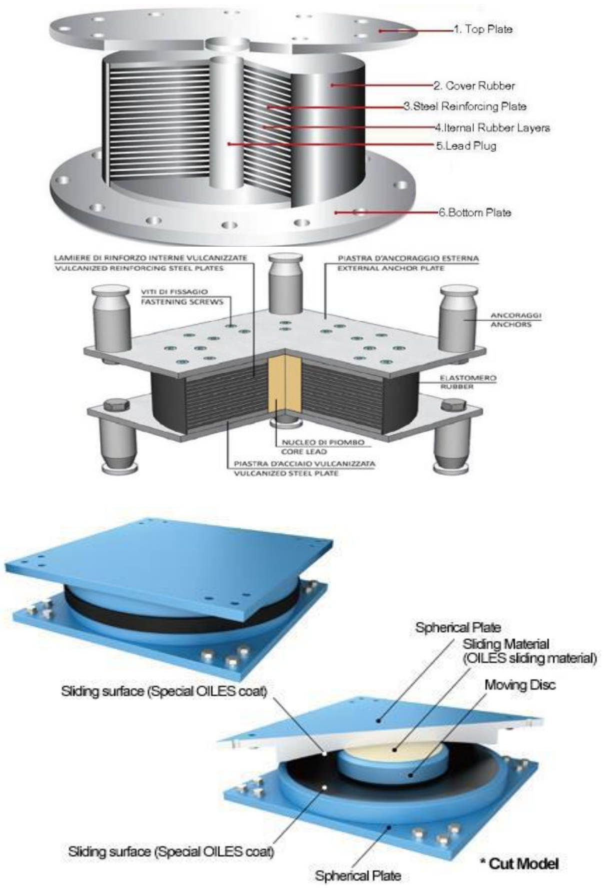

Fig. 1Elastomeric systems and Sliding Type Base Isolator

2.1.1 Types of Seismic Isolation Bearings
Isolation systems can be classified into two different categories
i) Elastomeric systems(Figure 1)

- Low –Damping Rubber Bearing.
- High-Damping Rubber Bearing.
- Lead –Rubber Bearing.

ii) Sliding type isolating systems(Figure 1)

- Isolator without re-centering capacity (Flat sliding Bearing).
- Isolator with re-centering capacity (Spherical Sliding Bearing).

The base isolation technique has been used successfully worldwide in many buildings for earthquake protection. A seismic base isolation system is typically placed at the foundation of a structure. By means of its energy absorption capability and flexibility, the isolation system partially reflects and partially absorbs some of the earthquake input energy before this energy transmitted to the structure. It comprises of basically inducing a mechanism which decouples the sub-structure from the super structure resulting in decreased response of the structure.

2.2 Shear Wall

Reinforced concrete (RC) buildings often have vertical plate-like RC walls along with slab, beam and column called Shear Walls in addition to slabs, beams and columns. Wind and seismic loads are the most common loads that shear walls are designed to carry. These walls generally start at foundation level and are continuous throughout the building height. Shear walls provide large stiffness and strength to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings (Figure 2). They could be placed symmetrically along one or both directions in plan. Shear walls are more effective when located along exterior perimeter of the building – such a layout increases resistance of the building to twisting. Door or window openings can be provided in shear walls, but their size must be small to ensure least interruption to force flow through walls. Moreover, openings should be symmetrically located. RC shear walls have high stiffness. Shear wall acts as a deep and slender cantilever. For efficient performance of building position of shear wall in an ideal location is very important. The shear wall can be either open section or closed sections around stair cores and elevators. Shear walls are oblong in cross-section, i.e., one dimension of the cross-section is much larger than the other. While rectangular cross-section is common, L- and U-shaped sections are also used (Figure 3).

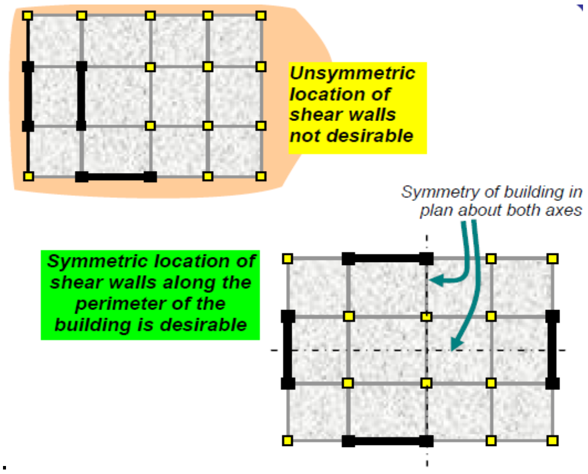

Fig 2 Location of shear wall

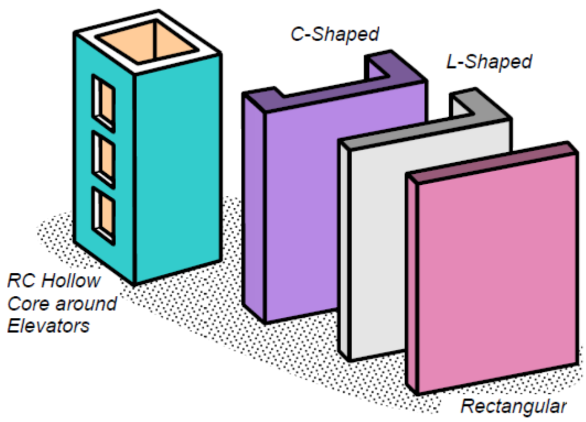

Fig 3 Different geometries of shear wall

Thin-walled hollow RC shafts around the elevator core of buildings also act as shear walls, and should be taken advantage of to resist earthquake forces. If shear walls are provided along only one direction, a proper grid of beams and columns in the vertical plane which is called as the moment-resistant frame must be provided along the other direction to resist strong earthquake effects.

2.3 Tunnel form type buildings

Multi-story RC (reinforced concrete) tunnel form buildings have been increasingly employed for mass construction industry in many countries. Tunnel form is a formwork system that allows the contractor to cast walls and slabs in one operation in a daily cycle(Figure 4).This system is very much attractive for the medium to high-rise buildings with repetitive plans due to good performance during past earthquake, industrialized modular construction technique, low cost and also saving in construction time. Reinforced concrete shear walls (RCSW) dominant buildings are constructed using a tunnel-form technique for many reasons. It is very attractive for a medium to high-rise buildings with repetitive plans. Also it is used for the construction of multi-unit housing, single-family residences, hotels, townhouses, military housing, prisons, and some warehouse applications. The simultaneous casting of walls and slabs results in monolithic structures unlike any other frame-type RC buildings. RCSW are used in multi-story buildings due to their good performance during strong seismic ground motions, because they provide good lateral stability and act as vertical cantilevers in resisting horizontal external forces. Also they provide nearly optimum means of achieving stiffness, strength and ductility. These three objectives are the basic criteria that the structure should satisfy. During construction, walls and slabs, having almost the same thickness, are cast in a single operation. Tunnel form buildings gain increased seismic performance by retarding plastic hinge formations at the most critical locations, such as slab–wall connections and around wall openings. The main components of this system are flat plate slabs and walls. Walls in tunnel form buildings have two functions: resisting lateral loads as well as carrying vertical loads. Tunnel form buildings diverge from other conventional RC (reinforced concrete) structures due to lack of beams and columns in their structural components. In these buildings, all of the vertical load carrying members are made of shear walls and floor system. In addition, in tunnel form buildings, slabs and walls are made of thin concrete plates and rebars should be placed in one layer.

Fig. 4 Tunnel form construction

3 LITERATURE REVIEW

Various literature reviewed on vibration control of structures are presented in this section. A number of works have been performed on seismic vibration control of structures. A review of literatures is presented in brief, summarizing the work done recently by different scholars and researchers.

Balkaya and Kalkan (2003) examined the applicability and accuracy of inelastic pushover analysis in predicting the seismic response of tunnel form building structures. The contribution of slab-wall interaction and transverse walls during the 3D action, the effects of 3D and 2D modeling on the capacity-demand relation, diagram flexibility, torsion and damping effects were investigated. 2-story and 5-story building models having similar plan and sections were analyzed by utilizing the 3D and 2D finite element models developed by iso parametric shell element. In general, total resistance capacities of the three dimensionally analyzed structures were observed to be higher than that of two dimensionally modeled cases.

Tavafoghi.A and Eshghi.S(2008) investigated the seismic behavior of tunnel form concrete building structures. The fundamental period and the proposed behavior factor (R factor) are used to compute the design base shear of a structure. This study showed that the building height can be considered as the main parameter in estimating formulas for fundamental period of tunnel form buildings. The orders of the first three modes of structures remain unchanged for building with different heights.

Gomase O.P and Bakre S.V (2011) studied performance of non-linear elastomeric base-isolated building structure. The analysis of fixed base and base isolated 3-D four storey building is performed. An exhaustive study has been performed on the performance of base isolated structures. The behavior of building structure resting on elastomeric bearing is compared with fixed base structure under maximum capable earthquake. Seismic base isolation can reduce the seismic effects and therefore floor accelerations, inter-story drifts, and base shear by lengthening the natural period of vibration of a structure via use of rubber isolation pads between the foundation and the columns. However, in case the deformation capacity of the isolators exceeded, isolators may rupture or buckle. Uniform Building Code-97, is widely used in design of base isolation systems which contains provisions accounting for near-fault earthquake effects.

Eshghi.S and Tavafoghi.A(2012) conducted an experimental study on seismic behaviour of tunnel form building structures. Experimental study was carried out to decrease the uncertainty of linear and nonlinear behaviour of the tunnel form buildings. The experimental study consists of testing the two three-story 1/5-scale of the tunnel form building. Some of forced vibration tests were done and both models were subjected to quasi-static cyclic lateral loading. The results were used to estimate the period of mode shape and to evaluate the fundamental period of cracked structures. The specimens had brittle failure mechanism that occurred in the shear walls above the foundation connections. The rebars of shear walls ruptured suddenly and crushing of the concrete were not observed.

Haider S et al (2014) examined the effect of shear walls on seismically isolated buildings of variable geometric configurations. Multi-story hypothetical reinforced concrete buildings of variable geometric configurations (vertically irregular, symmetrical, horizontally irregular); with and without shear walls; base isolated via high damping rubber bearing and friction pendulum systems, are analyzed using the finite element method under seismic load function. The results showed that, inclusion of shear walls has minor effects on the maximum acceleration responses and total base shear whereas, a considerable reduction in the maximum relative displacement is reported. The inclusion of shear walls has negligible effect on total base shear and maximum acceleration of the isolated buildings.

BinuSukumar et al (2015)carried out Non-Linear Analysis of Frames with and without Structural Wall Systems. A typical low rise building is considered with two types of modeling for the structural wall, one with equivalent column element and other with multi-layer shell element . The results obtained were compared with a normal frame building designed to with stand lateral loads without shear wall. The building was modeled and analysed using SAP2000 (V-17.3). From the analysis, it was observed the pushover curves observed for equivalent column elements and multi-layered shell element are almost equal. Hence, the modelling of structural wall as a column element can predict the behaviour similar to multi-layered shell element. In comparison with LLRS lateral load resisting system building, building with structural walls can with stand lateral loads without much deformation. The monotonic pushover curves for the shear wall modelled using multi-layered shell element and by equivalent column were almost similar. Any one of the method can be used for modeling the shear wall.

Anusha R Reddy and V Ramesh (2015) gives details about the seismic analysis of base isolated building in RC framed structures. Two building's are considered first structure is G+13 storey building and second is G+5 storey building which is analyzed in E TABS 13.2.1 software. Lead rubber isolator are provided to both the structures and then time history analysis and linear response spectrum are carried out for both fixed base and base isolated buildings under zone v and soil type II i.e. medium soil (according to IS 1893(part 1):2002). The mode period, acceleration, base shear, and displacement are compared for response spectrum and time history analysis for fixed base and base isolated buildings. It is investigated that the mode period is increased after providing rubber isolator due to the flexible property of the isolator. When compared with fixed base structure, the base shear is reduced in base isolated structures, thus the response of building is good in base isolated structures than fixed base structures.

JunwonSeo et al (2015) studied the seismic performance of multistory reinforced concrete moment resisting frame structure with shear walls. This paper is intended to evaluate the seismic performance of a G+12 story reinforced concrete moment-resisting frame structure with shear walls using 3D finite element models according to some seismic design regulations. Response spectrum analysis and nonlinear time-history analysis were used. Seismic fragility curves for each floor of the structure were generated using the ratios from the time history analysis with the FEMA guideline so as to evaluate their seismic vulnerability. The maximum displacements for both response spectrum and nonlinear time history analyses increased along the height of structure as the story level of the structure was higher. The nonlinear time history analysis provided 28.1% and 54.0% greater values in maximum displacements and drift ratios compared to those for the response spectra analysis.

Syed Farroqh Anwar et al (2016) conducted a study on soil structure interaction and base isolated system for seismic performance of structures resting on different types of soils. This aims to determine the significance of using Base Isolation as a technique to withstand the seismic forces. The comparison is mainly done between structures with soil structure interaction effects and base isolated structures. The modeling and analysis was done using computer program SAP2000 v18. The method of analysis was Fast Nonlinear Analysis. There are 18 models which are analyzed in which there are symmetric and asymmetric in plan models, which are modeled and analyzed as fixed base models, models with the consideration of soil structure interaction, and models with base isolation. These models are assumed to be resting on three soil types namely stiff clay, limestone, and loose sand. All the models are G+13 storey. Considering soil structure interaction for structures resting on medium (stiff clay) and soft soils (loose sand) is more significant when compared to structures resting on hard soil (limestone) as there is not much difference in the response of structures resting on hard soil with and without the consideration of soil structure interaction. Base isolation system is found to be most effective for structures resting on hard soil (limestone) when compared to structures resting on medium soil (stiff clay) and soft soil (loose sand).

4 SUMMARY AND CONCLUSION

Earthquakes can create serious damage to structures. Structures already built are vulnerable to future earthquakes. From the literatures it is found that many of them explains the comparative study of building with and without isolator for different number of stories. Linear response spectrum and time history analysis are carried out for both fixed base and base isolated buildings. Relative storey displacement &storey drift has been reduced in the case of isolated buildings. Some literatures show the comparison of buildings with and without shear wall and also they examined the effect of shear walls on seismically isolated buildings of variable geometric configurations. Seismic behavioral and experimental studies of tunnel form concrete building structures are also carried out. The essence of experimental and analytical studies available in literature sheds light on the need for further comparative and parametric studies on the tunnel form buildings. From the literatures it is found that there is no comparative study between the tunnel form type building with the conventional building with base isolated systems and building with shear walls. Further detailed studies are required for better understanding of seismic performance of these buildings.

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