RESPONSE SPECTRUM ANALYSIS OF MULTI STOREYED BASE-ISOLATED BUILDING

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ABSTRACT

The basic idea of seismic isolation is based on reduction of the earthquake induced inertia loads by shifting the fundamental period of the structure out of dangerous resonance range, and concentration of the deformation and energy dissipation demands at the isolation and energy dissipation systems, which are design for this purpose. In this paper, after a brief introduction, the response spectrum to the earthquake resistant structure is described. As a numerical example, a fourteen storey structure analyzed with three different seismic protection alternatives as fixed base, rubber bearing, friction pendulum bearing. In determining the specifications of isolators, such device features are taken into consideration, which would transfer minimum effects on to the structure as tested by numerous experiments on the basis of the criteria, including base and storey shear forces, storey and relative storey drifts while the isolators would undergo reasonable displacements. Nevertheless, such analysis could not provide full optimization; the main objective here is to make a comparison between the seismic isolation and fixed based building, rather than comparing the seismic isolation alternatives within themselves. In the analysis, total base shear forces, storey shear forces and relative storey drifts are compared and results are discussed.

KEYWORDS: Base isolator, Seismic analysis, Base shear, Displacement, Relative Drift.

INTRODUCTION

Engineers and architects have been carrying out studies for over one hundred years to find applicable methods to reduce the response given to the ground motions by the structures. Seismic isolation systems are one of the design strategies applied to increase the earthquake resistance of the structures. In simple words, seismic isolation is a process to decrease the response shown to the impacts such as earthquake by separating the superstructure from the ground. In this way, the period and the damping ratio of the structure isolated from the ground are increased. This, in turn, reduces the earthquake forces on the structure. The increase in damping ratio is a natural characteristic for most isolators, and if desired, additional energy dissipating devices may also be installed on to the structure.
Storey displacements in the structure together with the accelerations shall be reduced significantly. While this reduction in the accelerations protects the non-structural elements from the acceleration originated damages, the reduction in the storey displacements shall allow both the structural and non-structural elements survive the earthquake without any damage or with little damage.

Specific seismic systems such as isolators should be evaluated during the design stage of the structure, and if deemed necessary, must be selected in conformity with the targets stipulated for the structure. The stipulated target is the degree of the performance expected from the structure subjected to design earthquake. As the earthquake demand and the expected performance increase, the application of the seismic systems becomes more attractive and feasible.

BASE ISOLATION CONCEPT

The concept of base isolation is to isolate the building from the ground in such a way that earthquake motion are not transmitted up through the building or at least greatly reduced.

If the building is made to rest on flexible pads that offer resistant against lateral movement, then some effect of the ground shaking will be transferred to the building above. If the building flexible pads are properly chosen the force induced by ground shaking can be a few times smaller than that experienced by the building build directly on ground.

TYPES OF BASE ISOLATORS

The most common types of base isolators used in buildings are

1. Laminated rubber bearing.
2. High damping rubber bearing.
3. Lead rubber bearing.
4. Friction pendulum system bearing.
Laminated Rubber Bearing

It is composed of alternating layers of rubber that provide flexibility and steel reinforcing plates that provide vertical load carrying capacity. At the top and bottom of this layer are steel laminated plates that distribute the vertical loads and transfer the shear force to the internal rubber layer. On the top and bottom of the steel laminated plates is a rubber cover that provides protection for the steel laminated plates.

High Damping Rubber Bearing

It is similar to elastomeric bearings where the elastomer used (either natural or synthetic rubber) provides a significant amount of damping, as shown in fig. (a & b).

Lead Rubber Bearing

It is a form of a lead plug force-fitted into a pre-formed hole in a low damping elastomeric bearing as shown in fig. The lead core provides rigidity under service loads and energy dissipation under a high lateral loads.

Friction Pendulum Sliding (FPS) Bearing

Figure. High damping rubber bearing, (a) Geometry and (b) Deformation due to loading

Figure. Lead rubber bearing, (a) Geometry and (b) Deformation due to loading.
Although a number of curve shapes are possible, the only curve sliding has been extensively used in which the sliding surface is spherical in a shape, termed the friction pendulum system. The FPS bearing allows the supported structure to return to its original position, rather than a flat sliding surface, thereby conquering the problem of recentering.

**EARTHQUAKE RESPONSE ANALYSIS FOR VARIOUS ISOLATION TECHNIQUES**

Three-dimensional nonlinear response spectrum analysis is carried out with the SAP2000 program, on the basis of various seismic isolation alternatives of a structure and comparison of the results are given place to in the application example taken into consideration in this study. In this context, a fourteen-storey building model shown in Figure 2 is taken into consideration. The model building is analyzed in the nonlinear response spectrum both for fixed base situation and also by using various seismic isolation and earthquake protection alternatives such as rubber bearing, friction pendulum bearing. Total base shear forces, maximum storey shear forces in the middle column, and the maximum relative storey drifts in the middle column are taken into consideration as the comparison criteria.

The building sits on a 36x12 m² area. The height is 3m; the thickness of the floor is 15cm on all storeys. The column cross-section used in the structure is 50x50cm, beam cross-section 70x40cm, and the live load is defined as 3kN/m² for the floors on all the storeys.

The characteristics of the isolators used are selected from the available or producible products in the light of the information obtained from the manufacturers. While deciding about the isolator characteristics; the characteristics of the device, which subject the structure to minimal effects, while themselves are displacing within reasonable scales, with the criteria such as the base shear forces, storey shear forces, relative story drifts, are selected. Nevertheless, it must be born in mind that this is not a proper optimization, and a judgement may not be passed about these systems superiority over each other by just looking at the results. The real objective of the obtained results is not the comparison of the seismic isolation alternatives, but their comparison with the classical fixed base building shown in the first alternative.
In the nonlinear analysis carried out, the 1. mode period of the structure is found to be 1.363 sec. in x direction and the 2. mode period as 1.27 sec. in y direction. In the analysis, the damping ratio for all modes is assumed to be 0.05.
Alternative with Rubber Bearing

The seismic isolators in the system are defined as Nlink components 0.5m in length placed between the fixed base and the columns (Figure 3). The parameters selected to define the utilized isolators in the SAP2000 program are as follows.

Nonlinear Link Type: Rubber, U1 Linear Effective Stiffness: 3500000 KN/m, U2 and U3 Linear Effective Stiffness: 1866.67 KN/m, U2 and U3 Nonlinear Stiffness: 5833.33 KN/m, U2 and U3 Yield Strength: 186.67 KN, U2 and U3 Post Yield Stiffness Ratio: 0.1

All the values remaining outside the above indicated parameters are entered as zero. The reason for the effective damping value being entered as zero is its non-functionality in the nonlinear time history analysis. Damping in here occurs with the conversion of hysteresis curve under the influence of seismic loading. The modal damping values for the first 3 mode are assumed to be zero while carrying out the analysis for this damping value not to coincide with the modal damping value. In this way, the structure shall behave as if without damping, and all damping requirements shall be met by the isolators. As the damping capability of the structure, which is approximately 5%, is neglected here, it must be taken into account that the values such as the relative storey drifts are slightly higher than the actual values. In the nonlinear dynamic analysis carried out, the 1. mode period of the structure is found to be 2.44 sec in the x direction and the 2. mode period as 2.400 sec in the y direction.

Alternative with Friction Pendulum Bearing

Friction pendulum isolators are defined as Nlink components 0.5m in length placed between the fixed base and the columns just like in the case of rubber isolators (Figure 3). The parameters selected to define the utilized isolators in the program are as follows.

Nonlinear Link Type: Friction Isolator, U1 Linear Effective Stiffness: 35000000 KN/m, U1 Nonlinear Effective Stiffness: 35000000 KN/m, U2 and U3 Linear Effective Stiffness: 1750 KN/m, U2 and U3 Nonlinear Stiffness: 3500 KN/m, U2 and U3 Friction Coefficient, Slow: 0.03, U2 and U3 Friction Coefficient, Fast: 0.05, U2 and U3 Rate Parameter: 40, U2 and U3 Radius of Sliding Surface: 2.23.

In the nonlinear dynamic analysis carried out; the 1. Mode period of the structure is found to be 2.485 sec in the x direction, and the 2. Mode period is found to be 2.45 sec in the y direction.

LITERATURE REVIEW

U. Akyuz et.al. (2007) have found out from the analysis A Comparative Study for Seismically Isolated different storied buildings. They have taken three symmetric and three nonsymmetrical types of buildings were analyzed by using Static Equivalent Lateral Force, Response Spectrum Analysis and Time History Analysis. A commercial computer package, namely SAP2000, is used for 3D analysis of the structures. The analyses of these isolated buildings were done for different types of soil. Seismic base isolation provisions of the FEMA-273 and IBC2000 have been utilized in the design examples.
A. V. SHOUSHTARI (2010) the purpose of this study is to evaluate the seismic behaviour of tall building structures by friction damper. The finite element modelling technique (SAP2000 Software) is used in this study to learn the behaviour of structure equipped by friction dampers. Three different methods of analyzing (Free vibration, Response spectrum, and Time History analysis) have been done to achieve this purpose.

(Marsono. A., 2009) Response of Tall Building Structures. Tall building is a building in which tallness strongly influence planning, design and use, or a building whose height creates different conditions in the design, construction, and use than those that exist in common buildings of a certain regions. A high-rise building is a complex system that consists structural elements, beams and columns, and also non-structural elements, claddings, floors and partitions that are assembled together by different connection types.

(Amr. S. E. and Luigi. D. S., 2008) response of tall building structures depends only on stiffness, strength and ductility. Stiffness is the ability of a component or an assembly of components to resist deformations when subjected to actions. Strength is the capacity of a component or an assembly of components for load resistance at a given response station. Ductility is the ability of a component or an assembly of components to deform beyond the elastic limit.

CONCLUSIONS

In this section; the results obtained from the analysis are examined within the framework of the previously determined comparison criteria. The natural period of the structure being 1.36 in the fixed base situation is increased to 2.4 sec. in the systems containing base isolators. When the storey shear and relative drift values are examined, it is seen that this value is adequate for the structure being completely removed from the resonance range of the earthquake. The weaker, y direction of the structure subjected to larger force, acceleration and deformation effects even though affected by the relatively weaker component of the earthquake.

The target period for the rubber and friction pendulum systems is selected as 2.4 sec. corresponding to the low spectral acceleration values in the acceleration spectrum in both directions.
Figure 4 Maximum Base Shear – X And Y Directions

Figure 5 Maximum Displacements
Figure 6 Maximum Relative Drifts – X Direction

Figure 7 Maximum Relative Drifts – Y Direction
In the base shear forces, the results of the rubber and friction pendulum alternatives are very close to each other, and they provided approximately 85% reduction in the x direction and 57% reduction in the y direction. This reduction in the forces indicates that the performance of the base isolation under the influence of earthquake is extremely good. When the reduction in the other effects are taken into account, it can be concluded that story isolation may also be considered as a strengthening alternative, as in the case of base isolation, when the characteristics of the structure allow this. It is seen that in all alternatives, apart from the first floor, the relative storey drifts is significantly reduced especially in the fixed-base alternative. This situation indicates that the superstructure exhibits behaviour close to rigid body behaviour in base isolation.

The reason for the reduction appearing low in the first floor is that when the analysis is carried out while the modal damping ratio for all modes is taken as 0.05 in fixed base alternative, the damping ratio is taken as zero for first three modes in all the other alternatives. Thus, in all alternatives, other than the fixed base alternative, the natural damping capability of the structures, which is approximately 5%, is neglected and the damping behaviour is left almost as totally depending on the behaviour of the seismic protection devices. For this reason, it must be known that in reality, with the contribution of the natural damping of the structures, the relative storey drift, and shear force values of the structures are slightly lower than the values given in the table in all the alternatives containing seismic protection devices.

REFERENCES

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