Design of Storey-Isolation System in Multi-Storey Buildings

Luca Zanaica
Earthquake Engineer
University of Patras
Patras, Greece
luca.zanaica@em-a.eu

Luca Zanaica, born 1980, received his Civil Engineering Laurea from the University of Padua in 2005 and his Earthquake Engineering MSc in the EM MEEES framework in 2007. He is Structural Engineer in NET Engineering (Padua, Italy) since 2006.

Summary

Non-structural components are sensitive to large floor accelerations, velocities, and displacements. When a building is subjected to an earthquake ground motion, it can amplify this motion, resulting in Peak Floor Accelerations (PFAs) higher than the Peak Ground Acceleration. A 4-storey reinforced concrete building is designed in accordance with EC8. The building is supposed to have in its interior, at a particular floor level (ideally located in the middle of the considered floor), some special facilities which need to not receive either big accelerations or high relative storey displacements. New types of Lead-Rubber Bearing based storey-isolation systems are here developed, investigating five different facilities isolation locations. The intent is to demonstrate the isolation positive effects on the facilities through non-linear time-history analyses, and to evaluate the global structure effects: PFAs, Peak Floor Displacements (PFDs) and interstorey drift ratios.

Keywords: storey isolation, base isolation, lead-rubber bearing, non-linear time history, reinforced concrete building, response spectrum, peak floor acceleration, peak floor displacement, interstorey drift ratio

1. Introduction

Non-structural components are sensitive to large floor accelerations, velocities, and displacements. When a building is subjected to an earthquake ground motion, the building can amplify this motion, resulting in PFAs higher than the PGA (Peak Ground Acceleration). As a matter of fact, facilities are subjected to these amplified accelerations, which cause severe damage to NSCs. Many problems can occur at lower deformation and acceleration demands than the supporting structure. In view of the importance of protecting the integrity of some special facilities during seismic events, there is a need to carry out additional research studies to develop reliable performance-based design criteria.

This work of research deals with a new type of base isolation application. A 4-storey RC building is designed in accordance with Eurocode 8 provisions [1]. The building is supposed to have in its interior, at a particular floor level, some special facilities that must be absolutely protected during an earthquake to prevent any irreparable damage. These facilities, ideally located in the middle of the considered floor, must not receive either big accelerations or high relative storey displacements.

LRBs are designed in order to isolate these facilities from the floor main frame. Five different facilities locations are studied: on the middle of each floor (from the 1^{st} to the 4^{th} one), and a whole-4^{th}-floor position, as the last experiment set.

The objective is to see, firstly, the positive effects on the directly isolated facilities through non-linear time-history analyses and, secondly, the global effects (positive or negative) onto the whole structure, taking into account PFAs, PFDs and interstorey drifts [2]. By this manner it could be possible to decide the effectiveness of this storey-isolation system, giving advices for future possible applications.

https://doi.org/10.2749/222137809796067605
Distributed by structurae

2. Numerical Testing

The computational tool is ANSRuop computer program, developed in the Structures Laboratory, University of Patras, as a development and expansion of the ANSR-I program developed at UC Berkeley. Modelling characteristics involve also the estimation of the effective (secant) stiffness of columns to yielding. The main developed method of analysis is here the non-linear time-history analysis.

3. Conclusions

ANSRuop is used for the 4-storey RC building modelling and also for the 112 time-history analyses.

Five isolation cases were treated, that means one per floor plus a last one getting a whole-top-storey isolation. Lead-rubber bearings are the target devices for isolating the facilities and 12 types of them were design for the purpose of isolating the facilities on the selected floor, case by case.

To see the real non-linear behaviour of the whole system (building plus facilities plus LRBs), non-linear time-history analyses were run with 7 real recorded ground motions which are made spectrum equivalent with the EC8 design spectrum.

The target design displacements of LRBs were always better verified with the 30DLRBs than with the 15DLRBs, after running the non-linear time-history analyses.

The isolation has always positive effects onto the isolated facilities. 30DLRBs usually work better: PFAs for the facilities show a decrease of 55-60% (in the 15DLRBs case 45-55%).

Generally speaking there are good global effect onto the building itself:

- 1^{st}-floor LRBs: PFAs, PFDs and interstorey drift ratios reduces for every floor;
- 2^{nd}-floor LRBs: PFAs, PFDs and interstorey drift ratios reduces for every floor;
- 3^{rd}-floor LRBs: even if PFDs decrease, PFAs and interstorey drift ratios increase but only for the 4^{th} floor;
- 4^{th}-floor LRBs: even if PFDs and interstorey drift ratios decrease, PFAs increase but only for the 4^{th} floor;
- whole-4^{th}-floor LRBs: even if PFDs and interstorey drift ratios decrease, PFAs increase for the 4^{th} and the 3^{rd} floors.

The tests clarified the interactions might happen during an earthquake in those particular isolation cases: the ground motion determines a certain building behaviour, that activates the isolation system influencing the isolated part of the floor motion, but also giving feedbacks to the building through the isolation.

4. Acknowledgements

A special thank to Prof M.N. Fardis who supervised all this work of research.

5. References

[1] EN 1998-1:2004 Eurocode 8 - *Design of Structures for Earthquake Resistance - Part 1: General Rules, Seismic Actions and Rules for Buildings*

[2] CHOPRA A.K., *Dynamic of Structures*, Prentice Hall, Upper Saddle River, NJ, USA, 2001

[3] SKINNER R.I., ROBINSON W.H., MC VERRY G.H. *An Introduction to Seismic Isolation*, John Wiley & Sons Ltd., England, 1993

[4] PANAGIOTAKOS T.B., FARDIS M.N. "Seismic Performance of RC Frames Designed to Eurocode 8 or to the Greek Codes 2000," *BEE*, Vol. 2, No. 2, 2004

[5] GRANT D.N., FENVES G.L., AURICCHIO F. *Modelling and Analysis of High-damping Rubber Bearings for the Seismic Protection of Bridges*, IUSS Press, Pavia, Italy, 2005