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Analysis of different base isolation systems for irregular structures under dynamic loadings

D. Cancellara and F. De Angelis

Department of Structures for Engineering and Architecture
University of Naples Federico II, Italy

Abstract

In the present work two different base isolation systems are analyzed for the reduction of the vulnerability of irregular in plan structures under dynamic loadings. The first considered base isolation system is realized by high damping rubber bearings placed in combination with friction sliders. The second considered base isolation system is realized by lead rubber bearings placed in combination with friction sliders. Different recorded accelerograms with bi-directional ground motions are employed in the analysis. A nonlinear dynamic analysis is performed by determining the time history of the base shear of the superstructure, the time history of the displacement at the base of the superstructure and the time history of the inter-storey drift under the considered bi-directional seismic actions. Accordingly, a comparative analysis of the different base isolation systems is performed and the results are compared with the ones of the fixed base structure in order to actually evaluate the effectiveness of the base isolation strategy.

Keywords: base isolation systems, dynamic analysis, nonlinear structural analysis, structural vulnerability, irregular structures, bi-directional ground motions.

1 Introduction

In the present paper we analyze a three-dimensional base isolated structure under the actions of dynamic loadings. A nonlinear dynamic analysis is performed for the base isolated structure. In the present approach the base isolated structure is designed and verified according to updated seismic codes in such a way that the superstructure is kept under an elastic structural behavior and the hysteretic behavior is intended to occur mainly in the base isolation devices [1][2][3]. Nonlinear hysteretic models are used to properly investigate the cyclic behavior of the base isolation devices [4-14]. In the dynamic analysis we consider two different base isolation systems and evaluate their performances with respect to the structural analysis of a base isolated building with high irregularities in plan, see also [15][16].

2 Methods

In the dynamic analysis we adopt seismic excitations defined by recorded accelerograms, so that the ground motions are characterized by bi-directionality. The adopted isolation systems are realized by a combination of elastomeric bearings and sliding devices. The first isolation system is characterized by high damping rubber bearings placed in combination with friction sliders (HDRB+FS). The second isolation system is characterized by lead rubber bearings placed in combination with friction sliders (LRB+FS). A nonlinear dynamic analysis has been performed and the results are compared for the evaluation of the seismic response of the structure with each of the adopted base isolation systems. The structure with fixed base response has also been considered in the dynamic analysis in order to compare the seismic performance of the base isolated structure with the fixed base structure, see also [17-22].

3 Results

In the dynamic analysis of the base isolated structure the time history of the base shear of the superstructure, the time history of the displacement at the base of the superstructure and the time history of the inter-storey drift are determined under the considered bi-directional seismic actions. A comparative analysis is illustrated between the base isolated structure with the two hybrid base isolation systems and the corresponding fixed base structure, see Table 1. In the comparative analysis is shown that lead rubber bearing isolators in combination with friction sliders experience peaks of the acceleration slightly greater than the high damping rubber bearing isolators combined with friction sliders. In the comparative analysis it has been also shown that the structure base isolated by lead rubber bearing isolators in combination with friction sliders experiences extremal values of the base displacements which are lower than the values of the base displacements shown in the structure base isolated by high damping rubber bearing isolators combined with friction sliders.

Furthermore, the structure base isolated by lead rubber bearing isolators in combination with friction sliders shows a more rapid damping with respect to the structure base isolated by high damping rubber bearing isolators combined with friction sliders.

Finally, the structure base isolated by both base isolation systems shows a drastic reduction of the maximum base acceleration and a drastic reduction of the maximum base shear with respect to the fixed base structure.

HDRB+FS	LRB+FS	FB
1410	1860	27932
585	826	16652

Table 1: Peak values of the base shear (kN) in X-direction (first row) and in Y-direction (second row) for the structure with the base isolation system HDRB+FS, the structure with the base isolation system LRB+FS and the fixed base structure FB (seismic input: record 000199xa, Montenegro).

4 Conclusions and Contributions

In the reported analysis we have considered a three-dimensional structure characterized by irregularity in plan and base isolated by different base isolation systems. A first base isolation system is realized by lead rubber bearing isolators in combination with friction sliders. A second base isolation system is realized by high damping rubber bearing isolators in combination with friction sliders. A nonlinear dynamic analysis has been performed for the structure base isolated by the two hybrid base isolation systems. Nonlinear hysteretic models are adopted in order to properly simulate the cyclic behavior of the base isolation devices. In the dynamic analysis the behavior of the structure base isolated by the two different base isolation systems has been determined and the performances of the base isolated structures have been evaluated and compared with the results of the corresponding fixed base structure.

References

[1] F. Naeim and J. M. Kelly, Design of Seismic Isolated Structures, John Wiley, New York, 1999.

[2] K. L. Ryan and A .K. Chopra, Estimation of seismic demands on isolators based on nonlinear analysis, J. Struct. Eng., ASCE, 130, pp. 392-402, 2004.

[3] C. Christopoulos, A. Filiatrault, Principles of Passive Supplemental Damping and Seismic Isolation, IUSS Press, Pavia, Italy, 2006.

[4] S. Nagarajaiah, A. M. Reinhorn and M. C. Constantinou, 3D-Basis: Nonlinear Dynamic Analysis of Three-Dimensional Base Isolated Structures: Part II, Technical Report NCEER-91-0005, Nation Center For Earthquake Engineering Research, Buffalo, N.Y., 1991.

[5] De Angelis, F., Taylor, R.L., A Nonlinear Finite Element Plasticity Formulation without Matrix Inversions, Finite Elements in Analysis And Design, Vol. 112, pp. 11-25, 2016.

[6] De Angelis, F., Taylor, R.L., An Efficient Return Mapping Algorithm for Elastoplasticity with Exact Closed Form Solution of the Local Constitutive Problem, Engineering Computations, Vol. 32, Issue 8, pp. 2259 - 2291, 2015.

[7] De Angelis, F., Extended formulations of evolutive laws and constitutive relations in non-smooth plasticity and viscoplasticity, Composite Structures, Vol. 193, pp. 35-41, 1 June 2018.

[8] De Angelis, F., On the structural response of elasto/viscoplastic materials subject to time-dependent loadings, Structural Durability & Health Monitoring, Vol. 8, No. 4, pp. 341-358, 2012.

[9] De Angelis, F., A variationally consistent formulation of nonlocal plasticity, Int. Journal for Multiscale Computational Engineering, Vol. 5, Issue 2, pp. 105-116, Begell House Inc. Publishers, New York, 2007.

[10] De Angelis, F., A comparative analysis of linear and nonlinear kinematic hardening rules in computational elastoplasticity, Technische Mechanik, Vol. 32 (2-5), pp. 164-173, 2012.

[11] De Angelis, F., Computational issues and numerical applications in rate-dependent plasticity, Advanced Science Letters, Vol. 19, Number 8, pp. 2359-2362, American Scientific Publishers, USA, 2013.

[12] De Angelis, F., De Angelis, M., On solutions to a FitzHugh-Rinzel type model, Ricerche di Matematica, Vol. 70, Issue 1, pp. 51-65, 2021.

[13] De Angelis, F., Meola, C., Non-smooth evolutive laws in multisurface elastoplasticity with experimental evidence by infrared thermography, Composite Structures, Vol. 265, Art. n. 113156, pp. 1-9, 2021.

[14] De Angelis, F., A multifield variational formulation of viscoplasticity suitable to deal with singularities and non-smooth functions, Int. Journal of Engineering Science, Vol. 172, Art. 103616, pp. 1-16, 2022.

[15] Cancellara, D., De Angelis, F., Assessment and dynamic nonlinear analysis of different base isolation systems for a multi-storey RC building irregular in plan, Computers and Structures, Vol. 180, pp. 74–88, February 2017.

[16] Cancellara, D., De Angelis, F., Dynamic nonlinear analysis of an hybrid base isolation system with viscous dampers and friction sliders in parallel, Applied Mechanics and Materials, Vol. 234, pp. 96-101, 2012.

[17] Cancellara, D., De Angelis, F., Nonlinear dynamic analysis for multi-storey RC structures with hybrid base isolation systems in presence of bi-directional ground motions, Composite Structures, Vol. 154, pp. 464–492, 2016.

[18] Cancellara, D., De Angelis, F., A base isolation system for structures subject to extreme seismic events characterized by anomalous values of intensity and frequency content, Composite Structures, Vol. 157, pp. 285–302, 2016.

[19] Cancellara, D., De Angelis, F., Dynamic assessment of base isolation systems for irregular in plan structures: Response spectrum analysis vs nonlinear analysis, Composite Structures, Vol. 215, pp. 98-115, 2019.

[20] De Angelis, F., Cancellara, D., Dynamic analysis and vulnerability reduction of asymmetric structures: Fixed base vs base isolated system, Composite Structures, Vol. 219, pp. 203-220, 2019.

[21] Cancellara, D., De Cicco, S., De Angelis, F., Assessment and vulnerability reduction of under-designed existing structures: Traditional vs innovative strategy, Computers and Structures, Vol. 221, pp. 44-64, September 2019.

[22] Cancellara, D., De Angelis, F., Base isolation systems for structures subject to anomalous dynamic events, Lecture Notes in Mechanical Engineering, 24th Conference of the Italian Association of Theoretical and Applied Mechanics, AIMETA2019, Rome, Italy, 15-19 September 2019, Code 238859, pp. 175-187, Springer, 2020.