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Editorial

Structural control benchmark problem: Phase II—Nonlinear smart base-isolated building subjected to near-fault earthquakes

Satish Nagarajaiah[1,*,†], Sriram Narasimhan[2] and Erik Johnson[3]

[1]*Rice University, Houston, TX, U.S.A.*
[2]*University of Waterloo, Ont., Canada*
[3]*University of Southern California, Los Angeles, CA, U.S.A.*

SUMMARY

Many branches of engineering, mathematics, and sciences, have relied on benchmark problems as a standard means to compare different solution techniques. Since 1996, the ASCE Structural Control and Monitoring Committee and Task Group on Benchmark Problems, the U.S. Panel on structural control, and IASCM have developed a series of benchmark control problems that offer a set of carefully modeled real-world structures in which different control strategies can be implemented, evaluated, and compared using a common set of performance indices. First-, second- and third-generation benchmark problems focusing on the response control of seismic and wind-excited buildings, and seismically excited long-span cable-stayed bridges have been developed and evaluated.

The U.S. Panel on structural control and monitoring (currently chaired by Professor Satish Nagarajaiah, Rice University, Houston, TX), IASCM, and the ASCE structural control and monitoring committee have developed a new benchmark study to compare control strategies designed for a base-isolated building subjected to strong near-fault pulse-like ground motions. The special issue on phase I smart base-isolated building benchmark problem with a linear isolation system was successfully completed and published. This special issue focuses on the phase II smart base-isolated building benchmark problem with nonlinear isolation systems—friction or elastomeric system. Copyright © 2008 John Wiley & Sons, Ltd.

KEY WORDS: benchmark; smart base-isolated building; friction bearings; bilinear bearings; active; semiactive; passive

INTRODUCTION

The smart base-isolated benchmark problem is the first benchmark building problem that is fully three-dimensional and subjected to both horizontal components of ground

*Correspondence to: Satish Nagarajaiah, Rice University, Houston, Texas, U.S.A.
†E-mail: nagaraja@rice.edu

excitation (vertical excitation is not considered). The benchmark structure is an eight-storey base-isolated building, similar to existing buildings in Los Angeles, CA. The superstructure is modeled as a linear elastic system with lateral–torsional behaviour. The base isolation system, which accounts for lateral–torsional coupling, includes both linear and nonlinear bearings and control devices; nonlinear biaxial interaction in the bearings is included. A new nonlinear, computationally efficient, computer program has been developed to facilitate a direct comparison of results of different control algorithms. The developed three-dimensional nonlinear dynamic analysis Matlab/Simulink program [1] can model nonlinear sliding or friction systems and bilinear or nonlinear elastomeric systems or any combination thereof. A host of control devices can be considered at the isolation level, but no control devices are allowed in any other level in the superstructure. The control algorithms may be passive, active or semiactive.

The seismic response of base-isolated buildings subjected to near-fault pulse-type ground motions has been the subject of intense debate in the past decade. The primary problem in such cases is the large base displacement in the flexible isolation system. Many new strategies, such as supplemental nonlinear passive dampers, have been suggested as a means to reduce the base displacement. Semiactive dampers and active devices offer an alternative control strategy to reduce base displacement while keeping the superstructure response within limits.

SMART BASE-ISOLATED BENCHMARK PROBLEM: PHASE II

The smart base-isolated benchmark problem is aimed at evaluating different control strategies; it includes four parts (1) part I, definition of the benchmark problem [1]; (2) part II, phase I sample controllers for the linear isolation system [2]; (3) part III, phase II sample controller for the bilinear elastomeric isolation system [3]; and (4) part IV, phase II sample controller for the sliding isolation system [4]. The earlier published special issue on the phase I [1–3] of the smart base-isolated benchmark problem focused primarily on linear base-isolated structures (parts I and II). Participants of the phase I study proposed different devices, active and semiactive control strategies, evaluated, and reported their results when compared with the results of the sample controllers for linear isolation systems. The phase II participants of the smart base-isolated benchmark problem have addressed nonlinear isolation systems, such as sliding and bilinear elastomeric systems (parts III and IV).

The phase II special issue consists of nine papers contributed by the participants of the study, which have proposed different devices, passive, active, and semiactive control strategies, evaluated, and reported their results and compared the results with that of the sample controllers for nonlinear isolation systems. Each research team has adhered to prescribed practical control constraints and has evaluated the performance of their control designs by prescribed performance indices.

Narasimhan *et al.* [4] present a sample controller for the phase II smart base-isolated benchmark building with a nonlinear isolation system. The sample controllers that have been presented include (1) for the semiactive control of a nonlinear friction isolation system using magnetorheological dampers [4] and (2) the sample controller for the hysteretic lead–rubber bearing isolation system, which has already been presented in the phase I special issue [3]. The controllers developed in [4] are not intended to be competitive; they are intended to serve as a guide for participants to design competitive controllers for the nonlinear base-isolated building benchmark.

Chang *et al.* [5] present four control strategies for the semiactive case made from two different control algorithms combined with two different MR dampers. Two different types of MR dampers are selected in the study; one is provided by the sample control of this benchmark control problem and the other is provided by NCREE and validated by the performance test at NCREE. The controller considers the output feedback control algorithm to generate the required control force. To adopt the nonlinear structural system, the control strategy is appropriately modified into two methods: one method considers the bilinear model for the nonlinear bearings and derives four respective control gains to calculate the control force, and the other method obtains a control gain based on the initially linear system and considers the nonlinear-bearing force into the control force at the same time. All the four control strategies are found to be effective in reducing the displacement at the base.

Taflanidis *et al.* [6] present a probabilistically robust nonlinear control design: the performance objective of which is the maximization of structural reliability, quantified as the probability, such that the structural response trajectory will not exceed acceptable thresholds. The approach explicitly takes into account nonlinear characteristics of the structural response and the control law in the design process. A realistic probabilistic model for the representation of near-fault ground motions is adopted in the design stage. The robust controllers proposed are found to be effective.

Pozo *et al.* [7] present robust active controllers for a nonlinear hysteretic benchmark problem by taking advantage of the discontinuous control theory. A static discontinuous active bang-bang-type control is developed using only the measured velocity at the base, which is extended to a dynamic acceleration feedback controller. The robust active controllers proposed are found to be effective.

Pradono *et al.* [8] present angular-mass damper-based passive controller. The device is found to be effective in reducing the seismic response of the benchmark building. However, in some earthquakes, the devices increase the floor acceleration due to the introduction of high-frequency forces.

Shook *et al.* [9] present a controller that includes a superelastic SMA recentering device with semiactive MR dampers. A neuro-fuzzy controller is developed using a multiobjective genetic algorithm for the optimal modulation of MR damper resistance levels. The presented approach is found to be effective.

Xu and Agrawal [10] present semiactive friction control strategies, which include semiactive a discontinuous pulse filter controller, a semiactive continuous pulse filter controller, and a visco-elastic friction controller. Both controllers are designed by using the augmented structure-pulse filter model. The controllers are found to be effective in mitigating the base displacements; however, the superstructure response quantities are increased.

Choi *et al.* [11] present an MR damper-based smart passive control system equipped with the electromagnetic induction device, which is a substitute for a feedback control system. It is demonstrated that the smart passive control system has comparable or superior control performance to the conventional MR damper-based semiactive controller.

Ali and Ramaswamy [12] present a genetic algorithm optimized fuzzy logic control (FLC) strategy with a variable rule base. Two optimal FLCs are proposed and optimized online at every simulation time step. The variable rule base is designed based on a geometric approach and therefore has less computational overhead. The variable rule base maintains a symmetry in the input–output space pattern and therefore assures stability. Performance of the proposed control system is found to be better than the sample control strategy.

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This is the first 3D benchmark nonlinear problem; additionally, several of the proposed controllers meet the original challenge of developing nonlinear controllers explicitly accounting for the nonlinear behavior of the base-isolated structure and the MR damper, which is a unique new contribution of this special issue. The special issue owes its success to the excellent contributions of the participating researchers, all of which met the high review standards of the journal (several contributions had to be declined because they did not meet the rigorous review standards). The phase II special issue guest editors wish to acknowledge the valuable support of the journal editors Professor T. T. Soong and Professor Lucia Farivelli during all stages of the effort.

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