

Structural Control with Emphasis on Nonstructural Components

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ABSTRACT

Most control techniques in the structural engineering literature are aimed at improving performance of the primary structural part, but they may have limited or adverse affect on the nonstructural component during strong seismic events. In our research, we emphasize the nonstructural performance using semiactive fluid viscous dampers and semiactive shape memory alloy dampers. Smart materials have defined the last two decades of material science engineering. These materials are able to vary their behavior in response to deformations, damage, or loads by changing their shape, position, stiffness, damping, viscosity or natural frequency by thermal or magnetic field changes.

Shape memory alloys exhibit two properties termed the “Shape Memory Effect” and “Superelasticity”. A look at two possible stress-strain curves for a shape memory alloy highlights these properties. It is also extremely important to point out that the area under these curves represents the dissipation of energy.

BACKGROUND

The engineering profession has now recognized the importance of the seismic design of electrical and mechanical equipment, pipelines, parapets, elevators, tanks, and other nonstructural elements that are usually attached to the walls and floors of large multistory buildings, nuclear power plants, industrial facilities, and offshore platforms. More importantly, it also has been recognized that after the occurrence of a strong earthquake the survival of these so called secondary systems may be vital to provide emergency services, as it is the case for equipment in power stations, hospitals, or communication facilities. At present, the most accepted performance indices concerning nonstructural components attached to buildings are the peak and root-mean-square (RMS) absolute floor accelerations.

Base isolation, the most mature passive control technique, has been used widely to protect these critical facilities. But certain severe seismic events, such as some near fault earthquakes dominated by high frequency ground acceleration, will increase the isolation deformation, and also increase the superstructure absolute accelerations that are vital to the nonstructural seismic performance. Thus various types of semi-active control devices can be combined to the base isolated structural system. In particular, the semi-active fluid viscous dampers and SMAs present excellent potential in civil engineering applications due to their easy mechanisms to dissipate energy yet return to their undeformed shapes.

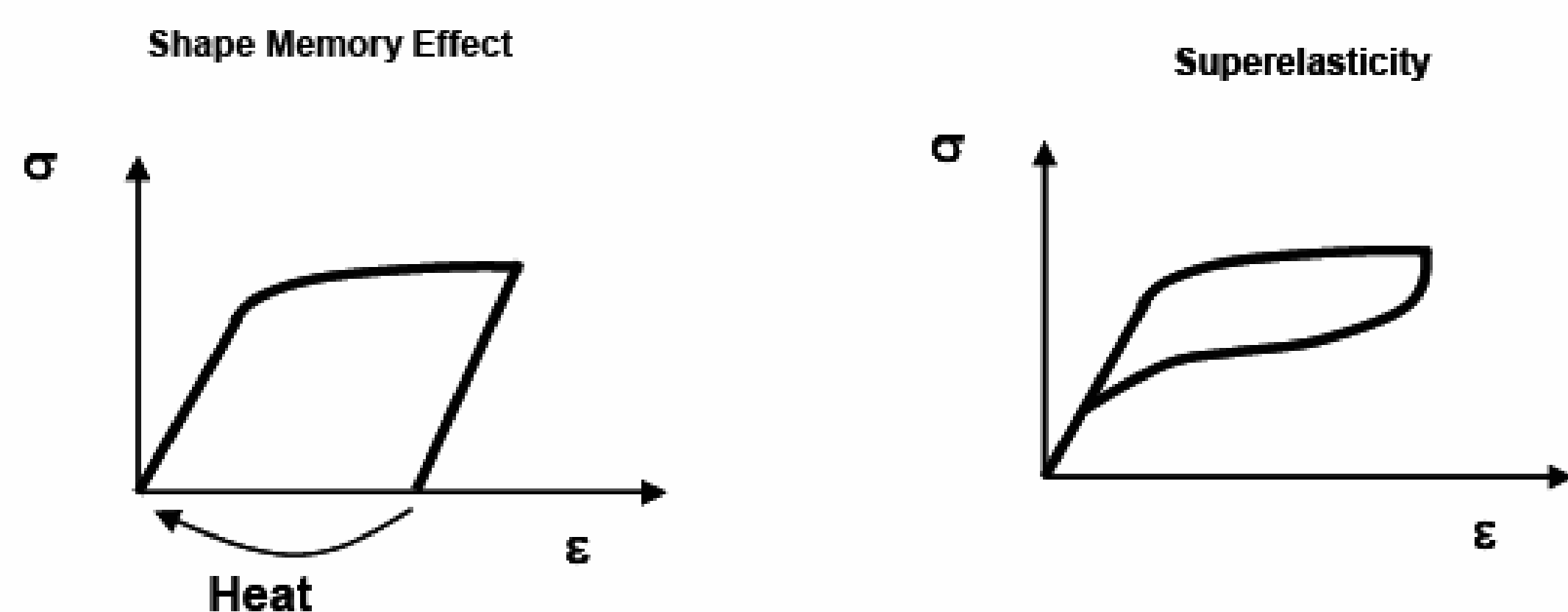


Figure 1. Possible Shape Memory Alloy (SMA) Stress Strain Curves

OBJECTIVES

The objectives of this research are:

- 1) Developing appropriate control laws for the digital controller built in the control system employed in a base isolated building
- 2) Developing appropriate constitutive models for the shape memory alloys under unidirectional loading
- 3) Comparing our study results using a benchmark base isolated building recently proposed by the ASCE Structural Control Committee

METHODS

We use the Krylov-Bogoliubov “averaging method” for obtaining analytical frequency response functions (FRFs) that approximate the periodic solution of a second-order nonlinear differential equation containing cubic terms. We add these cubic terms in the controller intentionally as the feedback component without changing any linear properties of the original linear elastomeric isolation system. The set of parameters where the single-degree-of-freedom (SDOF) oscillator behaves regularly are found, and the nonlinear oscillator is optimized for obtaining minimum relative deformation and absolute acceleration based on its FRFs.

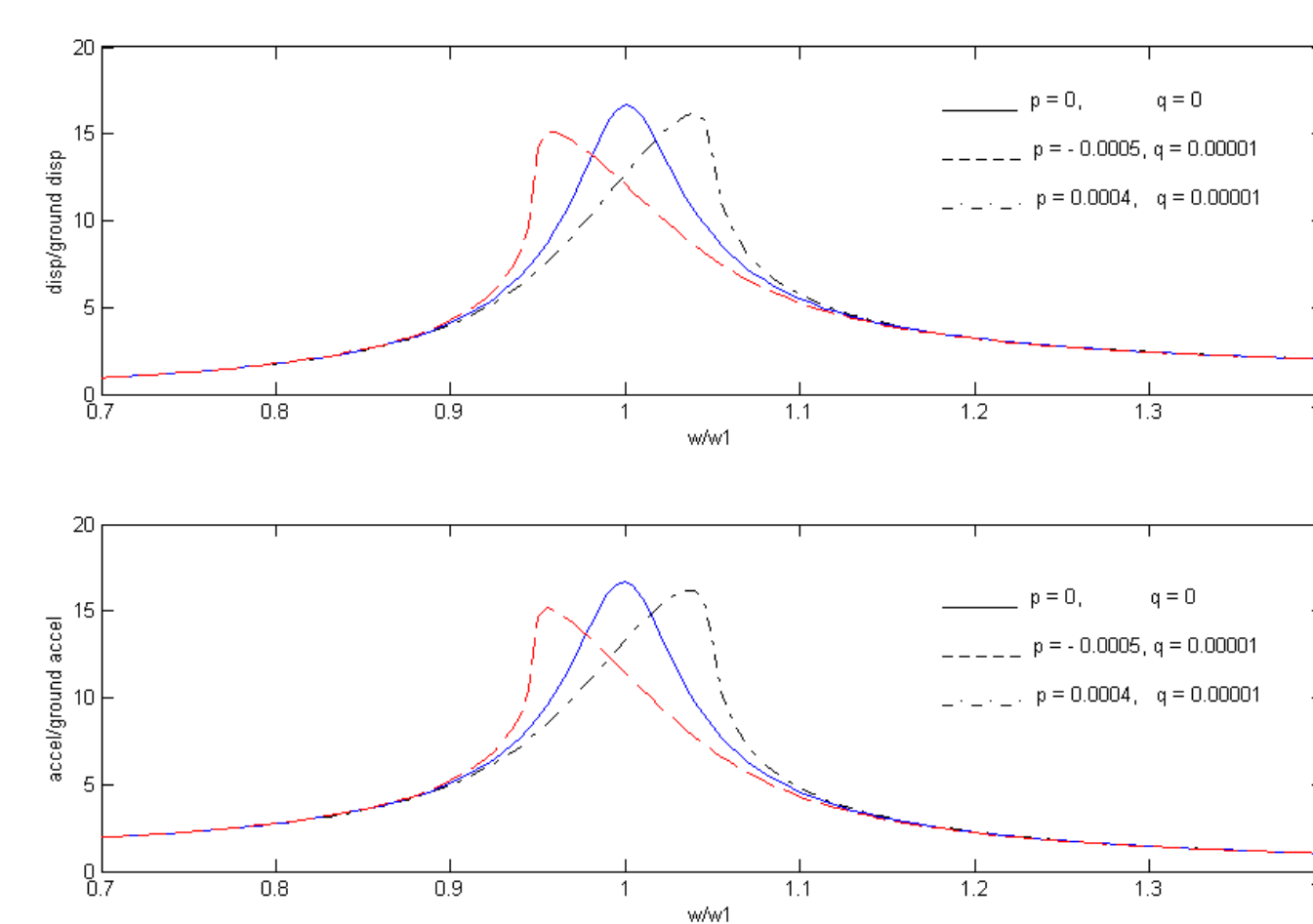


Fig 2. FRFs for nonlinear oscillators with different parameters (no bifurcation)

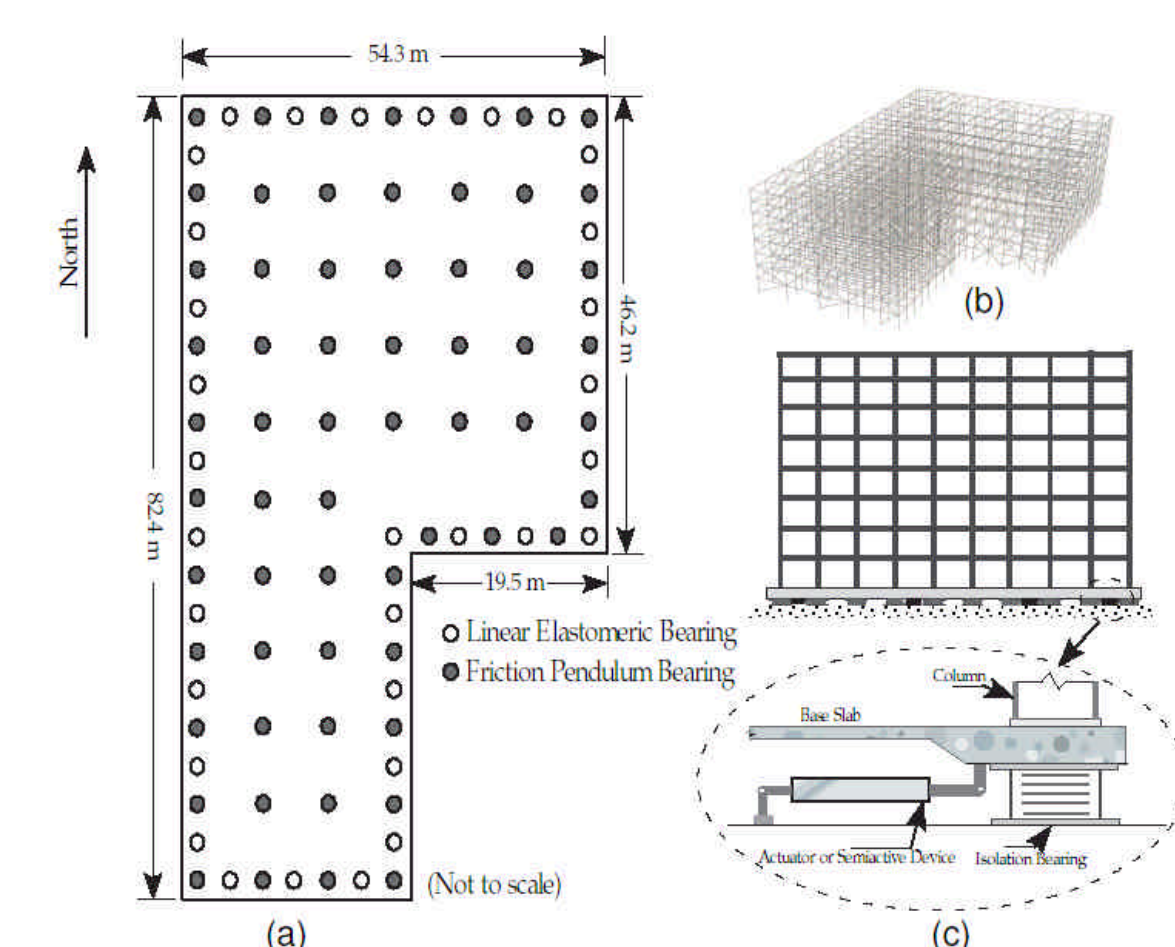
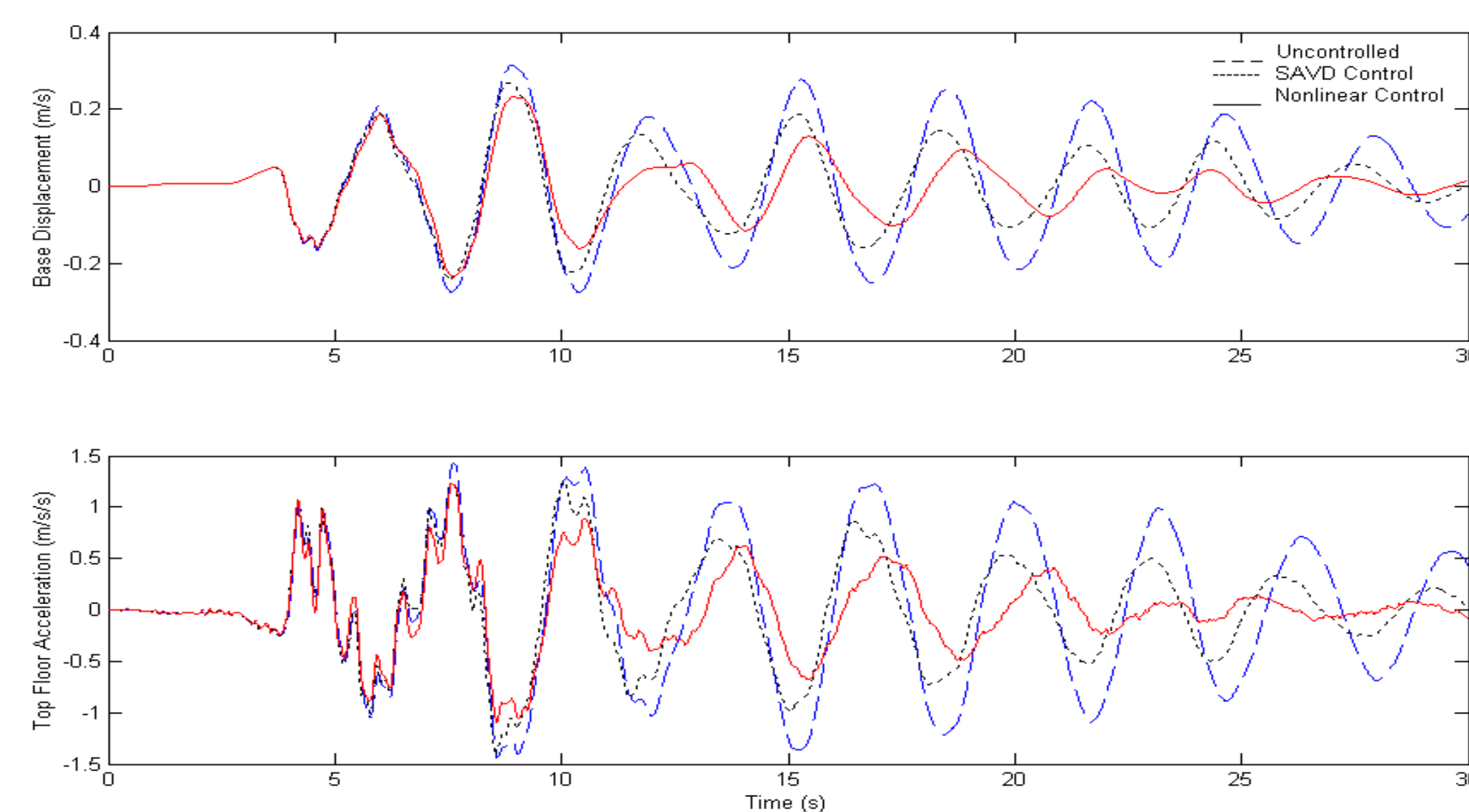


Figure 3. (a) Isolation plan, (b) FEM model superstructure, (c) Elevation view

RESULTS

To compare our nonlinear control effect, a semi-active control system is also designed to trace the common used LQG controller already developed by other researchers. The SMAs' effect is under investigation now. A typical time history under the Newhall earthquake is as follows. From it we can see our nonlinear control system generally has better nonstructural performance than the other systems.



CONCLUSIONS

Our semi-active fluid viscous damping control system shows that, the traditional LQG control is mainly in the form of time varying damping forces. Our nonlinear control system using semi-active fluid viscous dampers is more suitable for protecting the superstructure and the nonstructural contents in a base isolated structure under near fault earthquakes by adding only cubic properties in the digital controller. The required output signal estimation in the presence of measurement white noise is also addressed. The control effect of SMAs are currently under investigation.

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