DUAL SEMI-ACTIVE FRICTION DAMPERS TO REDUCE BUILDING RESPONSE TO SEISMIC INPUTS

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SUMMARY

Simulations predict that the lateral accelerations and inter storey drift of a two block building subject to horizontal ground excitation can be approximately halved compared to the passive case when two semi-active friction dampers are employed . The logic employed is dynamic spring cancellation or 'dynamic detuning' which does not affect the static stiffness of the structure. The degree of alleviation achieved by the the semi-active system increases with building stiffness

INTRODUCTION

In recent years the merits of semi-active control systems have been recognised.

'….appropriately implemented semi-active control systems perform significantly better than passive devices and have the potential to achieve the majority of the performance of fully active systems' [Spenser and Sain 1998]

In the case of buildings, attention has been paid to variable – orifice dampers [Symans 1994], electrorheological fluids [Li 1998], magnetorheological fluids [Baltimore 1998] and controlled friction dampers [Fujita 1994]

The authors have experience in developing an experimental system using controlled friction , initially for the reduction of vibration in machines [Stammers 1999], but here consider the application of such a system to controlling the response of buildings to seismic excitation.

ANALYSIS

THEORETICAL MODEL

As in [Naeim and Kelly 1999] the building is modelled as a double mass. Because the main objective is to reduce or even cancel accelerations (achieving sliding mode control when acceleration is made zero), absolute displacements are employed rather than relative. The notation is indicated in Figure 1.

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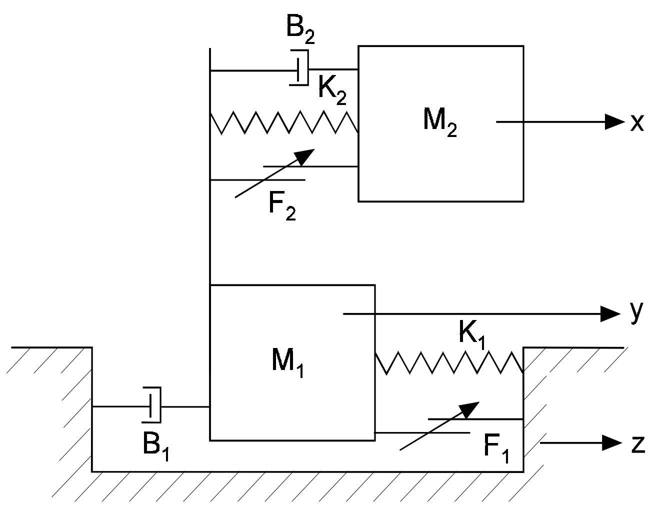

FIGURE 1 Analytical Model

The equations of motion (Figure 1) are

$$M_2 \ddot{x} = K_2 (y - x) - B_2 (\dot{x} - \dot{y}) + F_2$$

$$M_1 \ddot{y} = -M_2 \ddot{x} - K_1 (y - z) - B_1 (\dot{y} - \dot{z}) + F_1$$

K_1 *and* K_2 are chosen so that the fundamental frequency of the two mass system is that of the N storey building under consideration. Viscous dampers are introduced , as is usual, to model soil and structural damping .The constraints on the friction forces are

$$F_1 \, (\dot{y} - \dot{z}) < 0$$
$$F_2 \, (\dot{x} - \dot{y}) < 0$$

If the condition is violated, the friction force must be zero.

The logic adopted here is to set

$$F_1 = \gamma K_1 (y - x) + M_2 \ddot{x}$$
$$F_2 = \beta K_2 \, (x - y)$$

$$\gamma \leq 1 \, ; \beta \leq 1$$

This force opposes and may completely cancel the restoring displacement force if desired.

Seismic Excitation

Forty sine waves of random phase were employed. The frequencies were multiples of 0.25 Hz together with a small transcendental term to reduce beating effects. Amplitudes were chosen to correspond to constant velocity up to 3 Hz and constant acceleration thereafter . The maximum frequency employed was 10 Hz.

Results

Responses were obtained for a broad range of building natural frequency. The method adopted was to specify the natural frequencies of the subsystems. i.e. $(K_j / M_j)^{0.5} / 2\pi$, from which the two natural frequencies of the building could be deduced. In the results given below, full spring cancellation was used ($\beta = \gamma = 1$)

The maximum lateral acceleration for a base natural frequency of 0.75 Hz is shown in Figure 2 as a function of top natural frequency.

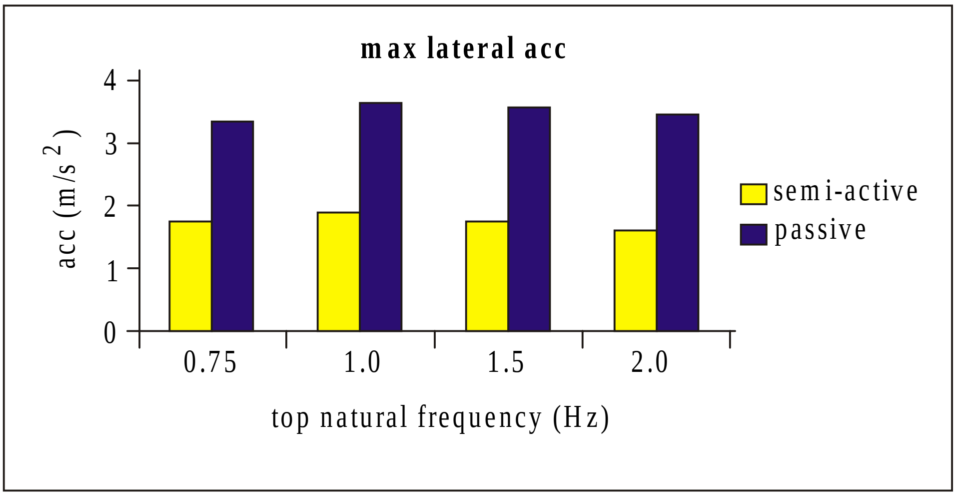

Figure 2. Response, base frequency 0.75 Hz

The corresponding results for drift are given in Figure 3.

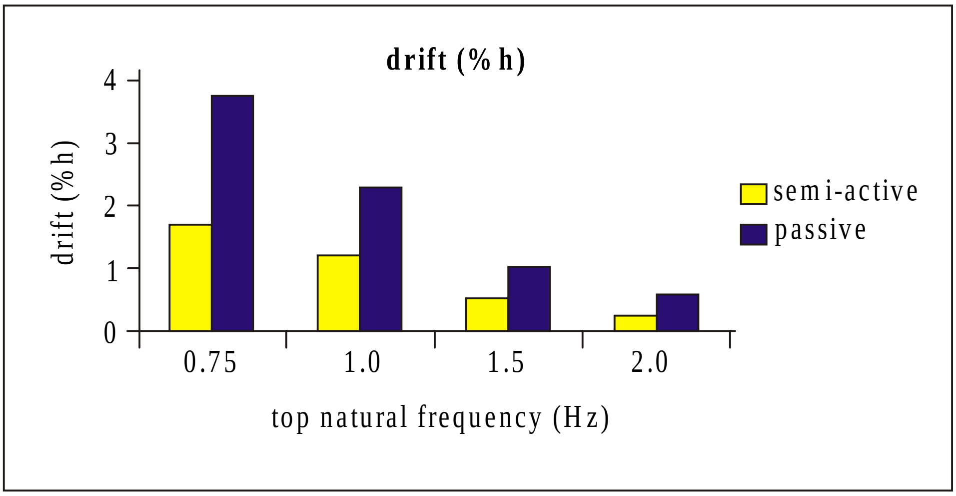

Figure 3. Drift, base frequency 0.75 Hz

Semi-active control approximately halves accelerations and drift. Since all the drift is concentrated at one location the actual values of drift can be high when the top natural frequency is low.

The corresponding results for a base frequency of 1 Hz are indicated in Figures 4 and 5.

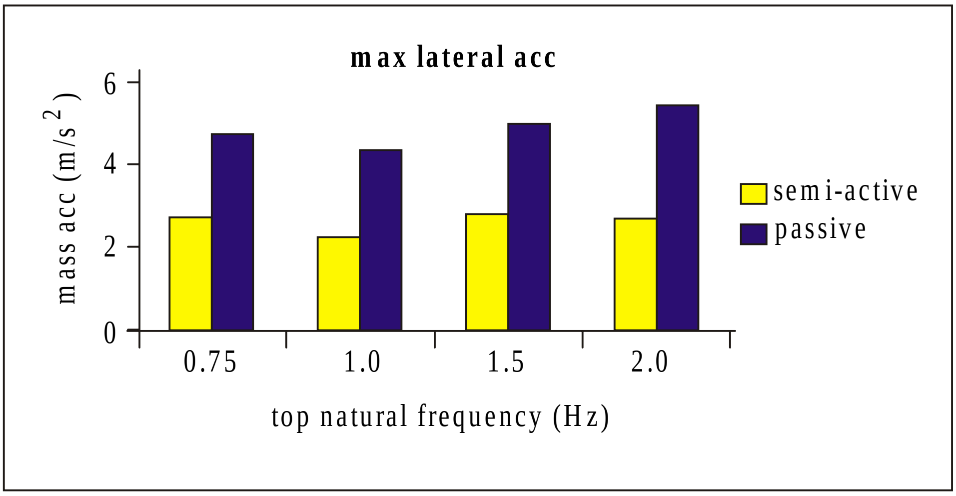

Figure 4. Response, base natural frequency 1 Hz

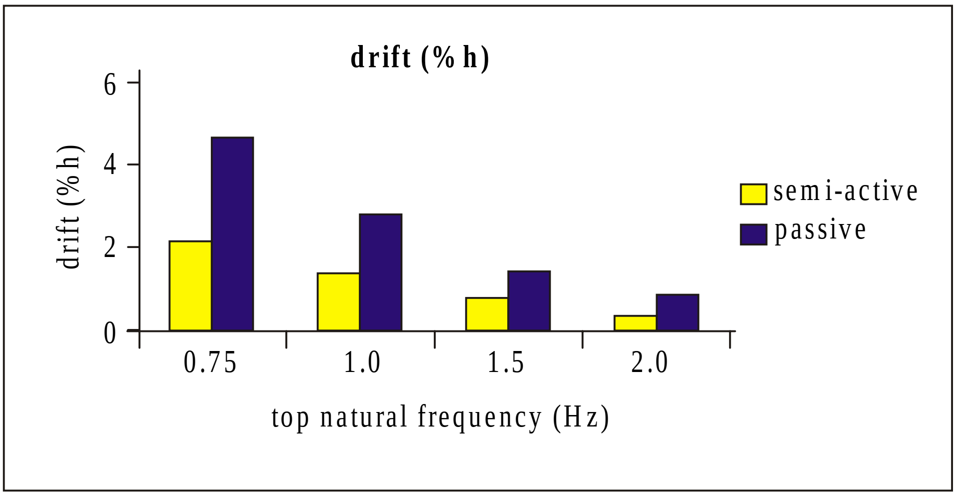

Figure 5. Drift, base frequency 1 Hz

CONCLUSIONS

Controlled friction forces using spring cancellation logic offer a simple method for reducing accelerations and drift in buildings. By selective choice of the spring cancellation factors (β and γ) it has been found that further improvements are possible but are not explored here.

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