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A hybrid structural control system using a tuned liquid damper to reduce the wind induced motion of a base isolated structure

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ABSTRACT

This study investigates the use of a tuned liquid damper (TLD) as a cost effective method to reduce the wind induced vibrations of base isolated structures. The TLD is modelled as an equivalent linearized mechanical system in which the damping and natural frequency of the sloshing fluid are amplitude dependent quantities. The base isolated structure is represented using a modified form of the linearized Bouc–Wen model, which enables the behaviour of Stable Unbonded Fibre Reinforced Elastomeric Isolators (SU-FREIs) to be described. The TLD and base isolated structure are combined to form a system of coupled ordinary differential equations, the solution to which produces frequency response curves for the structure and TLD. A preliminary TLD design procedure is presented which allows the proper tank dimensions and damping screen properties to be established. The equivalent linearized mechanical model is validated using time simulations which account for the nonlinear behaviour of the structure and fluid. The models are found to be in excellent agreement. A TLD is found to be an effective means to control the wind induced vibration of a base isolated structure.

1. Introduction

The function of a base isolation system is to shift the fundamental natural frequency of the structure away from the strong frequency content of an earthquake. A base isolated building tends to respond like a rigid mass, with the majority of deformation occurring within the flexible base isolation layer. While this flexible layer protects the building from damage during an earthquake, it produces a large displacement demand on the bearings. To reduce the displacement demand, it has been suggested that a dynamic vibration absorber (DVA) could be implemented [1,2].

In the early 1990s, several researchers began considering using DVAs, such as the tuned mass damper (TMD) to improve the performance of a base isolation system. The TMD-base isolation system was found to be most effective at reducing the structural response when the damping in the bearings was low [3,4]. Palazzo and Petti [4] found that utilizing a TMD to control the displacement of a base isolated system produced better performance characteristics than increasing the damping of the isolators. Arfiadi and Hadi [5] demonstrated that a TMD could preserve the small inter-storey drift typical of a base isolated structure while reducing the displacement demand of the bearings. Optimal TMD-base isolation control strategies in the frequency domain are presented by Palazzo and Petti [3]. Optimum TMD parameters for the hybrid system were studied and it was found that the TMD could be designed assuming a single degree of freedom structure [3,6]. Tanichuch et al. [7] simulated TMD-base isolation systems subjected to white noise, as well as near- and far-field earthquake ground motions. The displacement demand was reduced by up to 25% for white noise and far-field excitations. For near-field ground motions, the reduction in displacement demand was found to be approximately 10%.

Studies have also considered the effects of wind excitation on base isolated structures. While reducing the natural frequency of the building can avoid the strong frequency content of earthquake excitation, the lower natural frequency may make the base isolated structure susceptible to wind-induced dynamic motion. Chen and Ahmadi [8] used the linearized Bouc–Wen model to consider the effects of wind loading on base isolated structures. Several base isolation systems were studied experimentally and numerically under the effects of wind excitation and it was found that high bearing damping or friction-type damping reduced a structure's sensitivity to wind excitation. Kareem [9] compared the RMS structural response of fixed base and base isolated structures when they were subjected to wind excitation. A TMD located at the top of the fixed base structure was found to reduce the RMS structural response. The base isolated structure was studied with TMDs located at the top and bottom of the structure. It was found that introducing a TMD at the top or bottom of a structure reduced the response significantly.

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