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DISCUSSION OF "STUDY OF VISCOELASTIC AND FRICTION DAMPER CONFIGURATIONS IN THE SEISMIC MITIGATION OF MEDIUM-RISE STRUCTURES"

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Izuru Takewaki writes:

The discusser is very interested in the paper presented by Julius Marko, David Thambiratnam and Nimal Perera. This paper includes various interesting aspects, for example, comparison of the effectiveness of various damper systems (viscoelastic, friction and hybrid), optimal damper configuration and location, and the influence of different types of earthquake ground motions on the response reduction by dampers.

The authors draw several references for readers. In the discusser's opinion, more versatile investigations on optimal damper configuration and location have been made in the scientific community of earthquake engineering, and computing algorithms based on certain theoretical backgrounds have been proposed [Austin and Pister 1985; Takewaki 1997; Takewaki and Yoshitomi 1998; Takewaki 1999; Takewaki et al. 1999; Takewaki 2000a; Takewaki 2000b; Takewaki 2000c; Garcia 2001; Singh and Moreschi 2001; Singh and Moreschi 2002; Garcia and Soong 2002; Liu et al. 2003; Silvestri et al. 2003; Kiu et al. 2004; Park et al. 2004; Trombetti and Silvestri 2004; Xu et al. 2004; Liu et al. 2005; Tan et al. 2005; Trombetti and Silvestri 2006; Wongprasert and Symans 2004; Lavan and Levy 2005; Lavan and Levy 2006; Aydina et al. 2007]. For example, the optimal quantity and location of dampers can be obtained automatically with the help of these algorithms; the *gradient-based algorithm* is a representative one [Takewaki 1997; Takewaki and Yoshitomi 1998; Takewaki 1999; Takewaki 2000a; Takewaki 2000b; Takewaki 2000c; Takewaki et al. 1999]. It is obvious that dampers have various kinds of nonlinearities, and a time-history response analysis is often required to simulate the behaviors of structures with such dampers. However, many useful equivalent linearization techniques have been proposed [Roberts and Spanos 1990], and these techniques certainly make it possible to treat those behaviors almost theoretically. Although the equivalent linearization techniques have some limitations on the range of applicability, most of building structures are designed within this range of applicability.

The authors point out another interesting aspect, that is, the influence of different types of earthquake ground motions on the response reduction by dampers. The broad-range parametric simulation using recorded ground motions may be attractive and lead to many useful conclusions. However, it is also true that theoretical approaches enable one to capture more essential features of permanent interest even if the range of applicability is limited. For example, the concept of critical excitation or worst-case analysis

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seems to provide a powerful means for overcoming the difficulties caused by uncertainties of earthquake ground motions [Drenick 1970; Shinozuka 1970; Takewaki 2000b; Takewaki 2001; Takewaki 2002a; Takewaki 2002b; Takewaki 2002c; Takewaki 2004; Takewaki 2007]. The tough and robust design may be possible using this concept [Takewaki 2000b; Takewaki 2002b; Takewaki 2007].

In closing, the discusser would like to call the attention of interested readers to the work reported in [Takewaki 1997; Takewaki and Yoshitomi 1998; Takewaki 1999; Takewaki et al. 1999; Takewaki 2000a; Takewaki 2000b; Takewaki 2000c; Garcia 2001; Singh and Moreschi 2001; Liu et al. 2003; Park et al. 2004; Silvestri et al. 2003; Trombetti and Silvestri 2004; Lavan and Levy 2005; Liu et al. 2005; Lavan and Levy 2006; Takewaki 2007] to provide a broader context for the results reported by Julius Marko, David Thambiratnam and Nimal Perera.

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The authors respond:

The authors would like to thank the discusser for the encouraging remarks and the valuable comments. We reviewed the work by Austin, Pister, Takewaki, Yoshitomi, Singh, Moreschi, Garcia, Soong et al. referred to by the discusser as part of this study and found that work to be very useful and informative. This specific research project is part of a comprehensive study by industry collaborators actively involved in the structural design of high-rise buildings with the intent of gaining an understanding of the relationship between nature of ground excitation, ground structure interaction, structural system response and the effective influence of damping systems to mitigate adverse effects. The ultimate aim of this research is to explore the potential for total interactive design that includes ground support, structural framing and the various forms and configurations of damping as an integral part of high-rise building design. In doing so, we believe that it is possible to design not only the dampers but the entire building and its foundations as an integral part of the response reduction mechanism. Hence our focus on the nature of ground excitation and its interactive response with dampers.

This was only possible via a study which involved the numerous parameters that we investigated, such as earthquake type (frequency band and magnitude), damper type, location and configuration, etc. We acknowledge the discusser's comments that "theoretical approaches enable one to capture more essential features of permanent interest", and we plan to continue our work incorporating such an approach combined with synthetic ground excitations to overcome the unpredictability of ground motions.

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