Chapter 4
Optimal Passive Damper Positioning Techniques: State-of-the-Art

Arun M. Puthanpurayil
University of Canterbury, New Zealand

Rajesh P Dhakal
University of Canterbury, New Zealand

Athol J. Carr
University of Canterbury, New Zealand

ABSTRACT
A consolidated review of the current-state-of-the-art on optimal damper positioning techniques is presented in this chapter. The inherent assumptions made in previous research are discussed and substantiated with numerical studies. Earlier studies have shown that optimal distribution of dampers is sensitive to in-structure damping. In this chapter the significance of optimal distribution of dampers coupled with the necessity for the use of a more realistic in-structure damping model is qualitatively illustrated using a comparative sensitivity study. The effect of inherent assumption of linearity of the parent frame on the ’optimality’ is also investigated. It is shown that linearity assumption imposed on the parent frame in a major seismic event may not be justified; thereby raising doubts on the scope of optimality techniques proposed in literature.

INTRODUCTION
The effectiveness of control strategies in achieving the objectives of performance based design is well accepted in structural engineering community. The theory of structural control as a field in itself was mainly enriched by mechanical and aerospace engineering and its adoption in structural engineering is rather more recent. The introduction of control techniques in structural engineering was mainly necessitated due to the growing demand for minimizing damage during a seismic event.
The adoption of control strategies to structures presented the structural engineering community with new challenges due to the inherent uncertainties associated with the system as well as with the excitation sources. The uncertainties associated with the excitation sources result in the inherent record to record randomness at a location. As no two earthquake-induced ground motions are similar, it is uncertain if a system proven to work for a structure in one ground motion will work equally efficiently in another ground motion. The inherent system uncertainties differ with respect to the type of control strategy adopted. Before delving into the details, we briefly describe the classification and types of structural control used in practice. Structural control is mainly divided into four types (Wada et al. 2004):

- **Seismic Isolation:** The art of insertion of mechanical devices between the sub-structure and super-structure which decouples the system from the damaging components of the earthquake ground motion.
- **Passive Control:** Mechanical devices distributed through the structure to provide “added damping” to the system to reduce the response to controllable limits.
- **Active Control:** Includes computer controlled actuators which provide seismic resistance by imposing forces on the structure to counter-balance the ground motion induced forces.
- **Semi-Active Control / Hybrid Control:** A combination of active and passive control which includes a combination of dampers and isolators.

The main focus of this chapter is on the passive control techniques. In line with this focus, the issues discussed herein would be limited to those associated with passive control. In deciding a passive control strategy, say for a building, two questions need to be answered: (1) What type of device is the most efficient? and (2) How should they be positioned in different floors and distributed across the height of the building? In the process, two system uncertainties associated with passive control have to be dealt with (Takewaki 2009):

- Local amplification of responses in the elements where a control device is attached
- The interaction between the structure and dampers distributed throughout the structure.

The first uncertainty needs to be addressed mainly in the structural design process, whereas the second needs to be addressed in the optimal positioning strategies (Takewaki 2009). Focusing on the second system uncertainty, the main purpose of this chapter is to present a consolidated review of the existing state-of-the-art on optimal positioning of dampers. Some inherent assumptions made in deciding the optimal positioning techniques in previous studies are critically scrutinized based on simplified numerical studies to assess their validity in the real world scenario. The authors have selected the most representative works known to them, and it is acknowledged that some important and stimulating works may have been unknown to the authors and unintentionally omitted.

Following the background presented in this section, the next section (i.e. Significance of Optimal Distribution) establishes significance of optimal distribution of dampers in controlling structural response. In this section, the need for optimal distribution of the dampers is emphasized with the help of numerical simulations. Previous Studies summarizes the current state-of-the-art. A consolidated review on the past researches in optimal damper positioning techniques is presented in this section. Effect of In-Structure Damping Models on Optimal Distribution of Dampers investigates and discusses the effect of in-structure damping models on optimal distribution of dampers. In this section, issues associated with the use of classical viscous damping model are discussed.
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