Chapter 10
Optimization of Tuned Mass Dampers to Improve the Earthquake Resistance of High Buildings

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ABSTRACT

To prevent high buildings in endangered zones suffering from seismic attack, TMD are applied successfully. In many applications the dampers are placed along the height of the edifice to reduce the damage during the earthquake. The dimensioning of TMD is a multidimensional optimisation problem with many local maxima. To find the absolute best or a very good design, advanced optimization strategies have to be applied. Bionic optimization proposes different methods to deal with such tasks but requires many repeated studies of the buildings and dampers design. To improve the speed of the analysis, the authors propose a reduced model of the building including the dampers. A series of consecutive generations shows a growing capacity to reduce the impact of an earthquake on the building. The proposals found help to dimension the dampers. A detailed analysis of the building under earthquake loading may yield an efficient design.

INTRODUCTION

Among the disasters people are exposed to, earthquakes are one of the most damage causing ones. Large numbers of fatalities and big economic losses are reported in many cases. In consequence engineering since long times is trying to design buildings that may withstand the dynamic attack or don't suffer too much from it. The local physical event of a seismic may be handled as a series of horizontal and vertical shock waves which excite the base of a building. The building will show a dynamic response (Chopra, 2000). This dynamic response may cause severe damage or even the total collapse of the structure. At high edifices the dynamic response may be increased by the large deformability of the building. To prevent such destruction different approaches are avail-

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able. They may be classified by increasing the static strength, isolation from the excited ground or compensation by elastically coupled masses along the buildings' height.

Tuned Mass Dampers (TMD) do the damping of the impact by sets of masses, springs and dampers. They might be active, driven by fast reacting control systems or passive, without any specific response to the actual loading. In any case the compensating system has to respond to a certain range of excitations. But as space in high buildings is expensive the total mass and space requirements of the TMD system have to be limited.

Designing efficient passive TMD requires a proposal of position, number and dimension of the compensators. This may include a certain number of compensators each defined by mass, stiffness and damping. As such a system with many degrees of freedom may have many local maxima, the optimization of a set of TMD's could be a non-trivial task. As gradient search strategies converge to the next local optimum only, they are not applicable as long as the proposed original design is far away from the best one. Bionic strategies like Evolutionary Strategy (ES) or Particle Swarm Optimization (PSO) may help to cover larger regions of the parameter space and increase the probability to find god values if not even the best ones.

EARTHQUAKE AND DESIGN FOR EARTHQUAKE LOADING

Often we regard an earthquake loading of a building as a base excitation of the building (Towhata, 2008; Bozorgnia & Bertero 2004). As the mass of the surrounding ground is essentially larger than the building's mass, the excitation may be considered as displacement controlled. The interface between the ground and the building has to follow these displacements.

Methods to Improve the Seismic Load Carrying Capacity of Buildings

The improvement of the static strength by enforcing the load-carrying elements is not always feasible in an economic and aesthetic way. Therefore we need dynamic approaches. To isolate the building's base from the excited ground by layers of elastic material shows very promising results (Naeim & Kelly, 1999, pp. 93-119; Ordonez et al., 2002). Here isolation implies the uncoupling of the buildings' base from the ground by less stiff but damping components. Unfortunately it may be very expensive to produce such an isolating base system for very large and high structures.

Other designs improve the earthquake resistance by dampers or soft parts in an overall stiff structure (Bozorgnia & Bertero, 2004). The dampers absorb some of the impact and limit the damage of the building. But the deflections during an earthquake may be very large, so the local damage could be essential.

We want to present some ideas about Tuned Mass Dampers (TMD) systems (Chopra, 2000, pp. 470-471; Den Hartog, 1956, pp. 103-145; Steinbuch, 2011). The Eigen frequencies, the Eigen forms and the amplitudes at a given excitation of a dynamic system may be changed by adding new masses and springs. One application of this observation could be a qualified selection of springs and masses to reduce the earthquake impact on the building.

Two main approaches are used in practice. Active TMD systems control the displacements of the compensator masses as soon as sensors indicate essential ground motion (Chen & Wu, 2001; Reiterer & Ziegler, 2005; Teuffel 2004). This can be very efficient but requires fast control systems and a lot of energy, which may not be available during the seismic. Compensators using active control have the advantage to respond in a specific way to the external event.

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