Chapter 10
Applications of Topology Optimization Techniques in Seismic Design of Structure

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ABSTRACT
During the last two decades, topology optimization techniques have been successfully applied to a wide range of problems including seismic design of structures. This chapter aims to provide an introduction to the topology optimization methods and a review of the applications of these methods in earthquake engineering. Two well-established topology optimization techniques are introduced. Several problems including eigenfrequency control of structures, compliance minimization under periodic loading, and maximizing energy absorption of passive dampers will be addressed. Numerical instabilities and approaches to overcome them will be discussed. The application of the presented approaches and methods will be illustrated using numerical examples. It will be shown that in seismic design of structures, topology optimization methods can be useful in providing conceptual design for structural systems as well as detailed design of structural members.

1. INTRODUCTION
Solving optimization problems is an inherent part of engineering design where one seeks the best design to minimize or maximize an objective function subject to some constraints. In structural optimization, depending on the nature of the design variables, three different optimization categories can be recognized. Sizing optimization arises when the design variables are connected to the dimensions of the elements. It can be useful where the layout and the shapes of the members...
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Figure 1. The three levels of structural optimization: top) sizing optimization; middle) shape optimization; bottom) topology optimization

are known and it is desired to find the optimum dimensions. On another level, one can choose the design variables to control the shape of the boundaries of the members. Such selection will lead to shape optimization. If the overall layout of the members is known and it is already decided where to put each member, in order to find the best shapes of the members, one can use shape optimization. In order to optimize the topology, connectivity, or layout of a system, topology optimization techniques should be used. In topology optimization the design variables control the topology and connectivity of the design. Figure 1 schematically illustrates these three categories of structural optimization.

Starting from topology optimization and feeding the results to shape and sizing optimization routines will generally result in far greater savings than merely using shape and sizing optimization. Topology optimization techniques can thus be considered as important and powerful tools in hand of design engineers.

In this chapter we review the application of topology optimization techniques in seismic design of structures. We start with a brief review of the history of topology optimization. Then we focus on two general optimization problems in seismic design of structures, the eigenvalue optimization problem and the problem of maximizing the energy absorption.

2. TOPOLOGY OPTIMIZATION

Initially addressed by Culmann (1866), the layout optimization problem is not quite new. The interesting work of Michell (1904) laid down the principles of topology optimization of structures more than a century ago. After that, the field remained untouched for nearly seven decades until Prager and Rozvany improved and generalized the Michell’s theory (e.g. refer to Prager 1969, 1974 and Rozvany 1972a,b). Yet the field didn’t attract much attention until Bendsøe and Kikuchi (1988) proposed a finite element-based numerical method for topology optimization of continuum structures. Usually referred to as the homogenization method, this approach soon became a basis upon which other topology optimization techniques have been developed.
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