Chapter 109
Metaheuristic Optimization in Seismic Structural Design and Inspection Scheduling of Buildings

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ABSTRACT

Optimization is a field where extensive research has been conducted over the last decades. Many types of problems have been addressed, and many types of algorithms have been developed, while their range of applications is continuously growing. The chapter is divided into two parts; in the first part, the life-cycle cost analysis is used as an assessment tool for designs obtained by means of prescriptive and performance-based optimum design methodologies. The prescriptive designs are obtained through a single-objective formulation, where the initial construction cost is the objective to be minimized, while the performance-based designs are obtained through a two-objective formulation where the life-cycle cost is considered as an additional objective also to be minimized. In the second part of the chapter, the problem of inspection of structures and routing of the inspection crews following an earthquake in densely populated metropolitan areas is studied. A model is proposed and a decision support system is developed to aid local authorities in optimally assigning inspectors to critical infrastructures. A combined particle swarm – ant colony optimization based framework is implemented, which proves to be an instance of a successful application of the philosophy of bounded rationality and decentralized decision-making for solving global optimization problems.

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INTRODUCTION

Earthquake loading transfers large amounts of energy in short periods of time, which might produce severe damages on the structural systems. During the last century, significant advances have been made towards the improvement of the seismic design codes. The philosophy underlying modern codes is that the building structures should remain elastic for frequent earthquake events. Under rare earthquakes, however, damages are allowed given that life safety is guaranteed. Hence, the main task of the design procedures is to achieve more predictable and reliable levels of safety and operability against natural hazards. Through extensive research studies it was found that the Performance-Based Design (PBD) concept can be integrated into a structural design procedure in order to obtain designs that fulfill the provisions of a safety structure in a more predictable way (ATC-40,1996, FEMA-350, 2000, ASCE/SEI Standard 41-06, 2006, FEMA-445, 2006, ATC-58, 2009). According to the PBD framework the structural behavior is assessed in multiple hazard levels of increased intensity. Consequently, it is very important to use robust and computationally efficient methods for predicting the seismic response of the structure in order to assess its capacity under different seismic hazard levels.

In the first part of the chapter, 3D reinforced concrete (RC) buildings with regular and irregular plan views were considered in order to examine the sensitivity of life-cycle cost value with reference to the analysis procedure (static or dynamic), the number of seismic records imposed, the performance criterion used and the structural type (regular or irregular). In particular, nonlinear static analysis and multiple stripe analysis, which is a variation of IDA, were applied for the calculation of the maximum inter-story drift and the maximum floor acceleration. The life-cycle cost was calculated for both regular and irregular in plan test examples taking into consideration the damage repair cost, the cost of loss of contents due to structural damage, quantified by the maximum inter-story drift and floor acceleration, the loss of rental cost, the income loss cost, the cost of injuries and the cost of human fatalities. Furthermore, the influence of uncertainties on the seismic response of structural systems and their impact on Life Cycle Cost Analysis (LCCA) is examined. In order to take into account the uncertainty on the material properties, the cross-section dimensions and the record-incident angle, the Latin hypercube sampling method is integrated into the incremental dynamic analysis procedure. In addition, the LCCA methodology is used as an assessment tool for the designs obtained by means of prescriptive and performance-based optimum design methodologies. The prescriptive design procedure is formulated as a single-objective optimization problem where the initial construction cost is the objective to be minimized; while the performance-based design procedure is defined as a two-objective optimization problem where the life-cycle cost is considered as an additional objective also to be minimized.

Infrastructure networks are vital for the well-being of modern societies; national and local economies depend on efficient and reliable networks that provide added value and competitive advantage to an area's social and economic growth. The significance of infrastructure networks increases when natural disasters occur since restoration of community functions is highly dependent on the affected regions receiving adequate relief resources. Infrastructure networks are frequently characterized as the most important lifelines in cases of natural disasters; recent experience from around the World (hurricanes Katrina and Wilma, Southeastern Asia Tsunami, Loma Prieta and Northridge earthquakes and others) suggests that, following a natural disaster, infrastructure networks are expected to support relief operations, population evacuation, supply chains and the restoration of community activities.

Infrastructure elements such as bridges, pavements, tunnels, water and sewage systems, and highway slopes are highly prone to damages caused by natural hazards, a result of possible poor construction or maintenance, of design inconsistencies

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