Chapter III

Evolutionary Seismic Design for Optimal Performance

Arzhang Alimoradi, John A. Martin & Associates, Inc., USA

Shahram Pezeshk, University of Memphis, USA

Christopher M. Foley, Marquette University, USA

Abstract

The chapter provides an overview of optimal structural design procedures for seismic performance. Structural analysis and design for earthquake effects is an evolving area of science; many design philosophies and concepts have been proposed, investigated, and practiced in the past three decades. The chapter briefly introduces some of these advancements first, as their understanding is essential in a successful application of optimal seismic design for performance. An emerging trend in seismic design for optimal performance is speculated next. Finally, a state-of-the-art application of evolutionary algorithms in probabilistic performance-based seismic design of steel moment frame buildings is described through an example. In order to follow the concepts of this chapter, the reader is assumed equipped with a basic knowledge of structural mechanics, dynamics of structures, and design optimizations.
Evolutionary Seismic Design for Optimal Performance

Introduction and Background

About 10 years ago, the rupture of a major blind trust fault in southern California drifted the path of developments in the area seismic design research and practice. The Northridge earthquake of January 1994 ($M_w = 6.7$) and its consequences appeared to be a story of coincidental success and failure. Prior to Northridge, almost all seismic design provisions were set forward based upon the philosophy of minimization of loss of life. During Northridge, only about 57 people lost their lives in an area that is highly developed. Yet, the direct and indirect financial losses in the aftermath of Northridge were estimated in the range of $40$ billion\(^1\). Shortly after, numerous steel moment frame buildings were discovered with a peculiar type of brittle damage in their moment connections in the form of cracking of the complete joint penetration welds that was often propagated into the columns (see Figure 1). The repair was costly but necessary because of a significant loss of lateral strength and stiffness these moment frames had experienced. The problem lead to a large research program on seismic behavior of steel moment frames in the United States (SAC Joint Venture\(^2\)). At the same time, Pacific Earthquake Engineering Research Center (PEER)\(^3\) was developing methodologies for design and evaluation of structures that could perform desirably and predictably under multiple scenarios of seismic attack. The extensive investigations at the PEER center, the SAC project, and other initiatives in California has led to a set of important methodologies and tools (e.g., OpenSees,\(^4\)FEMA-350, FEMA-356, and FEMA-440) for performance-based seismic design and evaluation—many of them currently being practiced in engineering offices (American Society of Civil Engineers [ASCE], 2000; Applied Technology Council [ATC], 2005; Federal Emergency Management Agency [FEMA], 2000a). These advancements make it possible to probabilistically and reliably estimate the structural response parameters (such as interstory drifts, story shear, etc.) under various seismic design scenarios.

Implementation of the new analytical developments and design provisions into reliable and practical computational tools appears to be of essential value to the success of post-Northridge investigations. Optimal seismic design for multiple performance-levels is computationally expensive. We propose and implement a formulation for design automation of structural systems for multiple levels of seismic performance using a naturally-inspired computational agent. The proposed formulation utilizes the advancements in the areas of second-order nonlinear dynamic response evaluation and evolutionary computation. The objective is to develop a general framework, with respect to model and mathematical formulation, as well as mechanical behavior of structural systems and components, in an optimal design formulation. The principles of optimal seismic design for performance, implementation of a genetic algorithm, and an example are explained in this chapter so that they could be used, programmed, and/or practiced by engineers, students, and researchers equally. More examples and a thorough coverage of the methodology can be found in references (Alimoradi, 2004; Foley, 2002; Pezeshk, 1998).
Steel Buildings' Seismic and Interaction Behavior, Under Different Shapes of Tunnel Drilling


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