CHAPTER 8

CONCLUSIONS AND FUTURE WORK

8.1 Conclusions

This Ph.D. study has focused on design optimization of steel special moment resisting frame (SMRF) structures with simultaneous consideration of practical multiple merit objective functions that reflect either present or long-term economic consequences as well as seismic structural performances. Current code provisions are used, including 2000 NEHRP seismic provisions and AISC-LRFD seismic steel design provisions. Genetic algorithms (GAs) are selected as an effective optimization method for the posed structural design problems with discrete standard steel section types as design variables. Three numerical example problems for optimized member sizing of regular plane steel SMRFs have been investigated and the major findings are summarized as follows.

(1) The first numerical example dealt with weight minimization of steel SMRF structures while considering the number of different steel section types as the other competing design objective to roughly account for degree of design complexity. It illustrated that traditional steel frame design procedures based on a minimum weight criterion without explicit consideration of design complexity usually lead to a final structural design consisting of a large number of different steel section types. Because the increased degree of design complexity indicates additional construction cost, an experience-based tradeoff analysis of optimized design solutions in terms of structural weight and degree of design complexity will locate a more realistic economical design from the overall initial cost perspective.

(2) In the second numerical example, design optimization of steel SMRFs was carried out within a performance based seismic design framework. Relevant merit objectives include a steel material weight, number of different steel section types, and maximum interstory drift ratio demands at two hazard levels with exceedance probabilities being 50% and 2% in 50 years, respectively, in accordance with FEMA-350 documents. The resulting large pool of optimized tradeoff alternative designs provided much flexibility for structural engineers to determine a structural design with the most desirable seismic performances as well as the balanced initial investment.

(3) Life cycle cost oriented design optimization was performed in the last numerical example. Most of the existing procedures sought for a design solution with minimum expected total life cycle cost, which was a direct summation of initial cost and the expected lifetime seismic damage cost. In this study, initial cost and damage cost were treated as two separate objective functions together with the number of different section types as the third objective function. In accordance with SAC/FEMA guidelines, percentile limit state probabilities based on user-specified confidence level were used to quantify the lifetime damage cost. Designers' risk-acceptance level is therefore integrated into the life cycle cost design optimization process. A designer can then actively select the final structural design with a preferred balance between initial coat and damage cost while taking into due account of design complexity as well as confidence level on seismic impacts.

In conclusion, the present GA-based multiobjective design optimization methodology provides a viable framework to automatically produce a tradeoff distribution of optimized design solutions, which help design engineers and/or other parties involved to actively select the structural design that balances all selected conflicting merit objectives in the most desirable manner. This represents a significant improvement from the conventional single-objective based design optimization procedures, which lead to a single final optimized structural design only and hence do not provide an explicit tradeoff among competing merit objective concerns to aid the design-making process.

8.2 Future work

The present study has laid workable basis for the following future research topics listed in the order of sophistication and/or knowledge accessibility:

(1) A simple structural model of the steel SMRF was used throughout this study. It is expected that, by incorporating other factors such as realistic panel zone and connection behaviors, the resulting refined model will better simulate 'true' seismic responses and thus will improve the quality of optimized design solutions.

(2) The fundamental structural mode based static pushover analysis was used in this study as an approximate means to evaluate seismic performances. Advanced/adaptive static pushover procedures have been proposed in the literature (e.g., Gupta and Kunnath 2000) that make use of higher mode contributions. More reliable response estimates could be obtained accordingly.

(3) Degree of design complexity was roughly accounted for in this study by the number of different steel section types. It will be more convenient for decision makers if this complexity concern could be directly converted to equivalent material usage or additional construction expenses with acceptable accuracy.

(4) In addition to side-sway steel frame systems investigated in this study, it will be interesting to optimize steel frames with various bracing scenarios as well as other structural types such as reinforced concrete frames or dual systems consisting of steel frame and structural wall.

(5) The closed-form damage cost estimate used in this study assumes that damaged buildings would be retrofitted to their original intact conditions after each major seismic event. In practice, however, retrofit may usually be performed only when damage severity exceeds some threshold or when the system reliability is below a predefined level. In view of these considerations, costs due to lifetime seismic damages and related retrofit efforts could be evaluated, for example, based on the Markov chain model and simulation techniques (Montes-Iturrizaga et al. 2003).

(6) In this study seismic energy imparted to the structural system was dissipated entirely through inelastic responses of bare structural members. Seismic performance can be significantly enhanced by introducing supplemental passive, semi-active, or active energy dissipation devices that decrease seismic energy demands on the primary structural system (e.g. Soong 1990; Soong and Dargush 1997). Existing research has emphasized optimizing allocation/location and parameterization of such devices to best possibly retrofit existing structures. Integrated design optimization of new civil structural systems with energy dissipation devices has not received adequate attention (Adeli and Saleh 1998). Recent seismic provisions (FEMA-273; FEMA-368) provide guidelines for designing building structures equipped with passive devices in order to improve structural performances. Development of practical automated optimization procedures in this regard would have the promises of achieving more cost-competent design solutions.