CHAPTER 1 INTRODUCTION

1.1 Background

Current seismic design is generally carried out assuming elastic structural behavior. Inelastic behavior is accounted indirectly using seismic performance factors such as the response modification coefficient (R), the system overstrength factor (Ω_0), and the deflection amplification factor (C_d). The design load is given by

$$V = \frac{V_e}{R} \tag{1-1}$$

where V_e is the base shear when the structure behaves elastically. Structures designed using this approach have been found to undergo large inelastic deformation in an uncontrolled manner. The unevenly distributed inelastic activities may result in unpredictable response and sometimes total collapse. The repair work may be very difficult or costly.

Societal demands are now requiring building structures to achieve higher levels of performance, safety, and sustainability including life cycle costs of maintenance. To respond to this requirement, the engineering community has adopted the performance-based framework (Bozorgnia and Bertero, 2004). This approach thoroughly examines the behavior of the system and individual element in a structure at various levels of ground shaking intensity to ensure that the performance of the structure is as intended. To this end, a complete performance-based plastic design (PBPD) methodology, which accounts for structural inelastic behavior directly and practically eliminates the need for any assessment or iteration after initial design, has been developed (Goel and Chao, 2008). The PBPD method has been applied and validated for many conventional structural systems such as moment frames, eccentrically and concentrically braced frames, and special truss moment frames (Chao and Goel, 2008).

In this research, a PBPD approach for an innovative structural system called Buckling-Restrained Knee Braced Truss Moment Frame (BRKB-TMF), illustrated in Figure 1.1, was developed. The BRKB-TMF system is invented by combining features of truss moment frames (TMFs), knee brace moment frames (KBMFs) and buckling restrained braced frames (BRBFs). In this system, the solid web beams are replaced by open-web girders in order to reduce self-weight and provide passages for ductwork. Buckling restrained braces (BRBs) are used to eliminate brace buckling behavior and increase the overall ductility of the system.

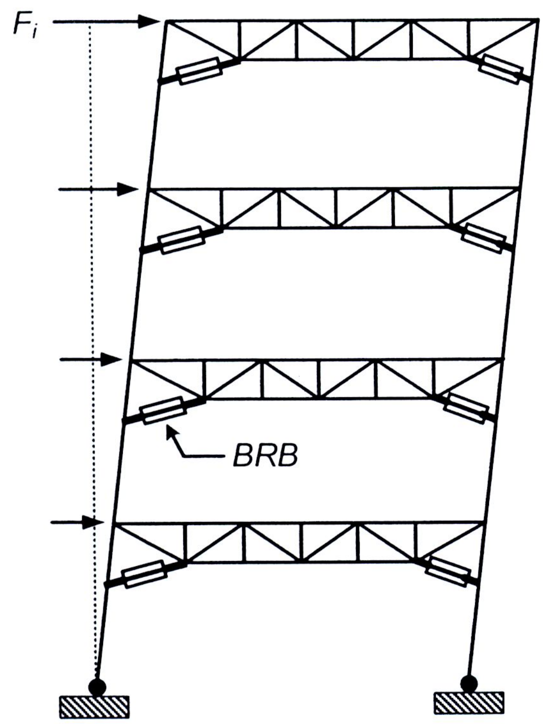

Figure 1.1 Buckling-Restrained Knee Braced Truss Moment Frame (BRKB-TMF)

To ensure that BRKB-TMF system designed by the newly developed PBPD approach is sufficiently safe and can be effectively used as a lateral force resisting system, a probabilistic seismic evaluation was carried out using a study frame. The evaluation of probabilistic collapse margin was done in accordance with FEMA P695 (2009) performance evaluation procedure. The probabilities of collapse were calculated for different levels of ground motion intensity and were compared with acceptable criteria. The end results from this research provide a theoretical verification of the effectiveness of BRKB-TMF system.

1.2 Objectives

1. To develop a design procedure for an innovative seismic resistant system called Buckling-Retrained Knee Braced Truss Moment Frame (BRKB-TMF) following the performance-based plastic design (PBPD) methodology.
2. To investigate dynamic behavior of a BRKB-TMF in a 4-story building located in a high seismic region.
3. To verify dynamic behavior and response of the BRKB-TMF structure designed by PBPD concept.
4. To perform a probabilistic collapse assessment of the BRKB-TMF example structure using incremental dynamic analysis approach (IDA) in accordance with FEMA P695 procedure.

1.3 Scope of Research

1. The archetype structure is a low-rise steel building located on soil profile type D.
2. All connections are assumed to be sufficiently strong and ductile with no fatigue failure.
3. Only truss members, BRBs and columns are explicitly designed.
4. The nonlinear analyses are performed using the far-field record set as recommended in FEMA P695.

1.4 Organization and Outline

This research is organized into seven chapters and four appendices. Chapter 1 presents the background and motivation leading to the development of the innovative BRKB-TMF system. Chapter 2 presents the studies related to relevant structural systems, design methodology, and performance evaluation method. Chapter 3 presents the PBPD method for the proposed system. The design and evaluation of the proposed system is implemented with an example 4-story building described in Chapter 4.

Chapter 5 presents force-deformation characteristics of all structural components used in the modelling of the BRKB-TMF system. The model is used in all nonlinear analyses presented in Chapter 6. In this chapter, dynamic response of the proposed system is investigated, including collapse evaluation. Fragility curves are also generated. Sensitivity of the frame response based on different value of BRB strain capacity is finally examined. The summary of this research is presented in Chapter 7.

Appendix A presents a guideline for the selection of the truss configuration and approximation of strain demand in the BRBs. Appendix B presents load definitions, including seismic masses, gravity loads, and load combinations used in design of the example structure. Appendix C presents an example of design calculations in detail. Finally, Appendix D presents a brief review of log-normal distribution and curve fitting of cumulative distribution function (CDF) used in the generation of fragility curves. The IDA results are also presented in this appendix.