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Seismic performance assessment of Strong-back braced frames at collapse level

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Abstract

In prescriptive seismic design codes, quantification of seismic performance factors (R, Ω, Cd) for new structural systems is decisive step. One of the recent introduced structural bracing systems is called Strong-Back System (SBS), which is a hybrid of a conventional inelastic system and an essentially elastic steel truss designed to distribute demands uniformly. The purpose of this study is to evaluate these factors for SBS. To this end, series of nonlinear static and dynamic analyses are conducted and the derived parameters are compared with the accepted values proposed by FEMA-P695. The results indicated that R=6 can be appropriate value for SBS.

Keywords: Braced frames, Seismic performance factor, Strong-back systems, CMR, Nonlinear analysis.

1. INTRODUCTION

The common pattern of conventional seismic design codes is to use linear behavior to evaluate the seismic response of the structure during earthquakes. Generally, the design process begins by choosing a resistant structural system whose functional requirements were determined earlier in the seismic code. These requirements specify the type, size, configuration, details, and minimum strength and stiffness. In these methods, the design of the structure is based on force and strength and to simplify the nonlinear response of structural systems we are using seismic performance factors; response modification factors (R), over-strength factors (Ω), and deflection amplification factors (Cd). With recent advancement in structural engineering, various structural systems have been proposed, which their seismic performance factors are often based on engineering judgment [1].

Among various structural systems, concentrically steel braced systems are an economical and effective system for preventing lateral deformations in buildings under earthquake or wind excitation. However, a number of failures have been identified in these systems in recent large earthquakes [2]. One of them is the tendency to form a soft-story mechanism. The main reason for the occurrence of this mechanism is a sudden change in the stiffness and strength of successive floors. Design codes have specific regulations for preventing this mechanism, but in concentric bracing systems, due to the buckling behavior of the compression brace element, sudden deformations are concentrated in one or more floors. Figure 1-a shows schematically the concentration of displacement under the earthquake excitation and the brace buckling that occurred on the first floor [2].

There are many strategies to improve the concentric bracing systems behavior that varies from component to system level. Buckling Restrained Braces (BRB) and self-centering bracing systems are two examples of these methods. However, they still do not resolve the concentration of deformation and large residual displacement. Even in some cases, the amount of residual displacement of these systems has been reported more than usual concentric bracing systems [2].

Therefore, there is a need for a bracing system that reduces the maximum displacement demand in the bracing member and also be able to control the amount of residual displacement value [2], [3]. In this regard, a new hybrid system called the Strong-back system was proposed by Lai and Mahin [2]. In this system, combination of a leaning frame into a vertical truss in a part of the bracing span prevents the formation of a soft-story by its elastic behavior. The vertical truss imposes a uniform deformation to the structure at its height. Figure 1-b presents the effect of using a strong-back system on the uniform distribution of relative displacement [2]. Many aspects of the seismic behavior of this system are unknown and further investigation