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Overall buckling behavior of all-steel buckling restrained braces

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ABSTRACT

One of the key requirements for the desirable mechanical behavior of buckling restrained braces (BRBs) under severe earthquake loading is to prevent global buckling until the brace member reaches sufficient plastic deformation and ductility. This paper presents finite element analysis results of the proposed all-steel buckling restrained braces. The proposed BRBs have identical core sections but different buckling restraining mechanisms (BRMs). The objective of the analysis is to conduct a parametric study of BRBs with different amounts of gap (between the core and the BRM) and initial imperfections to investigate the global buckling behavior of the brace. The results of the analysis showed that BRM flexural stiffness could significantly affect the global buckling behavior of a brace, regardless of the size of the gap. In addition, a minimum ratio of the Euler buckling load of the restraining member to the yield strength of the core, P_e/P_y is suggested for design purposes. This ratio is the principal parameter that controls the global buckling of BRBs.

1. Introduction

Buckling restrained braced frames (BRBFs) for seismic load resistance have been widely used in recent years. A BRBF differs from a conventionally braced frame because it yields under both tension and compression without significant buckling. Most buckling restrained brace (BRB) members currently available are built by inserting a steel plate into a steel tube filled with mortar or concrete. The steel plate is restrained laterally by the mortar or the steel tube and can yield in compression as well as tension, which results in comparable yield resistance and ductility, as well as a stable hysteretic behavior in BRBs. A large body of knowledge exists regarding conventional BRBs' performance. Black et al. performed component testing of BRBs and modeled a hysteretic curve to compare the test results and found that the hysteretic curve of a BRB is stable, symmetrical, and ample [1]. Inoue et al. introduced buckling restrained braces as hysteretic dampers to enhance the seismic response of building structures [2]. As shown in Fig. 1, a typical BRB member consists of a steel core, a buckling restraining mechanism (BRM), and a separation gap or unbonding agent, allowing independent axial deformation of the inner core relative to the BRM. Numerous researchers have conducted experiments and numerical analyses on BRBs for its incorporation into seismic force resisting systems. Qiang investigated the use of BRBs in practical applications for buildings in Asia [3]. Clerk et al. suggested a design procedure for buildings incorporating BRBs [4]. Sabelli et al. reported seismic demands on BRBs through a seismic response analysis of BRB frames [5], and Fahnestock et al. conducted a numerical analysis and pseudodynamic experiments of large-scale BRB frames in the US [6].

The local buckling behavior of BRBs has been studied by Takeuchi et al. [7]. The effective buckling load of BRBs considering the stiffness of the end connection was recently studied by Tembata et al. [8] and Kinoshita et al. [9]. Previous studies have demonstrated the potential of manufacturing BRB systems made entirely of steel, called all-steel BRBs [10]. In a common all-steel BRB, the steel inner core is sandwiched between buckling restraining mechanisms made entirely of steel components, thus avoiding the cost of mortar needed in conventional BRBs. This eliminates the fabrication steps associated with pouring and curing the mortar or concrete, significantly reducing manufacturing time and costs. In addition, such a BRB can be easily disassembled for inspection after an earthquake. Experimental and analytical studies on the deformation performance and dynamic response of BRBs have been performed by Kato et al. [11], Watanabe et al. [12], and Usami et al. [13]. The restraining member proposed previously was a mortar-filled steel section, which made an extremely rigid member. In such types of BRBs, the brace member and the BRM were integrated, and overall buckling did not occur. However, in all-steel BRBs, which are considered to be a new generation of BRBs, the brace system is completely made of steel, and the BRM system is lighter in comparison with conventional BRBs, which leads to a high potential for brace overall buckling caused by the low rigidity and stiffness of the BRM. The hysteretic behavior of all-steel BRBs was experimentally investigated by Tremblay et al. [10]. An experimental study on the hysteretic behavior of all-steel BRBs was also conducted by Eryasar et al. [14].

The following characteristics are considered necessary for the safe performance of BRBs: 1) the prevention of overall buckling, 2) the prevention of core local buckling, 3) the prevention of low cycle

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