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Seismic responses of reinforced concrete frames with buckling restrained braces in zigzag configuration

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A B S T R A C T

A new buckling restrained braced frame system was proposed in a previous study for reinforced concrete frames, which was featured by the zigzag configuration of buckling restrained braces to ease the steel-to-concrete connection. Experimental tests were conducted to establish realistic numerical models of the brace connections in the proposed system. With these numerical models, a nonlinear dynamic analysis of a prototype building was conducted to investigate the seismic behavior of the new braced frame system. The results indicate that the buckling restrained braces in the new system are efficient in reducing the responses of the building, even if the nonlinearity of the brace connection is considered. Furthermore, the strength demands for the brace connections are significantly influenced by higher modes of the system after the braces yield.

1. Introduction

The seismic performance and design of gusset connections are critical for steel braced frame structures. In addition to the brace action that is well addressed in design codes such as AISC 360 [1], corner gusset plates are frequently subjected to 'frame actions,' which can be quite complicated [2,3] and may lead to premature fracture of welds or buckling of gusset plates, thus impairing the seismic performance of the system [4]. It is impractical to include such complicated behavior of gusset connections in structural modeling for routine design purposes. Instead, the braces are usually assumed to be pin-connected to the frame by using truss elements in the structural analyses, such as those conducted by [5,6].

The frame action in gusset connections remains a problem when implementing steel braces in reinforced concrete (RC) frames. In addition to its detrimental effects on the gusset plates, it may also result in considerable over-strength in RC frames [7] and sometimes unfavorable shear failure of adjoining concrete columns [8] by reducing their effective lengths. To make it worse, steel braces in conventional configurations impose large concentrated tensile force on gusset connections. It is not easy to transfer this force to concrete members because concrete is weak in tension. While fundamental tests were conducted to investigate the performance of steel gusset-to-concrete connections [9,10], new solutions other than conventional corner gusset connections have been proposed, such as that of fastening the gusset plates to the side surfaces of RC beams by post-tensioned steel rods [11–14], and that of anchoring the gusset plates by shear-key plates that are exempt from significant tensile forces [15,16]. Another example is the 'unconstrained gusset connection' on the top surface of RC beams [17], which is an extension of a similar idea for steel frames [18]. Similar connection details was also applied to the BRB-to-pile cap connections in the tests specimens of strengthening non-ductile RC frames with BRBs [19].

Taking advantage of the capacity of buckling restrained braces (BRBs) to develop full plastic strength in both tension and compression [20], a zigzag buckling restrained braced frame system was proposed for RC structures in previous studies (referred to as 'continuously bucking restrained braced frame' in [21,22]). As illustrated in Fig. 1(a), BRBs in the proposed system are arranged in a zigzag layout and those in neighboring stories share the same gusset plate so that they run continuously along the height of the structure. Instead of fitting into the corners of beams and columns, the shared gusset plates are attached to the sides of beam-column joints so that the 'frame action' in conventional corner gusset

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