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Modeling the panel zone in steel MR frames composed of built-up columns

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ABSTRACT

This paper proposes an analytical model for the panel zone of connections of steel moment-resisting frames (SMRFs) composed of built-up columns with double sections and a vertical continuity plate. Panel zone in these connections consists of a middle panel, which is the vertical continuity plate, and two side panels, which are the webs of double sections of the column. Since the general behavior of these frames is governed by deformation of the middle panel, this panel is assumed as the primary one and the two side panels are assumed to be secondary. The column cover plates connecting the double sections and vertical continuity plate play an important role in providing compatibility of deformations. The new model proposed in this study is based on the previously developed models for the panel zones of connections in which the webs of beam and column are in the same plane, however, a number of refinements are introduced to capture the behavior of this type of connections. This quadri-linear model can be used for monotonic loading and accounts for both shear and bending deformations of panel zone. The results of this model are compared to those of finite element (FE) models verified by full scale experiments. The proposed model shows a good agreement, especially in elastic range, with the FE results. The results of FE analysis for important parameters affecting the panel zone behavior have also been compared to those obtained from the model in order to confirm the proposed model.

1. Introduction

Moment-resisting frame (MRF) is a structural system, which is widely used in steel building construction, and thus many investigations have been carried out to determine its behavior and performance, especially in seismically active regions. Panel zone in connections of this type of frame, which is a part of the column framed by column flanges and horizontal continuity plates, has been studied extensively in the past due to its important influence on seismic behavior of MRFs and design criteria have been proposed for traditional connections in which the webs of beam and column are in the same plane. Large shear forces are induced in the panel zone when lateral load is applied to a MRF. Since well-designed joints are ductile elements, it has been proposed to design panel zones so that they yield in shear and participate in energy dissipation in severe earthquakes. Hence, the best design is considered to be the one in which inelastic deformation demands in beams and joints are balanced [1].

Deformations of the panel zone can significantly affect the frame response both in linear and nonlinear regions [2,3]. Therefore, some relations have been proposed to describe the elastic and inelastic behavior of this part of the structure. Some design codes allow the plastic hinges to form in the panel zones of MRSFs under earthquake loading [4–6]. Thus, in order to evaluate the frame response under earthquake loading, an accurate model for predicting the panel zone response is needed.

Several researchers such as Krawinkler et al. [7], Fileding and Huang [8] and Wang [9] proposed relationships between the shear force, V, and deformation , γ , in panel zone for monotonic loading. These relationships have been used as the basis of mathematical models for non-linear rotational springs representing the panel zone. Krawinkler's V–γ relations have been adopted in several building codes [4,5] as the basis for computing the shear strength in panel zones. However, Krawinkler recognized that a new model might be needed for the joints with thick column flanges since his V–γ relations were derived from experimental and analytical results for the panel zones with relatively thin column flanges [7,10]. Wang showed that Krawinkler's V–γ relations may overestimate the panel zone's shear strength for thick column flanges [9,10]. As the ratio of column flange thickness to column depth increases, the influence of column flange thickness on the panel zone yield strength and elastic stiffness increases too [9]. However, the panel zone models that include just shear deformations cannot account for this increase in yield moment and elastic stiffness. Kim and Engelhardt [10] proposed a model with quadri-linear $M^{pa}-\gamma$ relations, in which both bending and shear deformation modes are included and can reasonably describe the increase of yield strength and elastic stiffness due to increase in the ratio of column flange thickness to column depth and inclusion of the bending deformation mode.

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