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# Compressive behavior of dual-gusset-plate connections for buckling-restrained braced frames

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ABSTRACT

This work conducts compression tests and finite element analyses for steel dual-gusset-plate connections used for buckling-restrained braced frames (BRBFs). Compared to a single-gusset-plate connection, dual gusset plates sandwiching a BRB core reduce gusset plate size, eliminate the need for splice plates, and enhance connection stability under compression. The experimental program investigated ultimate compression load by testing ten large dual-gusset-plate connections. Out-of-plane deformation of the gusset plate in the test resembled that of a buckled gusset plate with low bending rigidity provided by the BRB end. The general-purpose nonlinear finite element analysis program ABAQUS was applied for correlation analysis. A parametric study of the dual-gusset-plate connection was performed to study the effects of plate size, presence of centerline stiffeners, and beam and column boundaries on ultimate compression load. The ultimate compression load of the dual-gusset-plate connection could not be predicted based on the AISC-LRFD approach due to beam flange out-of-plane deformation. The ultimate compression load of the dual-gusset-plate connection was reasonably predicted using a column strip length from the Whitmore section to the workpoint of the beam and column centerlines and a buckling coefficient of $K=2$.


## 1. Introduction

Buckling-restrained braced frames (BRBFs) for lateral load resistance have been increasingly used in recent years [1–5]. The BRBF differs from a steel concentrically braced frame (CBF) because a buckling-restrained brace (BRB) yields in both tension and compression without global buckling. Since the restraining member provides continuous lateral support for the BRB core, high-mode buckling in the core maintains stable energy dissipation under compression [4]. For a BRB with a single core, a single gusset plate, commonly used in CBFs, is adopted in BRBFs to connect a BRB to the beam and column (Fig. 1(a)). Many splice plates and bolts are used to connect a single gusset plate and a BRB core. During a severe earthquake, braces in CBFs are subjected to large axial deformations in cyclic tension and compression into the post-buckling range. For a brace buckling out of plane with single plate gussets, weak-axis bending in the gusset is induced by member end rotations. Satisfactory performance of a brace can be ensured by allowing the gusset plate to develop restraint-free plastic rotations, *i.e.* buckling [6]. Conversely, no gusset plate buckling is allowed in a BRBF during a severe earthquake, ensuring stable energy dissipation in the BRB. The AISC seismic design provisions [6] require consideration of gusset plate instability because recent BRBF tests by Chou and Liu [5], Aiken et al. [7], Tsai et al. [8], and Chou and Chen [9] demonstrated out-of-plane gusset plate buckling before a BRB reached ultimate compression load.

The compressive behavior of gusset plate connections in a CBF has received limited attention [10]. Thornton [11] proposed that buckling load of a gusset plate ($P_{cr,Th}$) can be considered as the compressive strength of a fixed–fixed column strip below the Whitmore effective width [12], $b_e$ (Fig. 1(b)). The length of the column strip, $L_c$, is the maximum of $L_1$, $L_2$, and $L_3$; the buckling coefficient, $K$, is 0.65. A column buckling equation combined with the Whitmore sectional area is adopted to estimate ultimate compression load of a gusset plate. Gross and Cheok [13], however, used the average of lengths $L_1$, $L_2$, and $L_3$ and $K$ of 0.5 to estimate the buckling load of a gusset plate ($P_{cr,GC}$). When the end of a brace moves out of plane, a conservative value of 1.2 or 2 for $K$ in the column buckling equation was recommended by Astaneh-Asl [14] and Tsai et al. [8], respectively. Thornton's design concept, adopted in the AISC-LRFD specification and design examples [15,16], is used to estimate ultimate load of a gusset plate under compression, $P_{cr,AL}$:

$$
\begin{aligned}
P_{cr,AL} &= (0.658)^{\lambda_c^2} b_e t F_y, \quad \lambda_c \le 1.5 \\
P_{cr,AL} &= \left(\frac{0.877}{\lambda_c^2}\right) b_e t F_y, \quad \lambda_c > 1.5
\end{aligned}
\tag{1}
$$

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