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Stiffness of Panel Zones with Cover Plates

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Abstract: In steel moment frames, panel zone flexibility contributes to story drift, so cover plates are often used to stiffen the panel zones. Detailed finite element models were used to evaluate the effectiveness and efficiency of different styles of cover plates. The finite element analyses found that standard cover plates, as used in DuraFuse Frames, provide the same panel zone stiffness as extended cover plates, while requiring less plate weight. When engineers are comparing moment frame systems with cover plates, they should use the same panel zone assumptions regardless of whether standard or extended cover plates are used. When rigid panel zones are assumed for DuraFuse Frames, cover plates will be checked to ensure they meet the requirements for that assumption per ASCE 41 guidance.

Introduction

The flexibility of panel zones in steel moment frames may significantly impact overall frame stiffness and must be considered in the structural design model (ASCE, 2016). Some moment connections use cover plates to strengthen and stiffen the panel zone. Fig. 1 illustrates two styles of cover plates, designated as “standard” and “extended” herein.

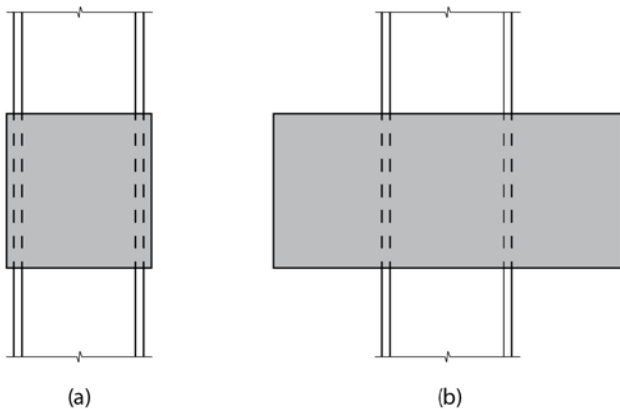


Fig. 1 Two styles of column cover plates: (a) standard, (b) extended

This bulletin reports a study that was done to quantify the effectiveness of standard and extended cover plates in stiffening panel zones. The bulletin includes discussion on how panel zones should be represented in structural design models.

FE Study

A parameter study was conducted to evaluate the panel zone stiffness for columns with different styles of cover plates. Two styles of cover plates (standard and extended) were considered in combination with two different column sizes (W18×175 and W27×178) and three cover plate thicknesses (1, 1.375, and 1.5 in.). Fig. 2 illustrates the geometries used in the study. The dimension d was 24 in. for W18×175 columns, and 36 in. for W27×178 columns (Fig. 2).

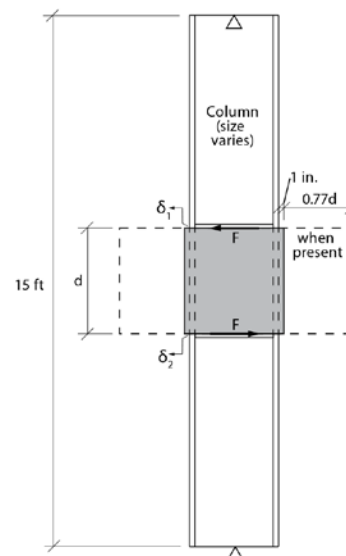


Fig. 2 Geometry and sizes for the models used in the study

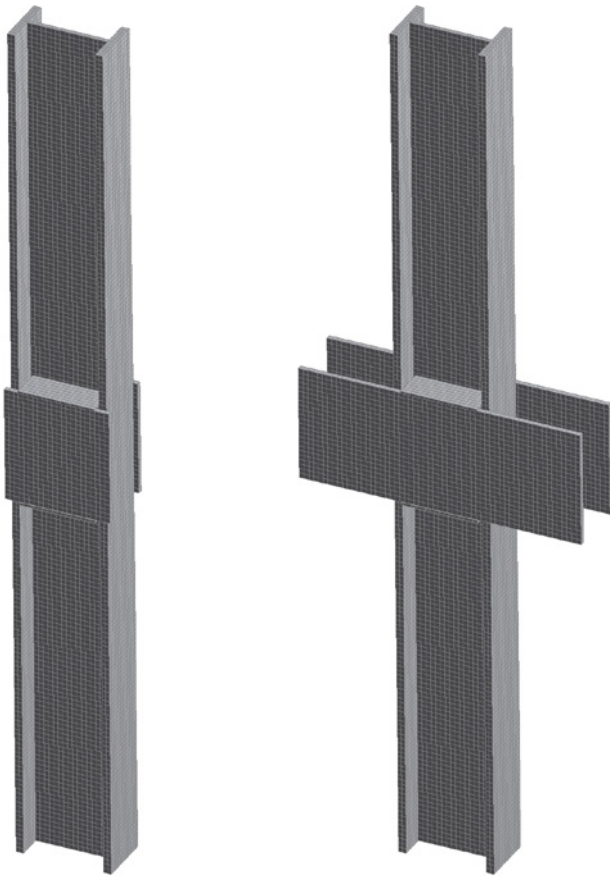


Fig. 3 Finite element models used for the analyses: (a) standard cover plates, (b) extended cover plates; cases with W18x175 column and 1 in. thick cover plates are shown

Finite element models were developed in ANSYS to investigate the panel zone stiffness for the different cases. The elastic material properties in the models were 29,000 ksi for the modulus of elasticity and 0.3 for Poisson's ratio. Brick elements (8 node) with a 1 in. size were used for the mesh (Fig. 3). Boundary conditions and loading were as illustrated in Fig. 2. The applied force (F in Fig. 2) was 10 kips, well below what would cause yielding.

The elastic panel zone shear deformation, γ , in the ANSYS models was computed as $(\delta_1 - \delta_2)/d$ (see Fig. 2). The elastic stiffness of the panel zone was computed as the applied moment ($F \times d$) divided by the panel zone shear deformation.

Results

Fig. 4 summarizes results for the cases that had a W18x175 column. The panel zone stiffness increased linearly as cover plate thickness was increased (Fig. 4), which is consistent with panel zone theory (Charney and Marshall, 2006). The results show no difference in panel zone stiffness for standard cover plates as compared to extended cover plates (Fig. 4). Mises stress plots show that the cover plate outside the panel zone is not active in resisting panel zone shears (Fig. 5), which is consistent with the results in Fig. 4 and theory.

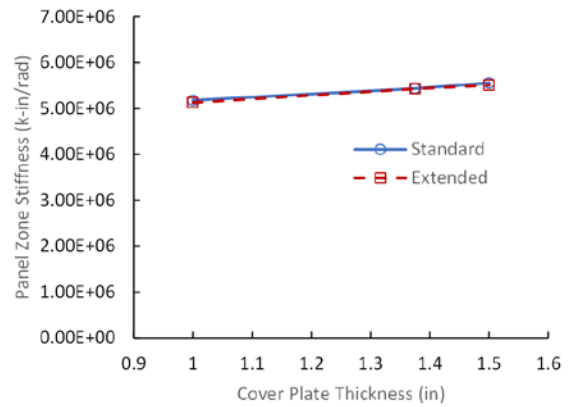


Fig. 4 Panel zone stiffness for cases with W18x175 column

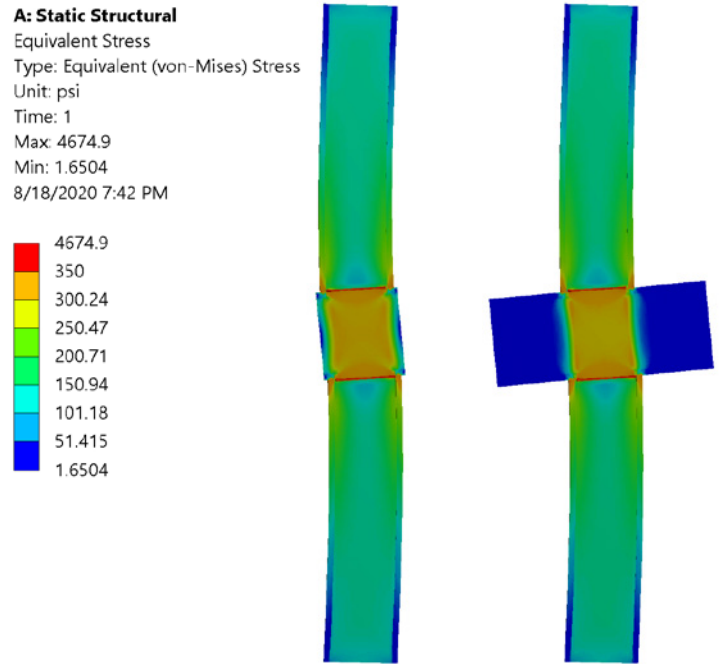


Fig. 5 Mises stress plots for cases with W18x175 column and 1 in. thick cover plates

Figs. 6 and 7 show similar results for the cases with a W27x178 column. The panel zone stiffness increased linearly as cover plate thickness was increased (Fig. 6) and there was no difference in panel zone stiffness for standard cover plates as compared to extended cover plates (Fig. 7).

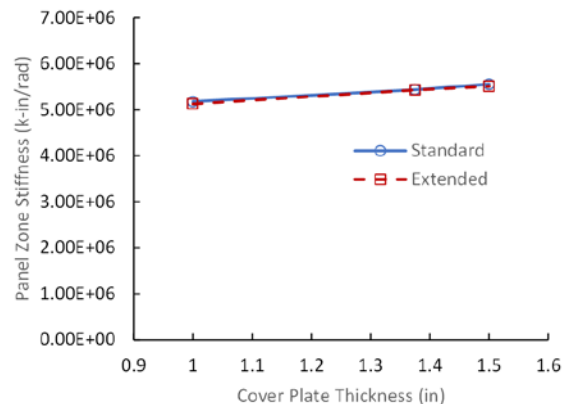


Fig. 6 Panel zone stiffness for cases with W27x178 column

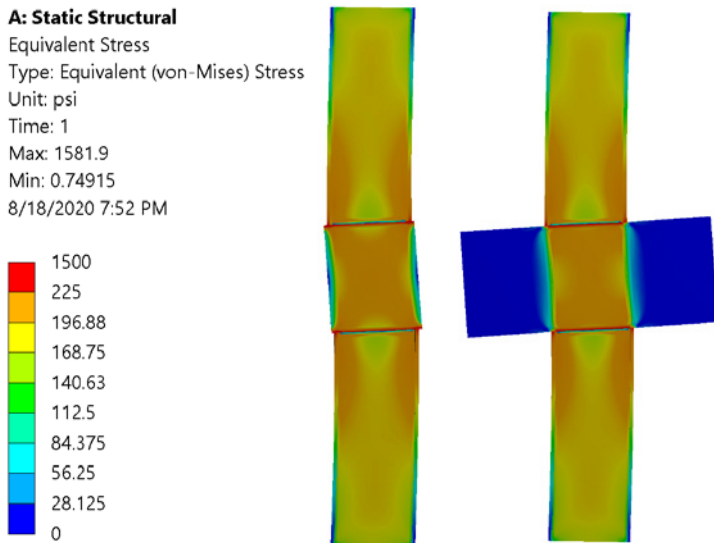


Fig. 7 Mises stress plots for cases with W27×178 column and 1 in. thick cover plates

Discussion

The results of this study clearly indicate that extended cover plates are no more effective in stiffening the panel zone than standard cover plates. In design, the same assumptions should be made for the panel zone stiffness of connections with standard cover plates as for extended cover plates.

ASCE 7-16 states that “for steel moment frame systems, the contributions of panel zone deformations to overall story drift shall be included” (ASCE, 2016). When panel zones are stiffened with cover plates, panel zone contributions to story drift are diminished. In some cases, the contributions are small enough that engineers do not consider them explicitly.

ASCE 41-17 provides some guidance on how stiff a panel zone should be in order to not have to consider the contributions explicitly. ASCE 41-17 9.4.2.2.1.3 says: “Where the expected shear strength of the panel zone exceeds the flexural strength of the beams at the beam-to-column connection, and the stiffness of the panel zone (converted to a rotational spring) is at least ten (10) times larger than the flexural stiffness of the beam, direct modeling of the panel zone shall not be required. In such cases, rigid offsets from the center of the column shall be permitted to represent the effective span of the beam” (ASCE, 17).

This approach to panel zones is similar to the approach to modeling connection stiffness. Connections, with sufficient stiffness to be classified as FR, are permitted to be modeled as rigid, while those that are classified as PR must have a spring included in the model to represent the connection flexibility.

One proprietary connection that uses extended cover plates recommends that the panel zone be modeled with 100% rigid end offsets in the beam (AISC, 2016). While this neglects some panel zone deformation, it is convenient for design. When DuraFuse Frames are

being compared with such SMFs, the same panel zone assumptions (100% rigid end offsets) should be made to achieve a fair comparison.

DuraFuse Frames panel zones, with cover plates proportioned for strength requirements, generally have more-than-sufficient stiffness to satisfy the criteria in ASCE 41-17 for using 100% rigid offset assumptions. When rigid panel zones are assumed in design, DuraFuse Frames engineers will check joints per the criteria in ASCE 41-17 and confirm that cover plates have sufficient thickness to make the panel zone stiffness at least ten (10) times greater than the beam flexural stiffness.

Summary and Conclusions

Panel zone flexibility must be considered in steel moment frame design. Some steel moment frames use cover plates to stiffen the panel zone. ANSYS models were used to evaluate panel zone stiffness, considering the effects of column size, cover plate thickness, and cover plate style (standard or extended). The FE analyses found that standard cover plates, as used in DuraFuse Frames, provide the same panel zone stiffness as extended cover plates.

When engineers are comparing moment frame systems with cover plates, they should use the same stiffness assumptions for standard or extended cover plates. When rigid panel zones are assumed for DuraFuse Frames, cover plates will be checked to ensure they meet the requirements for that assumption per ASCE 41-17 guidance.

References

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