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Parametric Study of Welded Gusset Plates Performance in Concentric Braced Steel Frames under Cyclic Loading

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ABSTRACT: In this paper, the behavior of gusset plates in concentric braced steel frames under cyclic loading has been studied. The behavior is studied by comparing dissipated energy, plastic strains of welds between the gusset plate and beam, column and bracing, plastic strains at the midspan of the bracing, and Von Mises stresses and plastic strains of the gusset plates. Studied parameters are the thickness and shape of the gusset plate, use of linear and elliptical clearance, non-existence of clearance, edge, longitudinal and internal stiffeners, and use of a single- or double-profile bracing. Non-linear analysis has been performed by the finite element ABAQUS code. Obtained results showed that by eliminating the clearance, the plastic strains in weld between the gusset plate and bracing and plastic strains in the gusset plate are increased considerably. The maximum value of energy dissipation has belonged to edge stiffeners with an increase of 15.4% compared to the unstiffened gusset plate.

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1. INTRODUCTION

Until recent years, the most of studies on the distribution of elastic or plastic strains in gusset plates have been focused on monotonic concentrated loads and less attention has been paid for their behavior under cyclic loads [1]. In general, concentric braced steel frames are designed so that under seismic loads the energy be dissipated by buckling or yielding of the bracing. Other members are designed for a load carrying level that leads to the buckling and yielding of the bracing [2-4]. In this research, the performance of gusset plates in a single bay concentric braced steel beam under cyclic loading is investigated. The model comprises a beam, two columns, a brace and two gusset plates (Fig. 1). Beam to column connection is rigid with the use of penetrated weld. A double profile is used for the bracing. The studied parameters are the thickness and the shape of the gusset plate, use of linear and elliptical bending lines and non-existence of the free line of bending, comparison of the effects of the edge and inner stiffeners, and the use of single-profile brace.

The objective of this research is the comparison of the performance of different lines of bending and their effect on the gusset plate, the effect of inner stiffeners, and the effect of used bracing on stress distribution and energy dissipation of the gusset plate.

2. ELEMENTS OF THE EXTENDED ABSTRACT

Steel profiles used for the beam and columns are those used by Nascimbene et al. [5]. The dimensions and size of the gusset plate and weld have been designed based on American codes [2, 3]. The initial dimensions of the gusset plates are 680×680×18.8 m^3.

For steel, the Poisson's ratio and modulus of elasticity have been considered 0.3 and 205 GPa, respectively. The stress-strain relationship of Cui et al. [4] is used for the steel and weld (Fig. 2). The ATC-24 loading protocol [6] is used for cyclic loading (Fig. 3). Analysis has been performed using the finite element code ABAQUS assuming non-linear behavior for materials (Fig. 4).

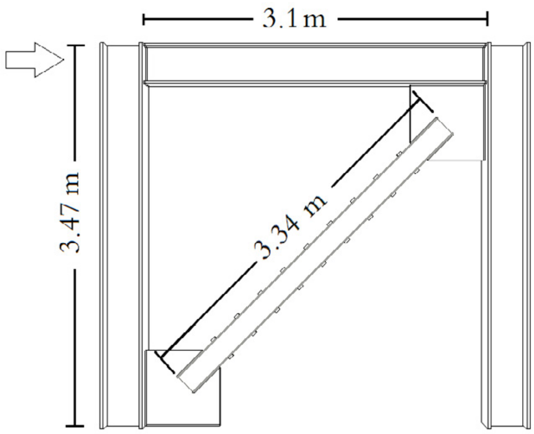

Fig. 1. Studied frame

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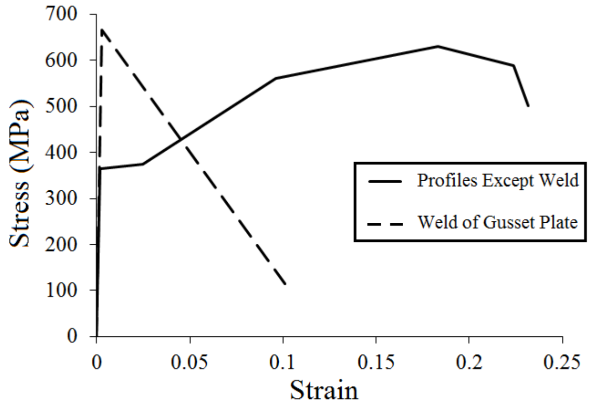

Fig. 2. Stress-strain diagram for steel and beam

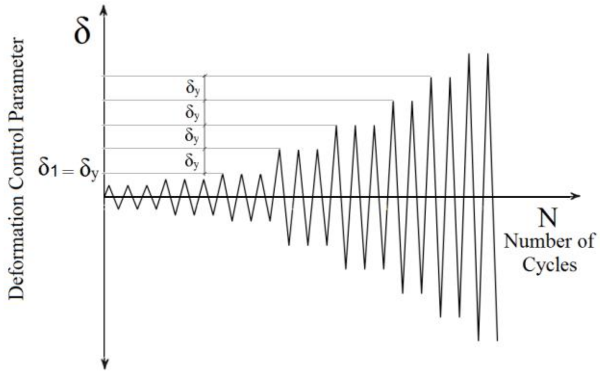

Fig. 3. Loading protocol

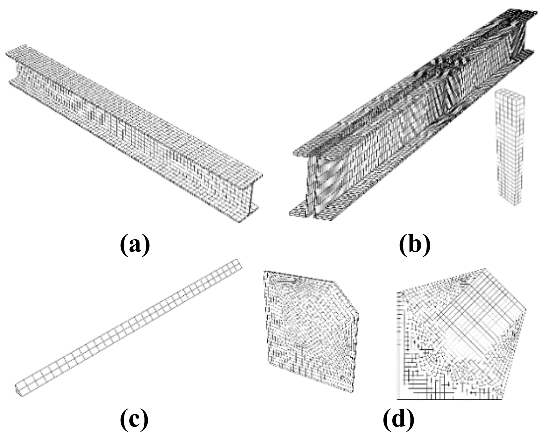

Fig. 4. Finite element mesh of the frame: a) beam and column, b) bracing, c) gusset plate, d) weld

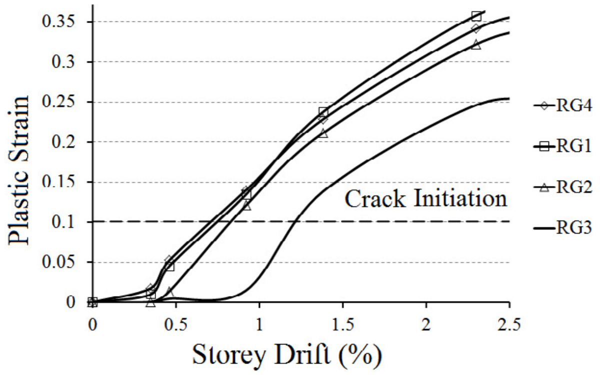

Fig. 5. Plastic strain-storey drift diagram for the weld of gusset plate to beam and column connection for different gusset plate thicknesses

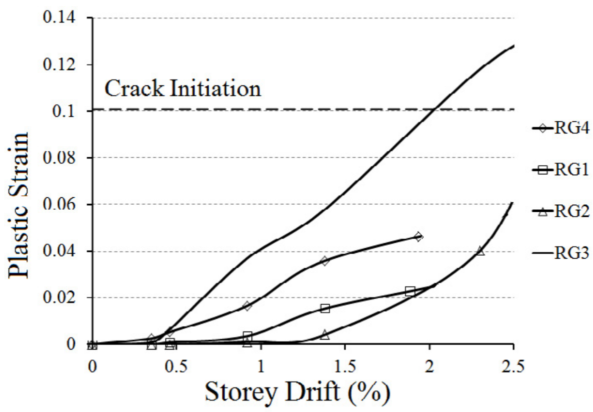

Fig. 6. Plastic strain-storey drift diagram for the weld of gusset plate to bracing connection for different gusset plate thicknesses

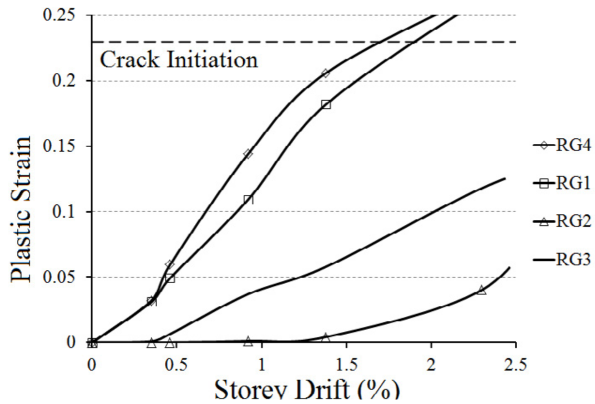

Fig. 7. Plastic strain-storey drift diagram for the mid span of the bracing for different gusset plate thicknesses.

3. PARAMETRIC STUDY

The effect of gusset plate thickness is shown in Figs. 5 to 7. It can be seen that by increasing the gusset plate thickness from 8 mm to 24 mm the plastic strains of the weld connecting the gusset plate to the beam and column are increased by 40% at the storey drift of 2%. This increase for the plastic strains at the mid span of the bracing is 150% at the same storey drift. In models with thickness of 18.8 mm and 24 mm, the plastic strain at the mid span of the bracing has reached the failure strain before the allowable storey drift (2.5%).

4. CONCLUSIONS

Main conclusions of the research are as follows.

1. By decreasing the thickness of the gusset plate

concentrated stresses transfer to the edge.

2. By reducing the dimensions of the gusset plate the value of plastic strain increases and dissipated energy decreases.

3. In gusset plates with less thickness and edge stiffeners the distribution of stresses becomes more uniform. The displacements of the edge vanish due to the edge stiffener.

4. The values of von Mises stress in elliptical line of bending is slightly more than that of linear line of bending.

5. Replacing the double-profile bracing with single-profile one decreases the plastic strains at the mid span of the bracing by 50%, and increases the dissipated energy slightly.

6. The maximum dissipated energy belongs to the model with stiffeners at the edges of the gusset plate.

7. The possibility of buckling of the gusset plate edge increases by decreasing the gusset plate thickness.

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