Amirkabir University of Technology
(Tehran Polytechnic)
Vol. 45, No.1, Summer 2013, pp. 1-2

Amirkabir Journal of Science & Research (Civil & Environmental Engineering)
(AJSR - CEE)

The Effect of Brace End Clearance on Ductility of Concentrically Braced Frames

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(Received 9 Jul 2011; Accepted 22 Apr 2013)

ABSTRACT

The need for ductility in Concentrically Braced Frames (CBF) has driven researches to study the different parameters which influence the ductile performance of this kind of structure. Brace end clearance in gusset plates is one of the most important of these parameters, which is considered by seismic codes to improve the seismic behavior of these structures.

This study examines the effect of brace end clearance on the behavior of CBFs. Both rectangular andtapered gusset plates are considered in order to gain a deep insight into this issue. Nonlinear analyses using the detailed inelastic finite-element model (FEM) are employed to perform this research. The equivalent plastic strain concept is used to determine the limits of ductile behavior and to predict fracture and failure in these models. Results shows that while in tapered gusset observing $2t_p$ clearance (which is recommended by codes) provides the optimum ductile behavior, in rectangular gusset plates, it is possible to reduce this distance and obtain a smaller gusset plate to maintain the ductile behavior of the frame.

KEYWORDS

Braced frame, Gusset Plate, Brace end Clearance, Ductility

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1- INTRODUCTION

Braces play the main role in the lateral resistance of concentrically braced frames. Tensile yielding and post-buckling deformation of braces dissipate energy during earthquakes. Out of plane buckling of braces impose significant inelastic deformations on the gusset plate connections. To ensure brace yielding, the current seismic design provisions require that the connections must be stronger than brace, because premature failure or fracture of connection results in poor performance. Furthermore, gusset plate connection must accommodate the cyclic end rotation expected in a buckled brace while supporting the expected tensile and compressive capacities of the brace. As a result, for the design of Special Concentric Braced Frames(SCBF), the current design practice recommends a "2tp" linear geometric offset to be used, where tp is the plate thickness[1]. This linear offset allows the end rotation resulting from out-of-plane brace buckling, however it results in relatively large gusset plates and the resulting connection may be uneconomical and not feasible for construction. In recent researches, uncertainties were observed regarding the effect of $2t_p$ linear clearance, which was initially suggested by Astaneh[2],[3], in order to improve seismic behavior of the concentrically braced frame. Some researchers [4],[5],[6] suggested 8tp elliptical clearance in the gusset plate in order to achieve better seismic performance of these structures, and a smaller and more economical gusset plate.

2- METHODOLOGY

Rectangular and tapered gusset plates were considered in this study to evaluate the influence of this parameter. The distance between the end of the brace and crossing point of centerlines of the frame members was assumed as the governing factor in this part of the study.The 2t linear model had the maximum clearance and the model with no clearance in its gusset plate had the minimum one. The clearances for other models were between these two models. In the reference model, two series of specimens with rectangular gusset plates were considered. Initially the thickness of gusset plates was constant in the models. However, it was later changed and designed to satisfy the compressive requirements of seismic codes.

3- SIMULATION RESULTS

Three series of models were constructed in order to evaluate the influence of brace end clearance. In the first series, rectangular gusset plates with constant gusset plate thickness were considered. In this series, except for the model with $2t_p$ clearance, the governing fracture mode was crack initiation near the gusset plate welds. However, the concentration of equivalent plastic strain increased in the middle of the brace by increasing the clearance. Although the ductility of models increased by increasing the clearance, the model which had a slightly smaller clearance than $2t_p$ indicated the same performance as the model with $2t_p$ linear clearance despite the fact that the governing fracture mode in these two models were different. In the second series, the thickness of gusset plate was increased by increasing the brace end clearance to satisfy the compressive requirement of seismic codes. In this series, the dominated fracture mode changed and for a larger brace end clearance, the dominated fracture mode was fracture at the middle of the brace. The influence of brace end clearance was also investigated in tapered gusset plates. In this series, the gusset plate thickness was constant. However, the model with $2t_p$ clearance demonstrated the best ductile performance.

4- CONCLUSIONS

In rectangular Gusset Plates, the models which had a brace end clearance slightly smaller than $2t_p$, demonstrated the best ductile performance. However, in tapered gusset plates, the model with $2t_p$ clearance showed best performance.

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