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Energy Dissipation Improvement in CBFs Using Perforated Gusset Plates

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ABSTRACT

Concentrically Braced Frames, CBFs, are the common systems to provide lateral stiffness and strength in buildings that in comparison with other systems such as moment resisting frames and eccentrically brace frames have less seismic energy dissipation and their ductility. This defect caused many studies in the recent years to improve ductility and seismic performance. In this paper, by making hole in the middle or end gusset plates on diagonal and X-brace samples through doing nonlinear static analysis with ABAQUS software, it was tried to provide more ductility and to improve the seismic performance of the brace. This performance is based on the brace buckling prevention. Therefore, holes should be designed in such a way that have less axial capacity than brace critical buckling load to help earthquake energy dissipation. Hysteresis curves show ductile behavior enhancing energy dissipation during cyclic loading of the final specimens and postponing the occurrence of buckling in the brace members until displacement about 2 cm while normal braces buckle in 1 cm displacement. The reduction of frame stiffness approximately 8-57% and 12-17% increment of equivalent damping prove more ductility and better seismic behavior of the proposed system.

KEYWORDS:

Concentric Brace, Perforated Gusset Plate, Ductility, Energy Dissipation, Non Linear Static Analysis

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1- Introduction

Concentrically Braced Frames (CBFs) are the common systems to provide lateral stiffness and strength in buildings that in comparison with other systems such as moment resisting frames and eccentrically brace frames have less seismic energy dissipation and ductility. This defect caused many studies in the recent years to improve their ductility and seismic performance. Usually, foundation of all the proposed methods is based on brace buckling prevention to reach its yielding load and increase energy dissipation in earthquake. Also, the fuse members are usually designed to dissipate significant input energy and prevent buckling of other main members. Compressive brace buckling before yielding leading to insufficient energy dissipation is a major defect in concentrically brace frames. The research on the behavior of concentrically braced frames which are substantially influenced by their seismic performance and ductility of compressive members shows a sharp decrease in stiffness and strength after buckling of compressive elements causing poor performance in the cyclic loading. So the strategy for preventing or delaying the brace buckling will improve its ductility. In this paper, by making hole in the middle or end gusset plates on diagonal and X-braces samples as shown in Fig. (1), it was tried to provide more ductility and to improve the seismic performance of the brace. Flexural capacity of the hole affected by hole's diameter and this diameter to plate width ratio is selected to prevent compressive member buckling. Circular hole's deformation under cyclic loading results in energy dissipation in this area and guarantees better behavior of the brace.

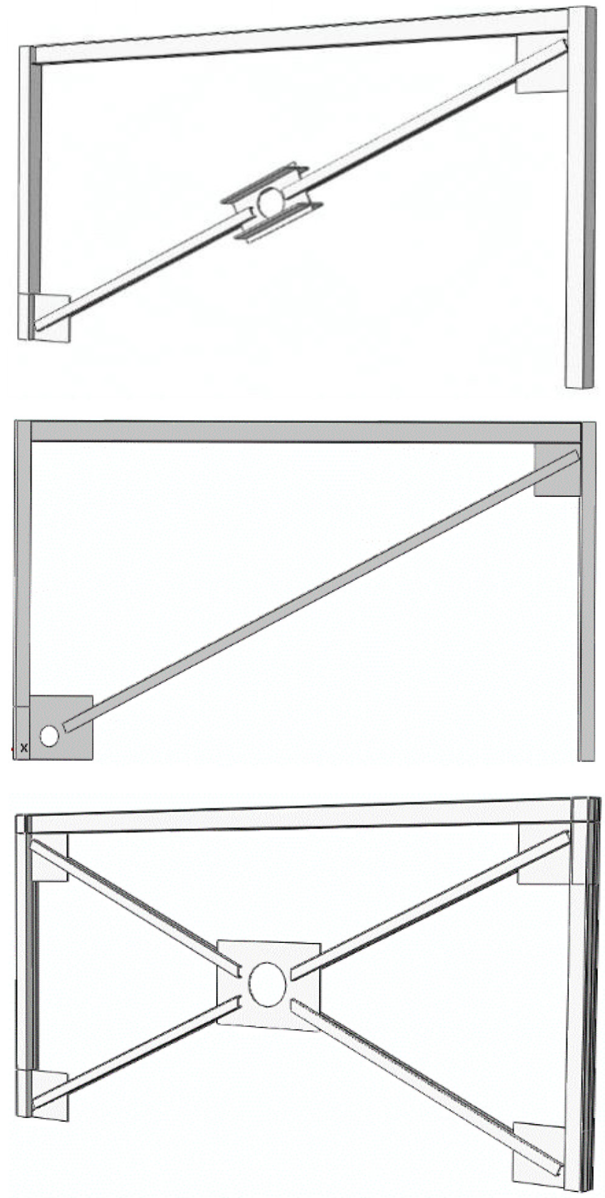

Fig 1. Proposed models

2- Methodology

In this research, six diagonal braces and two X-brace models described in Table (1) were tested. Because of more simple behavior of diagonal brace, to discover benefits of the proposed connection, the behavior of proposed member in diagonal and X-braces was evaluated using 8 samples. Afterward, equivalent damping was calculated for all samples to compare the proposed model ability to dissipate seismic energy.

3- Results

Results indicate improved seismic performance and ductility of CBF systems. Concentration of inelastic response in hole neighborhood results in high energy dissipation and prevents from nonlinear behavior in other elements. In addition, comparing the hysteresis loop of the proposed model with that of normal braces shows symmetric and stable rational behavior where strength and stiffness degradation are not observed in the displacements up to about 2 cm, while the usual brace buckles in about 1 cm displacement. Comparison of results obtained from cyclic loading, demonstrates less input energy and base shear up to 58% and appropriate seismic behavior of proposed model due to sensible stiffness reduction of proposed brace.

In addition, equivalent damping ratios in proposed samples are significant of about 20% as presented in Table (2).

It should be noted that due to the appropriate

Table 1. Details of proposed samples

Samples	Length	Height	Section	Property	*D/B* ratio
Sample (1) diagonal	5	3	2UNP14	Normal	–
Sample (2) diagonal	5	3	2UNP14	Hole D=20 cm	0.5
Sample (3) diagonal	5	3	2UNP14	Hole D=30 cm	0.75
Sample (4) diagonal	5	3	2UNP14	Hole D=20 cm Stiffener	0.5
Sample (5) diagonal	5	3	2UNP14	Hole D=30 cm Stiffener	0.75
Sample (6) diagonal	5	3	2UNP14	Hole end gusset plate	0.75
Sample (7) X brace	5	3	2UNP14	Normal	–
Sample (8) X brace	5	3	2UNP14	Hole D=40 cm stiffener	0.75

Table 2. Equivalent viscous

sample	A_h	A_e	ξ_{eq} (%)
1	230	425	4.3
2	912	420	17.28
3	1012	434	18.56
4	1298	473	21.84
5	833	334	19.85
6	612	259	18.81
7	530	724	5.8
8	1605	698	18.3

results obtained in numerical analysis, specimen fabrication and experimental work should be on the agenda to verify the results in the next stage of research.

4- Conclusion

Regarding the fact that flexural capacity of the proposed model is less than the buckling load capacity of the brace, buckling prevention is ensured. The final proposed hysteresis curve samples (samples 5, 6 and 8) were stable until displacement of 2 cm while buckling of conventional braces in approximately 1 cm displacement could have caused non ductile behavior.

Designing the hole in the gusset plate reduces system stiffness and base shear up to 58%. In addition, achieving about 20% equivalent damping without use of complex instruments is one of the major advantages of the proposed system. Increasing 13-19% in brace ductility ensures better seismic behavior in severe earthquakes.

The proposed model is relatively easy to implement in a variety of braces such as X-braces, chevron and diagonal configurations without spending too much cost. In this research by slight change in typical steel frames without using complicated device, energy dissipation is provided that is one of its distinctive features compared to other research projects.

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