

Research Article

Examining the behavior of modified connecting plates of convergent steel braced frames under the influence of tensile loads

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ABSTRACT

The gusset plates' connections usually are used for connecting the brace to beams and columns in the steel structures. In gusset plates, by parting forces into tensile and compressive forces the behavior of gusset plate can be separately examined. Under the tensile forces the fracture mood is dominant in the cutting connecting plate and the connecting plate without any buckling begins to give up and as a result it depreciates energy. In this article for the relative improvement of increasing plasticity in the connecting plates of bracing and to reach the maximum energy loss, the changes in the gusset plate and the impact of the level of changes in gusset plates under the monotonic tensile forces, have been examined. The achieved results and curves show that the behavior of the connecting plate under tensile forces has improved and also it shows the high capacity of plasticity in the modified connecting plate.

Keywords: Gusset Plate, Plasticity, Buckle, Brittle fracture.

INTRODUCTION

After the Northrich earthquake in 1994 the weaknesses were observed in the curved frame system. After which again the favored the use of steel braced frames as the resistant system to lateral loads were observed among engineers. The disadvantage of steel bracing convergent is the result of difference between the pressure and elasticity capacity in braces and decline in the strength of braces under comprehensive loading. Therefore, due to low deformation plasticity, they have instability capacity and more buckling. Hence, a lot of researches have done to improve the braces to achieve the ideal behavior. In connection of Gusset plate, with analysis of cycle tensile and pressure forces can address to model tensile and pressure loading uniformly. Under the tension the prevailing mode is Gusset plate and the attachment sheet without any buckling start

to waste energy. But connection sheet under the pressure forces have different comprehensive modes that it causes damage to the energy dissipation of Gusset plate. Therefore, a parametric study of the behavior under the connecting sheets under the cyclic loads was done which is described below. The first part is the history of researches on the connection sheets has been reviewed and the summary of the results of work is provided. As well as the modeling and validation of a numerical model based on the most recent research is expressed. Finally, a parametric study is done to investigate the formability of connection sheet.

Done research

Hu and Cheng were carried out an experimental and numerical study on the behavior of brace

connecting sheets under monotonic compressive loads [3].

Their experimental program was concentrated on thickness, geometry, boundary conditions and eccentricity. Cheng and Ho's work showed that by modifying the brace connection sheets, buckling of thin plates happened at lower loads, which is obtained by Vitmor method. As well as, for the promotion of compressive behavior of connecting sheets and use of energy dissipation, the use of hard edge is good. Study on the hard edge has done for the first time by Williams and Richard [4] on the diagonal braces. Then after Cheng [5] the study on the hard edge was continued widely. Cheng research showed that the hard edge will improve the absorption of energy by Gusset plate. Walbridge et al [6] have done the numerical study on the connection behavior under cyclic loads with the construction of a number of numerical examples in ABAQUS software. They validate their models for monotonic loading used the results of tests by Yum and Cheng [7] and for cyclic loading modes used the results of Rabinovich and Cheng [8]. In this study, factors such as thickness, geometry of sheets, the frame, the non-linear behavior of materials, initial defect parts, screw slip boundary conditions were investigated. As well as, for exploring the Ribinovitch and Cheng theory on how strong bracing design, weak

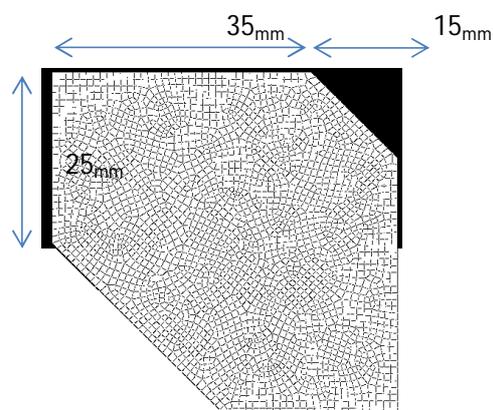


Figure 1: The characteristics of modified Gusset plate

sheets have been presented in their models. Based on the results, they provided the suggestions on how to model the behavior of materials, screws and initial defects on connection sheets. Studies showed that a curve of force- deformation in the mode of monotonic loading-hysteresis curves cover the same subjects under the cyclic loads. According to Walbridge et al., when the connection sheet buckles sooner, the energy dissipation is much better. In this study, a modified connector plate with stiffeners and low resistance steel independently with Gusset plate were compared simply. Modified connection sheets before buckling like fuses can cause the absorption and energy dissipation and can prevent the development of structural damages to other organs.

Modeling the Finite Elements of Gusset Plate Introducing Elements and Used Criteria

For modeling different components of connection sheets of Gusset plate including bar, column, organ and stiffness edge like figure (1) in the ABAQUS software was used the C3D8I elements from three-dimensional elements of eight knots. This element is able to show all attempts, strain hardening, large deformations (the effect of buckling) and elasticity in nonlinear analysis. Also, the direction of buckling applied to the model used the primary defect in the edge of connection sheets.

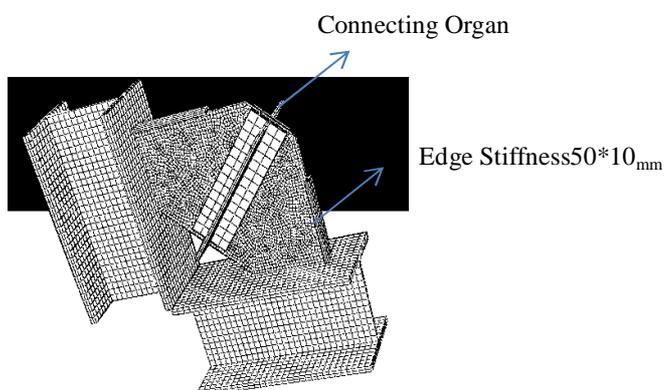


Figure 2: The finite elements of system model

Used Materials

Steel used for beams, columns, structural steel ST37 and steel used for Gusset plate sheets and steel ST37 and steel LYS have been used with

different models. Specification and stress-strain values are shown in table 1.

Table 1. Specification of usable materials

Type of Steel	Strain failure	Yield Strain	Ultimate Stress(kg/cm ²)	Yield Stress (kg/cm ²)	Module Elasticity (kg/cm ²)
ST37	0.2	0.0012	3700	2400	2000000
LYS	0.4	0.00062	3000	1200	1950000

The behavior of material have been considered as non-linear and in all models the measure of Von Misses and Kinematic hardening law have been used to evaluate the results.

Uploading

Uploading has been carried out as a shift to the junction of bracing as the organ. Because the uploading to shift is done in the Abaqus software the integration is better than force. Also, in the

most regulations in the world, the uploading patterns to shift is used for forming structural members. In this study, uploading is done by shifting. Uploading has been done to the charge and cyclic uploading. In order to include the cyclical nature of dynamic loads and reducing calculation errors, the procedure ATC-24 has been used. Figure 3 shows the uploading diagram.

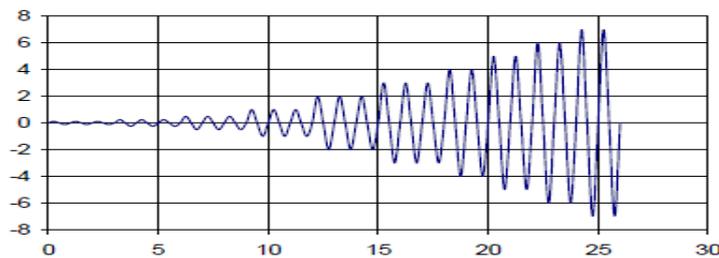


Figure 3. Cycle number – Act displacement curve

For assessing of buckling and dropping of resistance, and also to specify the amount of energy loss, and obtain attenuation in the nonlinear behavior of the system and the

connection uploading of samples we used the cyclic analysis.

Boundary conditions

In all models, as shown in figure 4, the end of beam and column was clamped.

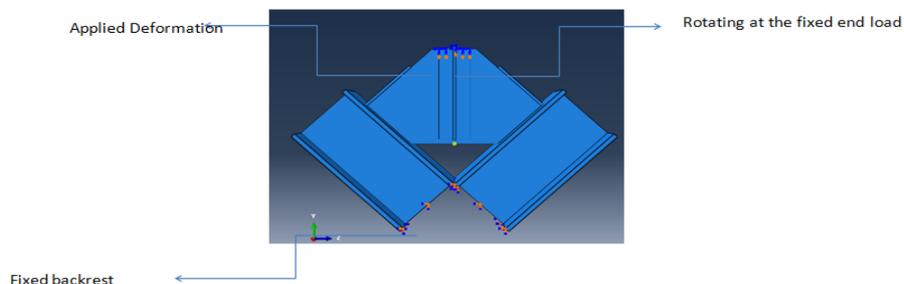


Figure 4: Imposed Boundary Conditions

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Verifying by using the test results of Yum and Cheng

In this study for the verification of software performance and modeling, the results of laboratory models of Yum and Cheng are used

[10]. According to figure 5, and the results are presented in table2, the results of analysis had a good match with the work of Yum and Cheng.

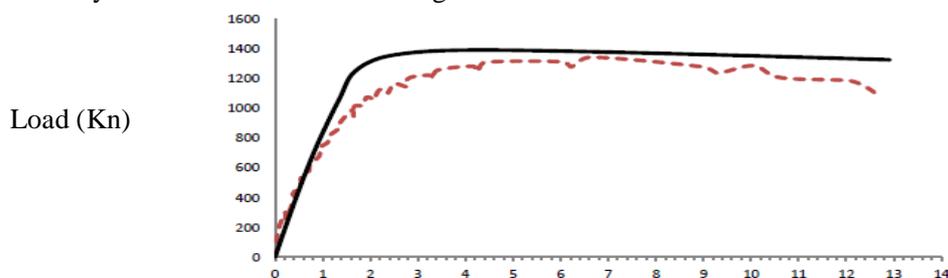


Figure 5. Verification of software model with experimental model

The connection thickness (mm)	Bracing Angle with Horizon (Degree)	Experimental (kn)	Software (kn)	Percentage of Difference Compressive Strength
9.8	30	1356	1420	4

Table 2. The comparison of verification results

Specification of studied models

Models with and without hard edge have been studied with the change in the geometry of

different steel in accordance with the dimensional given in table 3.

Table 3. Specification of Models

Row	Model Name	Sheet Thickness (mm)	The angle of Bracing with Horizon	Section beams and Column	Organ	Type of Steel	Hardener edge (mm)	Geometry Changes
1	GP1	10	45	IPB300	1/2INP300	ST37	-----	Not have
2	GP2	10	45	IPB300	1/2INP300	LYS	50*10	Not Have
3	GP3	10	45	IPB300	1/2INP300	LYS	50*10	have

Examining the Results

Comparing the simple gusset plate and gusset plate with edge hardener and Steel LYS

The intended simple gusset plate is the same recovered gusset plate, with the difference that the angle of bracing against the horizon is 45 degrees and the modified gusset plate with edge hardener has edge hardener width of 50 millimeter and a thickness of 10 millimeter. It is

worthy of mention that all the conditions for the models are the same and the only difference is in the existence and non-existence of the edge hardeners and the created changes in the geometry and the used materials of gusset plate. With comparing submissive tensions after applying the load and analyzing the matching models we come to the conclusion that unlike the simple gusset plate that has a little submissive

level, the modified gusset plate contains a higher level of submission and as a result there is more energy depreciation. With consideration of table 3 the plasticity rate determination of models show that the modified gusset plate is more ductile comparing to simple gusset plate. Here

Table 4. Determine the form factors of samples

Name of Model	The maximum displacement (mm)	The surrender of displacement (mm)	Form index
GP1	8	1.2	6.66
GP2	17	2.05	9.2

As shown in figure 8, it can be seen that Hysteresis curve of modified Gusset plates has flattened circles and are regular. It represents the ability to absorb more energy than simple Gusset

for calculating the plasticity, the maximum level of the curve displacement for power cycle–system shift is split into the displacement of system’s current disruption and we calculate the plasticity rate.

plates. It also modified model shows the same behavior in tension and pressure. This represents an increase of plasticity in the pressure loading on frame system with the coaxial steel bracing.

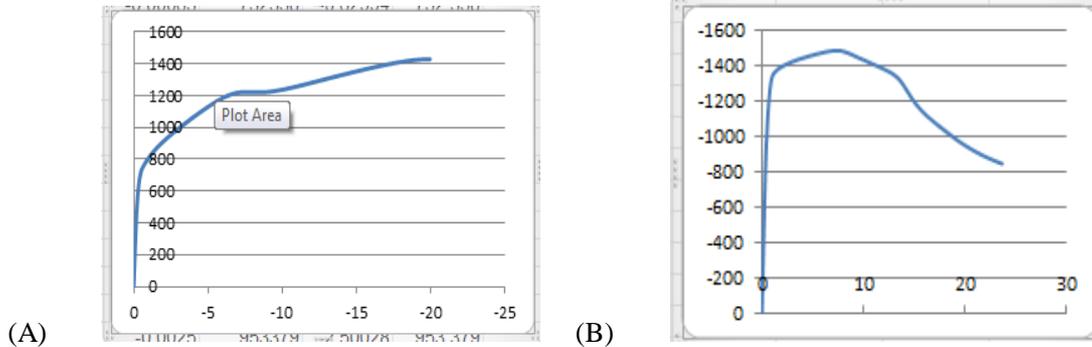


Figure 6. Hardening effect on power displacement curves (a) GP2 Model and (b) GP1 Model

The comparison of simple Gusset plates and modified Gusset plates with hard steel edge and steel LYS

In the corresponding member of the models for loads less than the yield stress, the answer is quite elastic and reversible. In one cycle of loading and unloading these is not any energy waste. But when stress exceeds the yield stress, the material has entered the deformation behavior which is irreversible. In this case, one

cycle of loading and unloading energy will waste which much of this energy is converted to heat. As shown in figure (9, 10) the amount of plastic hinge in modified Gusset plates is more than simple Gusset plates. This represents the good behavior for wasting of modified Gusset plate.

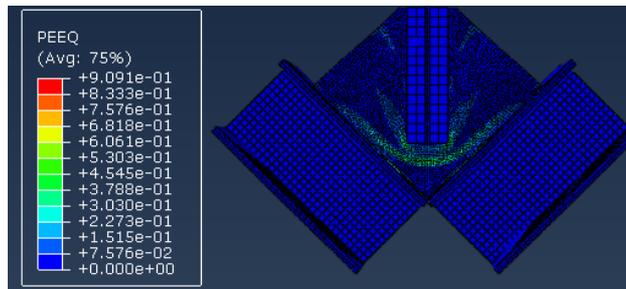


Figure 7. The location and amount of formed plastic hinge in original model

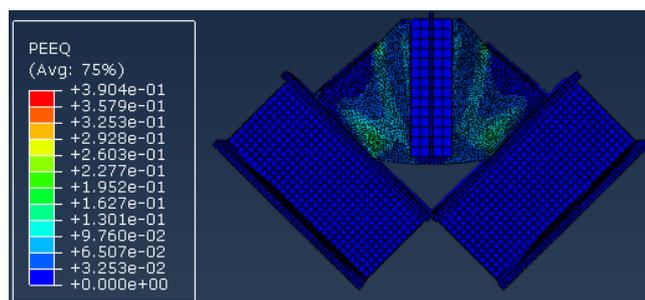


Figure 8. The location of plastic hinge in the model with stiffeners and low resistance steel

Also according to the figure 11, comparing the analytical results of models leads to this that Hysteresis curve of Modified Gusset plates have reel and regular spindle. It represents the ability to absorb more energy than simple Gusset plate. Also the modified model shows the same behavior in pull and push situation. This shows that an increase of plasticity in the loading pressure on frame systems with steel coaxial bracing.

CONCLUSION

In this article the effort was made to examine the tensile behavior of the connecting plate and to have a better behavior in the tension by making changes in the connecting plate of bracing. The examinations show the existence of modifications cause an increase in the plasticity of gusset plate. The conducted analytical studies showed that:

1. Increase forming is possible by modified Gusset plate.
2. The capacity of modified Gusset plate is related to the materials and the changes in the geometry, designing for variety of loadings is possible and can be designed as bracing and connector sheets to ensure that a lack of bracing buckling.
3. Change the mode of failure from edge bracing to state bracing according to threshold definition, will improve ductility of the model.
4. Yield stress of steel LYS is less than steel ST37, while modulus of elasticity of both

steel is approximately equal to each other, so Gusset plate sheets with steel LYS before the Gusset plate sheets and bracing start buckling will begin to surrender and energy depreciation. It can be use as a fuse in the structure.

5. Gusset plate sheets have little movement out of the screen that it increases the ability of the organ.
6. Change the Gusset plates is simple in terms of implementation and does not need to experts and expensive materials and technology and there is the possibility of making and implementing in Iran.

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