Evaluation of the effect transverse fillet weld at nose of flange plate in moment connection between I beams and box columns

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ABSTRACT

The studies of effect of geometry and welding details of elements of moment connections on their seismic behavior, especially in the case of box column, have a special importance. This article presents the result of analytical study on the behavior of steel moment–resisting connections using flange plates. Two groups of models of moment connection of I–beam to box column with flange plates were studied. First group of models of connections have IPE600 beam while the second one have IPE400 beam. In this paper damage indexes, including Triaxiality index and Rupture index, were extracted and compared under the monotonic load. The result of this study show that using transverse fillet weld at the nose of flange plate in models with higher beam, increase the brittle fracture potential at the face of column and also applying transverse fillet weld cause more uniformly distributed stress at the face of column.

Keywords: Moment Connections; Flange Plate; Damage Index; Box Column**.**

1-Introduction

The 1994 Northridge earthquake revealed serious damage to conventional bolted web welded flange (BWWF) connections, which were formerly known as ductile moment connections. Since then, a great deal of research has been conducted on the existing moment connections to find deficiencies and to improve their cyclic behavior [1-2]. The most severe stresses in the connection assembly occurred where the beam joins to the column. Unfortunately, this is also the weakest location in the assembly. At this location, bending moments and shear forces in the beam must be transferred to the column through the combined action of the welded joints between the beam flanges and column flanges and the shear tab. The combined section properties of these elements, for example the cross sectional area and section modulus, differ from those of the connected beam. As a result, stresses were locally intensified at this location [3]. Researchers have proposed different methods for modifying the connection to avoid stress concentration and formation of the plastic hinge in the

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connection. Moment connection with top and bottom flange plates (flange plate connection) that was studied in this paper is one of these modified moment connections.

One of the parameters that affect the behavior of flange plate connection is the type and emplacement of the connecting welds. Although, the transverse fillet weld at nose of the flange plate has no significant effect on the global behavior of this type of connection, but it affects locally the beam flange and causes the buckling of flange plate from the nose toward the face of the column [4]. Transverse fillet weld of the flange plate to the beam flange is one of the confusing points; given that it is explained in different ways in the structural codes. AISC [5] recommends employing transverse fillet weld at nose of flange plate. In this paper the effect of this weld regarding the height of the beam connected to the column were carried out.

2. Design of models

Two groups of models have been considered. First group, named **wfp1** consists of an IPE600 beam and second group named, **wfp2** has IPE400 beam. Column of both groups has the box section of 45*45*2.8 cm. dimension. Length of beams and columns respectively are 340 cm and 320 cm. Each group contains 2 models; model **L** and model **LT**. In model **L** only the longitudinal edges of flange plates are fillet welded to the flange of the beam. However, in model **LT** the longitudinal edges and transversal edge (nose) of flange plates are both fillet welded to the flange of the beams. All models have strong panel zone and have been constructed of St37 steel. Table 1, present the specifications of models and Table 2 is devoted to the characteristics of flange plates. To obtain more accurate, reasonable and rational results, two different depths of beams were studied.

table1 Specifications of specimens

specimens	beam	column
WFP1-LT	IPE600	BOX 45x45x2.8
WFP1-L	IPE600	BOX 45x45x2.8
WFP2-LT	IPE400	BOX 45x45x2.8
WFP2-L	IPE400	BOX 45x45x2.8

Table2-Summary Information on Specimens

WFP2-L	WFP2-LT	WFP1-L	WFP1-LT	
38	38	55	55	lenght of top plate
38	38	55	55	lenght of bottom plate
36	36	53	53	lenght of fillet weld
–	14	–	18	lenght of transverse weld
2.4	2.4	4.2	4.2	top plate thickness
1.6	1.6	3	3	bottom plate thickness

3. Finite element analysis

In this research, ABAQUS software was used for numerical studies of models. "Nonlinear static analysis" method was used to study the connections. Combined effects of the non-linear behavior of materials and large displacements were considered. All components of joint, beams and columns are modeled by three-dimensional solid -brick elements.

These elements have three degrees of transitional freedom at each node. Figure1 shows the solid element.

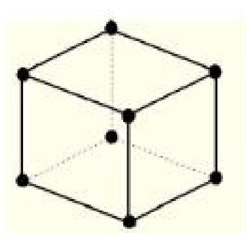


figure1.three-dimensional solid -brick elements **[6]**

4. Damage and Response Index

In this research, two indexes; triaxiality index and rupture index, were used to identify potential of *brittle* and *ductile* fracture.

Hydrostatic pressure: A large *tensile* (negative) hydrostatic stress is often accompanied by large principal stresses and generally implies a greater potential for either brittle or ductile fracture. In the presence of a crack or defect, large tensile hydrostatic stress (or pressures) can produce large stress intensity factors at the tip of the crack or defect, and increase the likelihood of brittle fracture. A large tensile hydrostatic stress can lead to rapid damage accumulation in metals due to microvoid nucleation, growth, and coalescence (ductile fracture) and a substantial reduction in component ductility [7,8]

Pressure index (PI) is defined as hydrostatic stress (σ_m) divided by the yield stress.

Mises index (MI): is defined as Mises stress divided by the yield stress. Where the Mises stress is defined as the second invariant of the deviatoric stress tensor.Triaxiality index (TI): this index is defined as the hydrostatic stress σ_m divided by the mises stress, that is:

$$\text{TI}=\frac{\text{PI}}{\text{MI}} \qquad (1)$$

Lemaitre have emphasized on the importance of these index to ductile rupture of metals [8]. Also according to the studies of E1-tawil et al [7], if triaxiality index is smaller than 0.6 brittle fracture potential is less. Also TI<0.75 and TI>1.5 can cause a large reduction in the rupture strain of metals and triaxiality index greater than1.5 can trigger brittle fracture.

Rupture index (RI): The definition of the Rupture Index (*RI*) used in this study is:

$$RI = a\frac{PEEQ}{\varepsilon_f} = \frac{PEEQ}{\exp(-1.5\frac{\sigma_m}{\sigma_y})} \qquad (2)$$

Which a is material constant and ε_f is rupture strain [9].

(El-Tawil et al) [7] expressed that this index can be used for comparison ductile fracture between different models used in the critical points.

For the case of studied models of connection, it can be shown that as the triaxiality index is related to the equivalent plastic strain, the equation (2) could not give the correct values. Only equation (2) is used to compare specimens on the known point. Index described above were calculated to compare the connection behavior at face of column (the welded joint of the flange plate to column flange). Figure 2 shows the considered region.

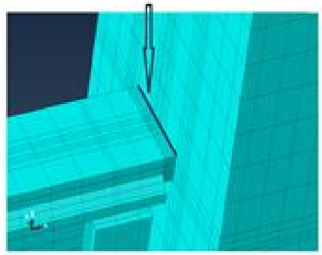


figure2.showing the desirable region

5-Results

As it was described two groups of models were studied. First group (models WFP1) with IPE600 beam and second group (models WFP2) with IPE400 beam. Each group contains two models; L and LT, representing models without or with transverse fillet weld at nose of the flange plates. Models WFP1-LT and WFP2-LT had transverse fillet weld and models WFP1-L and WFP2-L are without transverse fillet weld at nose of flange plate (Figure 3).

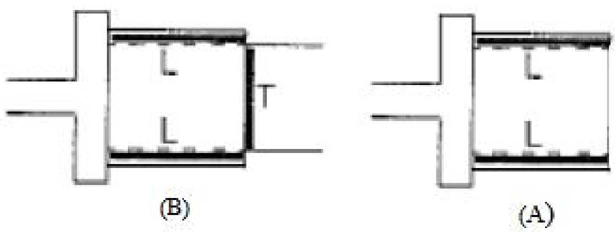
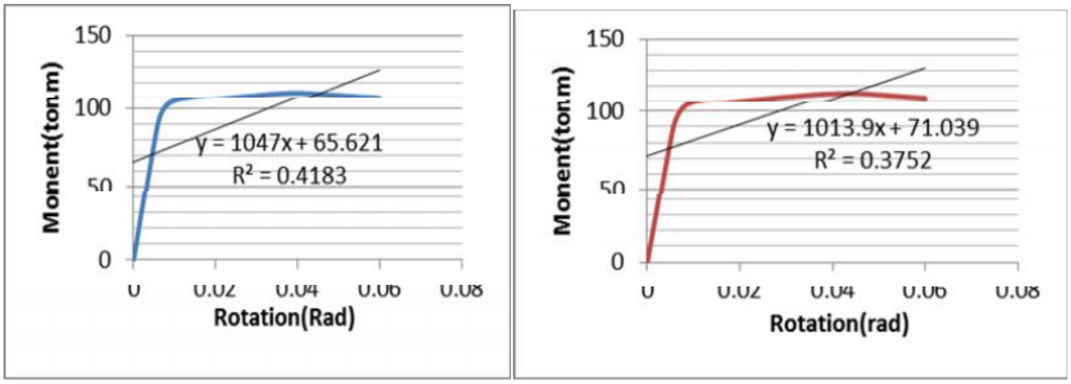


Figure3.show studied specimens: A: specimens without transverse fillet weld, B: specimens with transverse fillet weld

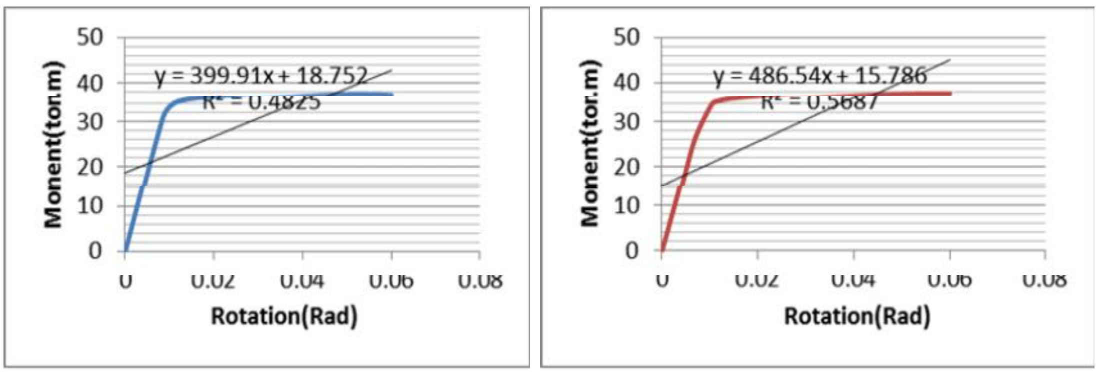
5.1. Global Behavior of the models

Figure 4 and 5 present the moment-drift curves for all models. The results show that the presence or absence of transverse fillet welds at nose of flange plate has not a significant impact on the global behavior of the connections. This means that presence or absence of transverse fillet welds at nose of flange plate do not affect the stiffness, ductility and resistance of moment connection with flange plate.



(a) WFP1-T specimen **(b) WFP1-LT specimen**

Figure 4. Global response of the specimens of first group



(a) WFP2-T specimen **(b) WFP2-LT specimen**

Figure 5.Global response of the specimens of second group

5.2. Local Response

Distribution of Triaxiality Index and Rupture Index along the transverse full penetration groove weld between the flange plate and column flange, for drift angle of 2% are presented by figures 6 to 9. With attention to the result in figure 6 that show the type and condition of failure, it can be found that potential of brittle fracture at presence of transverse fillet weld increases at face of column. While for connection without transverse fillet weld, the risk of brittle fracture exist only at the corners. Figure 7 shows the index rupture value of 0.036 for model WFP1-LT and 0.013 for model WFP1-L. These values indicate that the fracture potential of model WFP1-LT (connections with transverse fillet weld) is greater than connections without transverse fillet weld (model WFP1-L). However, depending on the amount of triaxiality index, this failure can be a ductile failure or brittle failure.

Figures 8 and 9 show the results of the numerical studies for second group of models (model WFP2-L and model WFP2-LT). It can be concluded from figure 8 that the values of triaxiality index are almost the same for both models. This explains that the potential of fracture (brittle fracture or ductile fracture) of models is similar. Since the Triaxiality index in corners is greater than 0.6, corners have a tendency to brittle fracture and because this amount in the middle is less than 0.6, then a ductile fracture would be expected. Figure 9 reveals that the maximum values of the rupture index belongs to the corners of the transversal groove weld of the flange plate and equal to 0.066. This shows that the potential of rupture in the corners is more than the other points. It can be seen in figure 9 that the diagrams of rupture index for both models (model with a transverse fillet weld and without a transverse fillet weld) are over matched. This means that the values of the rupture index do not depend on transverse fillet weld at the nose of flange plates.

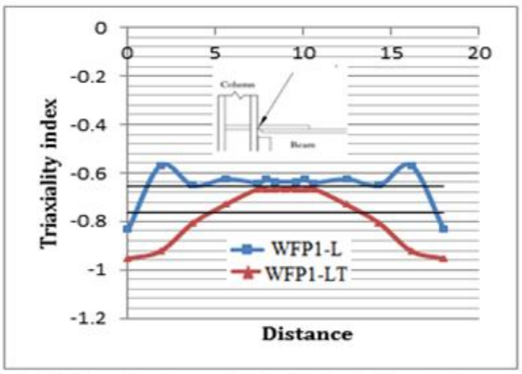


Fig6.Distribution of the Triaxiality index at the junction of beam to column at 2.0% rad story drift

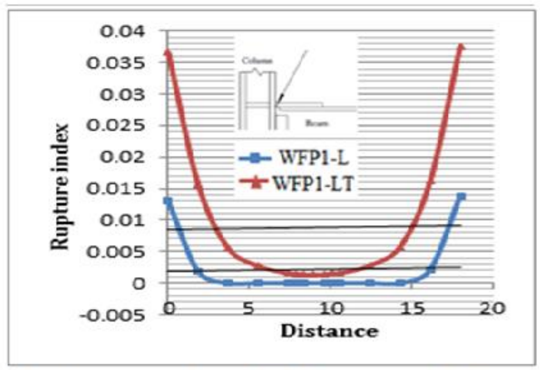


Fig7.Distribution of the Rupture index at the junction of beam to column at 2.0% rad story drift

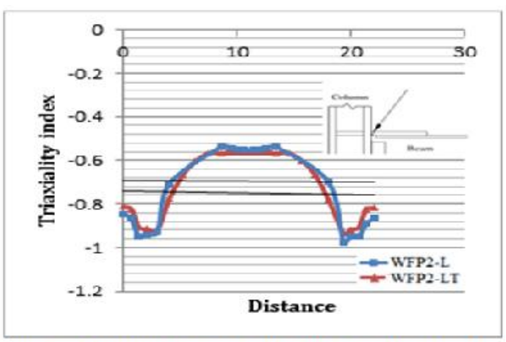


Fig 8 .Distribution of the Triaxiality index at the junction of beam to column at 2.0% rad story drift

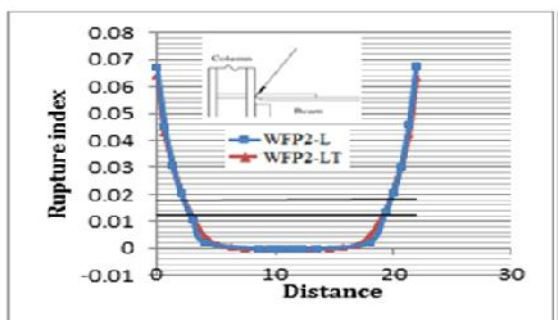


Fig 9 .Distribution of the Rupture index at the junction of beam to column at 2.0% rad story drift

6. Conclusion

1-The presence of transverse fillet weld does not impact on the connection global behavior. So that parameters such as stiffness, strength and ductility are almost independent from this weld.

2-As beam depth increases, (IPE600) the effect of transverse fillet weld can be better felt in increasing of damage index. So for the case of connections with IPE600 beam (first group of models) the comparison of two models, (with and without transverse welds) shows the difference of the rupture index about 64%. But this difference of rupture index for connections with IPE400 beam (second group of models) was less than 1%. This reveals that for lower depth beams, the existence or non-existence of the transverse fillet weld is not important.

3-In the case of connection having beams with higher depth (IPE600), the brittle fracture potential at the connections is higher, when the transverse fillet weld is used..

4-For connections having lower depth beams (IPE400) the damage index values is nearly overlapped for connections with and without transverse fillet weld. In other words, for beams with lower depth, the existence of transverse fillet weld does not affect the damage index values of the connection at the junction of flange plate to column flange.

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