Discussion about effecting of stiffener in four bolts in a row end plate connection for long span and heavy load steel structures in Vietnam

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Abstract. Nowadays, steel structure industry in Vietnam is in strong development. The construction of steel structure becomes larger span and heavier load. The issue spawned a number of issues arise from optimizing connections. Typical of steel connections in prefabricated steel structure that is an end plate (face plate) bolted connection. When the connection carried a heavy load, then the number of bolts is required much more. Increasing the number of rows bolts will less effective because can still not enough strength requirements, the bolts in row near rotational center will level arm reduction, then it cannot carry heavy loads. The current solution is doing multiple bolts in a row. Current standards such as EN [1], AISC [2] are no specific guidelines for calculating the connection four bolts in a row that primarily assumes the way works like a T-stub of the two bolts a row. Some articles studied T-stub four bolts in a row [3], [4], [5], [6] by component method but it has some components which weren't considered. In this paper, in order to provide a contribution to improve the T-stub four bolts in a row, the stiffener component in T-stub will be added and compared with T-stub without stiffener by the finite element model to demonstrate effectiveness in reducing stress and displacement of T-stub. It gives ideas for the economic design of four bolts in a row end plate connection in Vietnam for future.

1. Introduction

In steel structures, end plate bolted connections are used very often because of its usability. Currently, most of the connection design only considers the tension zone of bolt group for bolt design. The structural details of the connection bolts based on the conditions of use and requirements of the architecture are typically one bolt row will be located on the extended end plate and usually have one or more bolt located on the inside of a beam flange. Due to the requirements of the current works in Vietnam have crossed the rhythm and increasingly heavy loads, so use two bolts in a row in these situations is impossible because not enough meet requirement. Increasing the number of rows bolts will less effective because can still not enough strength requirements, the bolts in row near rotational center will level arm reduction, then it cannot carry high loading. The current solution is doing multiple bolts in a row. Based on the structural conditions of actual column flange, architectural requirements, and four bolts in a row connection are considered the optimal solution available today for the end plate bolted connection. Although many projects from around the world used this connection, but in Vietnam doesn't have many projects which used this connection. Solution of the steel company in Vietnam today is using four bolts in a row with two or multiple bolt rows connection, shear and compression zone of the connections are assumed in the standards EN 1993-1-8 [1] or AISC 2010 [2] like two bolts in a row. The ability of the tension zone depends on the ability of the components as the column flange, beam flange, end plate (there are no stiffener or have stiffener).

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For these connections have two bolts a row, the capacity of connections will base on T-stub, however, if we have four bolts in a row and multiple rows, the traditional model of T-stub may not suitable.
As mentioned, currently had some preliminary research about the four bolts in a row connection, typically of Pisarek et al. [3], [4], Demonceau et al. [5], [6] using the component method and experiments to demonstrate the suitability of the model and experiments analysis. However, these studies only the thin plate with low intensity, the component method has yet to mention the other components such as the column web, the add stiffener in column flange and end plate. It means that the current design for this connection is not the most economic. Here is the case study that Vietnam' project applied, particularly the reinforcement in the extension of the plate due to Vietnam's manufacturing technology yet to control distortion when fabrication, stiffener at the extension of the plate will solve these problems when welding. In addition, the previous research before just the static analysis, dynamic or cycling load research required to apply for the construction of large wind or earthquakes. In the actual situation of current applied research T-stub, 4 bolts in a row with multiple rows is essential research. In the next step, in order to provide a contribution to improve the T-stub four bolts in a row model, the stiffener component in T-stub will be added and compared with T-stub without stiffener by the finite element model.

2. Typical steel structure projects in Vietnam.

As discussions, although many projects from around the world used this connection, but in Vietnam doesn't have many projects which used this connection. Solution of the steel company in Vietnam today is using the four bolts in a row with two or multiple bolt rows, shear and compression zone of the connections are assumed in the standards EN 1993-1-8 [1] or AISC 2010 [2] like two bolts in a row. We can refer the Jooco Vina project in Dong Nai province (figure 1), Vietnam [7]. This building is used for shoe factory. It is the large building with 96m width and 15m span spacing, while in normally of industrial building, its only 30m width and 6m to 8m span spacing. Because of large span, so use two bolts in a row in these situations is impossible because not enough meet requirement. Increasing the number of rows bolts will less effective because can still not enough strength requirements.

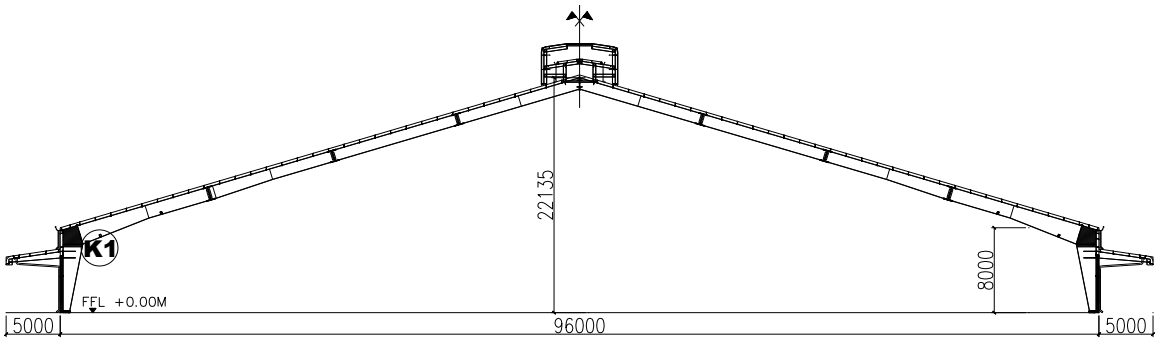


Figure 1. Cross section of main frame, Jooco Vina project [7]

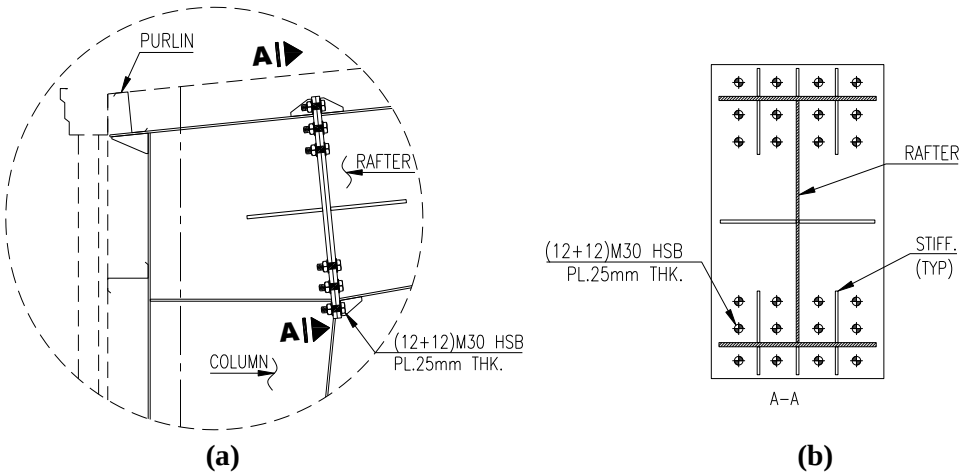


Figure 2. Detail K1

a) The four bolts in a row connection b) Cross section A-A

The solution of designing is in detail K1 (figure 2), this connection is 24M30 bolt diameter with plate thickness 25mm. They use four bolts in a row end plate connection, which have enough space to locate many bolts with multiple rows to carry the large moment. They also provide stiffener to strengthen an end plate, this extended end plate with stiffener is so popular in Vietnam. The problem is this detail just for typical, they aren't allowed to consider stiffener to their calculation because lack of standard and researches about this component, for other purpose, Vietnam's manufacturing technology doesn't control distortion well, so stiffener at the extension of the plate will solve these problems when welding. But is has uncomfortable because of long time fabricate and harder to tightening the bolt when end plate has many stiffeners, another inconvenience, this is stiffener need be welded to end plate by hand, so it is hard to control the quality of welding. The next step, by the analyses FEM model of T-stub four bolts in a row, it has provided some evidence of stiffener effective in reducing stress and displacement in this connection.

3. Finite Element Analysis

3.1. Failure mode of T-stub

There were some studies of T-stubs with 4 bolts a row. In the EN1993 standard [1], the design of four bolts in a row would be assumed to be similar to two bolts a row, based on the predicted working on the T-stub two bolts in a row is the same as four bolts a row. Therefore, the results of the resistance of these T-stubs also depend on the type of failure mode such as T-stub 2 bolts. According to EN1993 [1], there are 3 main failure modes (figure 3). Where mode 1 and mode 2 are failure of the bolt with the complete or partial yielding plate (figure 3a and 3b), mode 3 is the failure mode of the bolts that the T-stub will not be effected (figure 3c). EN1993 [1] also proposed for further studies that the component method would be a widely used method in the development of T-stub research. Component method is the method in which the moment resistance of the connection is based on the capabilities of the connection elements such as end plate, column flange, beam flange, bolt and stiffener…

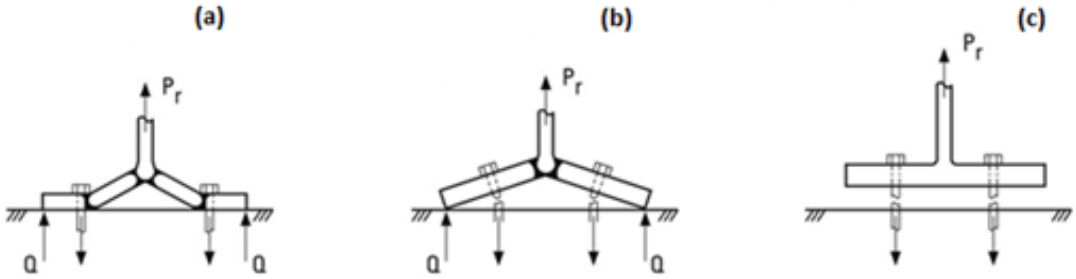


Figure 3. Three failure modes of T-stub [1]
a) Mode 1. Complete flange yielding b) Mode 2. Bolt failure with flange yielding c) Mode 3. Bolt failure

3.2. FEM Model and result for T-stub four bolts in a row with and without stiffener

In order to compare the effectiveness of the component stiffener to the T-stub four bolts in a row. The FEM model will with two samples consist of two T-elements bolted together by four M20 bolts. The mode of failure for such a connection depend on the tensile resistance of the bolts in relation to the resistance of T-element and it occurs one of three failure modes in figure 3. To reduce variable factor, the geometry and dimensions of two samples will be the same. The dimensions of the test samples are presented in figure 4. The T-elements were made of steel grade Q345, and the steel grade of bolt is grade 8.8 for both of two samples. The increasing tensile force 500N/mm2 on top of T-stub. The ABAQUS program software will be used for FE Model. The FE model has four parts: the rigid support at the bottom of T-stub web. Bolt and T-elements material is elastic-plastic isotropic model. The mesh size has been defined by cutting plane to divide mesh in circular and rectangle member to ensure it runs exactly. Interaction type of the two plates is surface to surface contact, normal direction is hard contact with friction coefficient is 0.2.

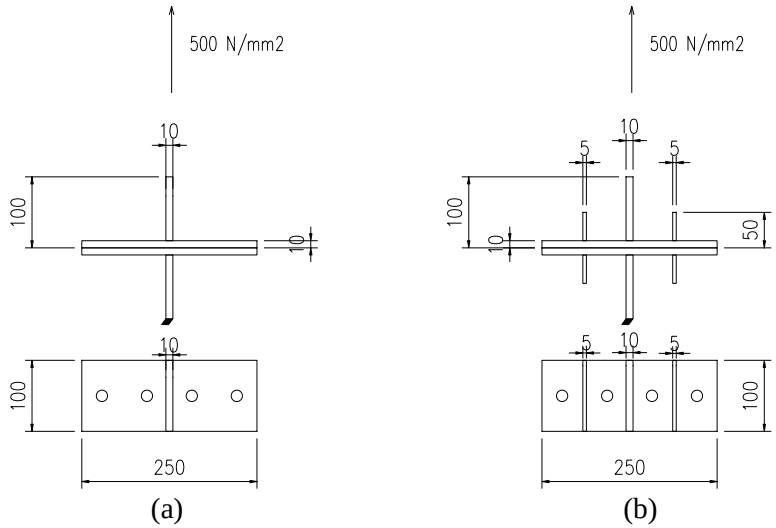
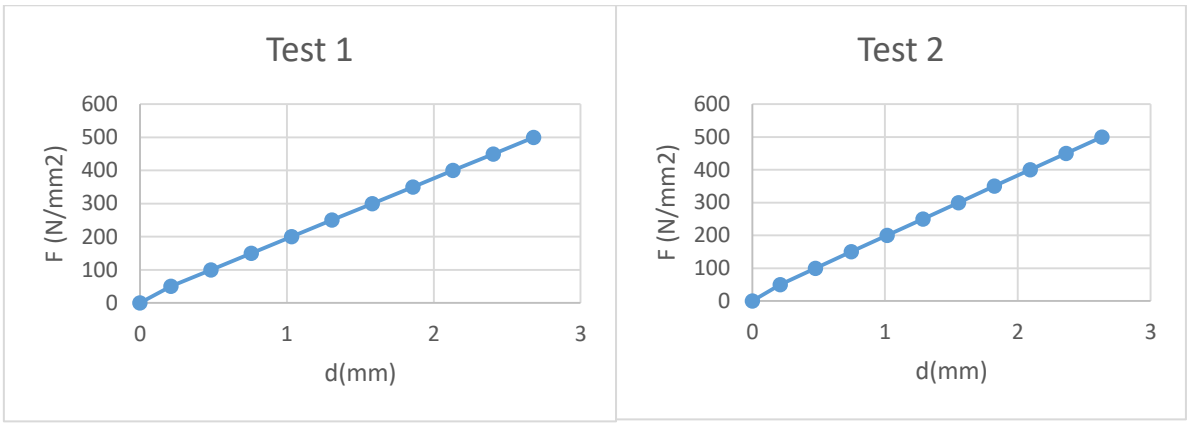
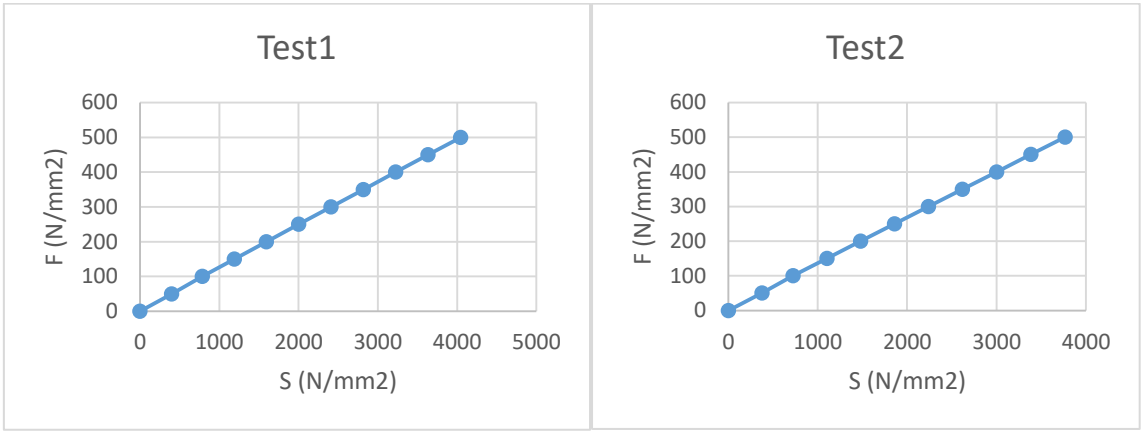


Figure 4. Samples of FE Model (dimension is mm)
(a) Sample 1: T-stub without stiffener, (b) Sample 2: T-stub with stiffener



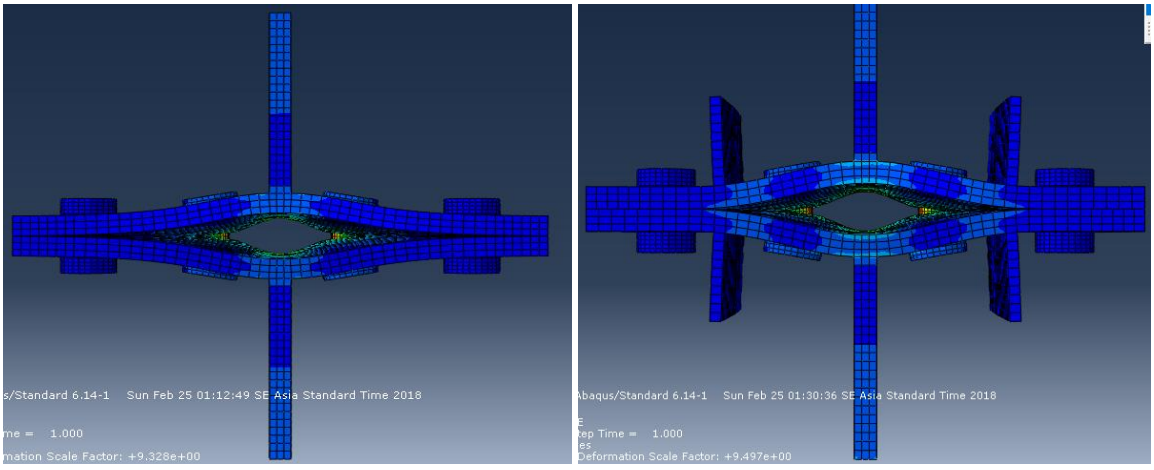
(a) **(b)**

Figure 5. Force-displacement graph for (a) sample 1, (b) sample 2



(a) **(b)**

Figure 6. Force-Von Mises Stress graph for (a) sample 1, (b) sample 2



(a) **(b)**

Figure 7. Failure mode of (a) sample 1, (b) sample 2

The main aim of the test observed behavior of the T-stub under increasing loading to identify the mode of failure and compare the stress and displacement between two samples. In figure 5a, the highest displacement of sample 1 is 2.68mm and in figure 5b, the displacement of sample 2 is 2.63mm. The displacement of sample 2 is equal 98.1% displacement of sample 1. In figure 6a, the highest stress in sample 1 is 4044N/mm^2 while the highest stress in sample 1 is 3770N/mm^2 (figure 6b). The stress of sample 2 is equal 93.2% displacement of sample 1. The failure mode both of two samples are mode 1 (sample 2) and mode 2 (sample 1) (figure 7)

4. Conclusion

Nowadays, the connections of four bolts in a row in Vietnam usually have a stiffener in the end plate, however, it is only a typical type for easy fabrication. There have been no previous studies showing the effect of these stiffeners on the stress and displacement simulation of the four bolts in a row connections. With the increasing loading T-stub model in FEM shows evidence of significant effects on T-stub stress and displacement, thus opening up further studies of the effect of stiffener on the four bolts in a row connections, which will have more economic design.

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