Numerical Study of CFST K-Joints with Different Connection Arrangements

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Abstract - *A reassembly connection is an effective solution to remove and reuse components after their first stage calculated life and could therefore save the environment by reducing material over use and saving natural resources. Blind bolts and through bolts are usually used as connectors in such demountable connections to replace normal welding works. This project conducts a parametric study on demountable square concrete-filled steel tubular (CFST) K-joints fabricated with concrete filled chord, hollow braces, flush endplate, blind bolts, and through bolts. Parametric study includes modification of joint between brace tube and flush end plate, different shapes to brace, introducing through bolt to different types of K-joints. Advanced finite element analysis models of the novel joints can be established using ANSYS software. From the study the model with circular brace takes more load. But, in circular brace model the stress is concentrated at a particular point. Extreme load than the designed load cannot be taken. Proper study and care must be taken while the designing of brace with circular shape. So, the square brace with bolted connection between brace and flush plate is considered as the appropriate model.*

Key Words: Reassembly, through bolt, Blind bolt, Flush endplate, K-joint, CFST.

1.INTRODUCTION

To reduce the negative impact on environmental, it is necessary to reuse constructional materials. The design of such reassemble structures lies in their deconstructive connections, which are usually achieved by using reassemble shear connectors or blind bolts. Reusing structural elements is an effective way to reduced energy consumption and gas emission. A reassemble connection is an effective solution to separate and reuse components after their calculated life. CFST (concrete-filled steel tubular) K-joint is joints with concrete-filled steel tubular (CFST) chords and hollow section braces connected using blind bolts. CFST K-joints formed by concrete filled chords and hollow section (CHS) braces are likely used in practice. The infilled chord concrete contributed to restraining the surface plasticity failure and enhanced the tensile performance for tubular connections and the overall structure. they are commonly used in large scale structures, e.g., long-span bridges and transmission towers, and temporary structures such as offshore platforms. A numerical study can be conducted to determine the various behaviors on different type of CFST reassembly K-joint.

1.1 Scope

• This work is limited to modelling and analysis of CFST K-joint using ANSYS
• Limited to 3 different shapes used for brace tube.
• This work is restricted to analysis under displacement, stress, and total deformation of models.
• The work mainly focuses on the different type of connection and their performances on loading under a single boundary condition.
• This type of joints reduces the cost of maintenance.

1.2 Objective

To conducts a parametric study on demountable square concrete-filled steel tubular (CFST) K-joints fabricated with concrete filled chord, hollow braces, flush endplate, blind bolts, and through-wall bolts.
Parametric study includes:
   • Modification of square CFST K-joint with:
   • To compare the result of numerical study on various shapes of brace used.
   • Study on using through bolt in connection between flush plate and chord.

2. MODELLING AND ANALYSIS

Models for numerical study of CFST K-joint is developed and analyzed using ANSYS software.

2.1. Models

In this study CFST K-joint models are arranged in such a way that a pair of brace tubes are connected to the flush endplate at an angle 45 degree in opposite directions. The flush endplate is placed over the chord tube and bolted at sides. When through is used it is placed across the chord tube from the top surface of the flush endplate to bottom of the chord tube through infilled concrete every model uses 4 blind bolts at both side of the flush endplate to connect to chord. While strengthening the connection an angle plate is used. It is done in 2 ways one is that the angle plate is welded to both flus plate and brace tube, another is a bolted connection. One side of the angle plate is welded to the flush plate and other side uses bolts to connect o the square brace tubes. Using of bolt in this connection allows more assembly parts. In this case the model has 4 assemblies.
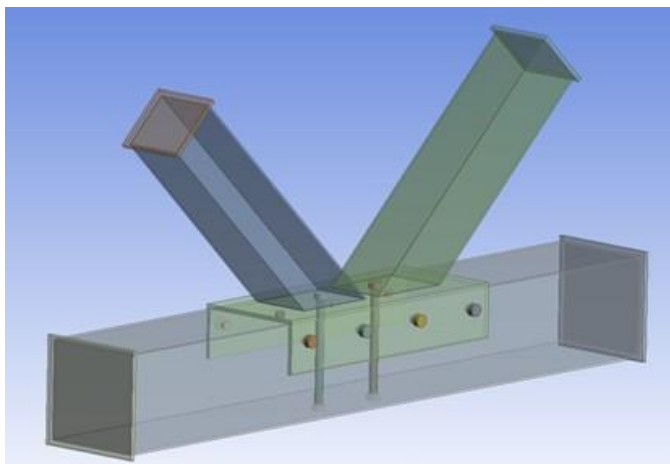
Fig -1: CFST K-joint.

Fig -1 shows the model where blind bolts and through bolts are used for connection.

Table -1: Labeling of models

Labels	
Connecting flush plate with brace using plate welding	Model 1-a
Connecting flesh plate with brace using bolts	Model 1-b
Square Brace tube welded to flush endplate	Model 2-a
Circular brace tube welded to flush endplate	Model 2-b
I-section brace welded to flush endplate	Model 2-c
Through bolt used in model connecting flush plate with brace using plate welding	Model 3-a
Through bolt used in model Connecting flesh plate with brace using bolts	Model -3-b
Through bolt used in model Square Brace tube welded to flush endplate	Model 3-c
Through bolt used in model I-section brace welded to flush endplate	Model 3-d

Table 1 shows the types of models used in the project and labels specified for each model. in this table it includes all the models and their labels used in the study. This label is used to give a unique name to each model. It helps to note a particular model with simple label.

2.2 Material properties and meshing

Material properties given to each part of the model is given in the Table 2. These are the properties that we used from the base journal[1]. Other properties excluding this are the default properties that are available in the ANSYS Engineering data

Table -2: Properties of specimens.

Components	Material properties		Meshing size (mm)	Specification (mm)
	Es/Ec (MPa)	Fy (MPa)		
Chord steel tube	206,000	438.1	20	240 x 4 x 1680
Brace steel tube	206,000	378.8	16	145 x 3 x 725
Flush Endplate	206,000	438.1	10	10 x 650
Angle plate	206,000	438.1	10	35 x 35 x 6
Bolt	206,000	660	5	20, 14
Chord concrete	34500		30	

It also shows the meshing size of each element in the model. As the meshing size reduce accuracy in the result increases.
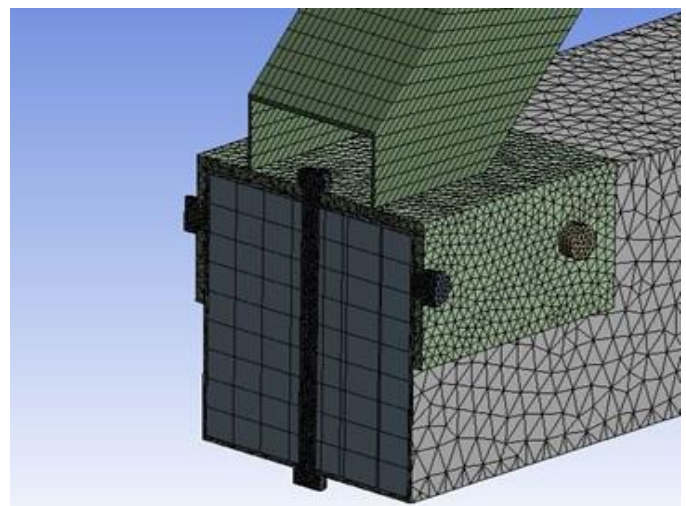
Fig -2: Meshing.

Fig -2 shoes the cross-sectional view of meshing of each element in the model

2.3. Boundary condition and loading

In every models analised pinned support is provided by using displacement. It is applied at the face of rigid plates connected athe the end of brace tubes Displacement data is provided in the form of tabular data. Displacement in x and z

direction is given as 0 while y direction is set as free. Boundary condition applied on the model is shown in Fig -3.
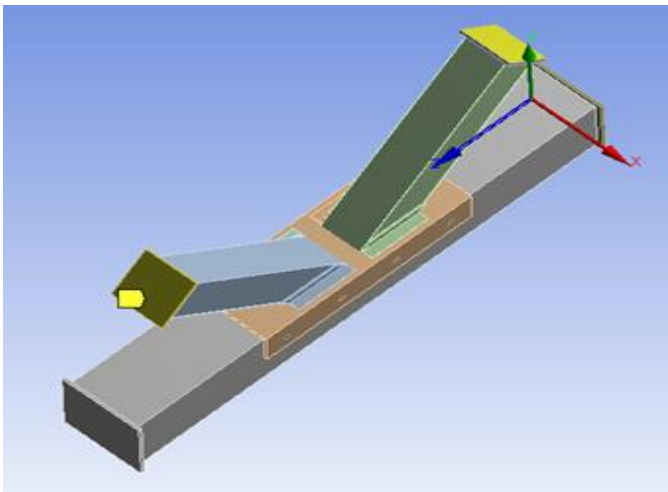

Fig -3: Boundary condition

One end of the chord tube is remains free while the other end is used to assign the force. Force is assigned at face of rigid plate attached to the ends of chord tube. Force is applied with respect to time. It is done by considering the displacement that occurs to the model. The displacement given to the model is shown in tabular form. Displacement is applied at 2 stages. At 0.5 second 5mm displacement and at 1 second 10mm displacement is considered.
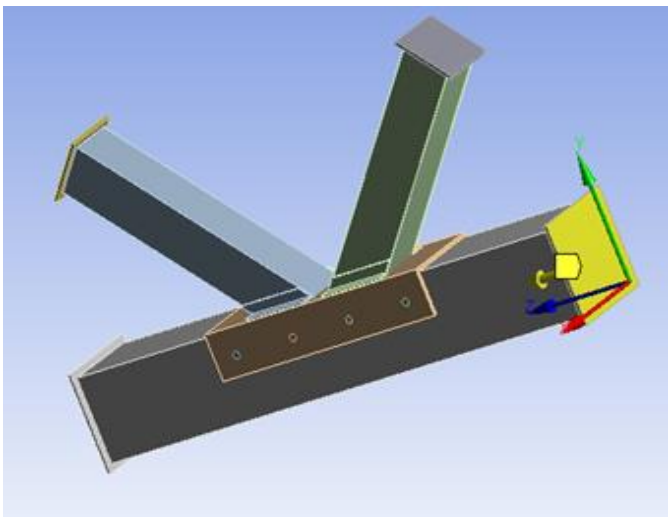

Fig -4: Force applied

Force applied on the model is shown in Fig -4. Boundary condition and loading condition applied on each model are same.

3. Result

From the study conducted, stress distribution and force-displacement relation of each model is obtained. This data obtained helps to identify the connection type which is efficient and does its design purpose.

Fig -5 shows the stress distribution diagram of model 1-a. This model which uses welded angle plate has the maximum stress value than others while comparing with other type of connection between brace and flush endplate.
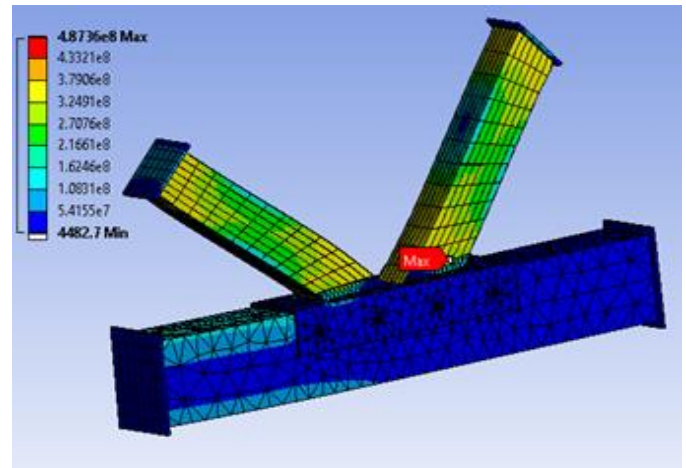

Fig -5: Stress formed on Model 1-a.

Here the maximum stress is formed at the welded angle plate which is 4.87e+2 MPa. The scale in the figure shows the minimum to maximum values of stress from blue to red.
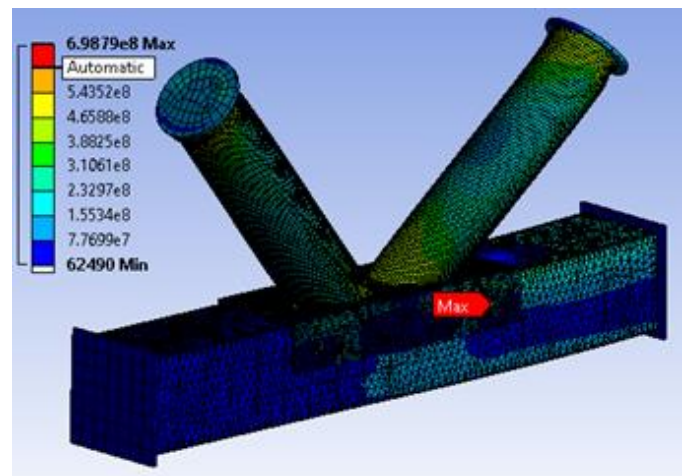

Fig -6: Stress formed on Model 2-b.

Fig- 6 shows the model having maximum stress distribution while comparing to the model having brace with other shapes. Model with circular brace tube have a maximum stress of 6.99e+2 MPa. In this model the stress is maximum at the flush plate near the bolt.

When I-section is used as brace in the model. The stress distribution is less as compared to other models. In model 2-c the maximum stress shown is 3.85e+2 MPa. It is much as compared to model with circular brace. In case of using I-section the maximum stress is formed at the base of the I-section brace which is near the connection to flush endplate. When through bolt is provided it shows a slight increase in the maximum stress formed.
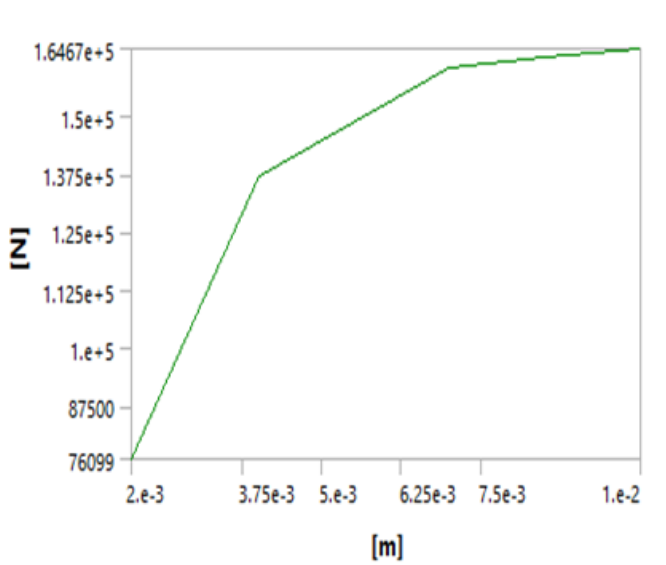
Fig -7: Force-displacement chart of Model 1-b.

Force-displacement chart of each model is obtained in the result of ANSYS. Fig -7 shows the Force-displacement chart of the Model 1-b in which the pair of brace tubes are bolted to the flush endplate with the help of angle plates.
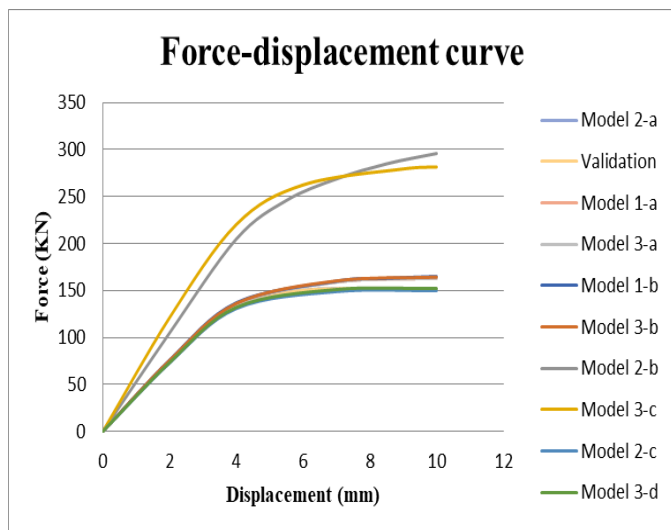

Chart -1: Force-displacement summay curve.

Chart -1 shows the comparision of didplacement curve all the models studied. The comparision shows that the models with circular brace takes large forces to other models. But while considering the stress distribution stress is concentrated at a single point in case of circular brace. So it cannot take load morethan an extent. In case of using corcular brace tubes propper deignin is necessary to fulfill the desired use. While comparing other models model 1-b has mode load carrying capacity which is 165KN. So CFST K-joint with bolted connection between square brace tube and flush endplate is considered as the K-joint with approperate load carrying capacity.

Table -3: Force-displacement summay.

Model	Maximum Force (KN)
Validated	152
Model 1-a	163
Model 1-b	165
Model 2-a	152
Model 2-b	296
Model 2-c	150
Model 3-a	163
Model 3-b	164
Model 3-c	281
Model 3-d	152

Table -3 shows the maximum force used by each model to make a displacement of 10mm in 1 second.

4. CONCLUSIONS.

This project conducted a parametric study on demountable square concrete-filled steel tubular (CFST) K-joints fabricated with concrete filled chord, hollow braces, flush endplate, blind bolts, and through-wall bolts. Parametric study includes modification of joint between brace tube and flush end plate, different shapes to brace, introducing through bolt to different types of joints.

From the study of different models conducted above we concluded:

1. While comparing CFST K-joint with connection between flush endplate and square brace modified Model 1-b have load carrying capacity as compared to Model 1-a and the validated model. Model 1-b have 8% more load carrying capacity as compared to validated model.
2. In comparison with CFST K-joint with different shape on braces, Model 2-b has high load carrying capacity as compared to others. It takes 296 KN to make 10mm displacement, which is above 30% of performance as compared to the validated model. The stress distribution in model 2-b is 699 MPa which is much higher than the square and I-section models.
3. While introducing through bolt to different type of k-joints, Model 1-a have maximum stress as compared to others. Maximum stress on this model is 487 MPa while the stress on model with bolted brace connection is 473 MPa, which shows a slight difference with the welded one.

Concrete in Chord tube helps in restraining the surface plasticity failure and enhanced the tensile performance for tubular connections and the overall structure. Bolt arrangement in the flush plate allows the re-assembly of the structure. From the study the model with circular brace takes more load. But, in circular brace model the stress is concentrated at a particular point. Extreme load than the designed load cannot be taken. Proper study and care must be taken while the designing of brace with circular shape. So, the square brace with bolted connection between brace and flush plate is considered as the appropriate model.

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