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Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 09, No. 05

October 2009, P.P.2009-2015

Theoretical Study on the Tensile Strength of the New Type Single Side Full Bolt Connection

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Abstract: It's easy to connect the square steel tube and H-shape steel beam with the new type full bolt joints. Different connections, different tension resisting capacities. Experimental study found that the tensile strength of the new type single side full bolt connection depends on the thickness of the plate, the type of steel, the rigidity of the steel sheet and so on. By using the related knowledge of elastic mechanics, It is obtained approximation formula of elastic thin plate at any point in the elastic deflection stage under the new type single side full bolt connection, in which welding attaching plate acted as a nut and screw worked as a concentrated force. the flex value of the corresponding point can be drawn through the formula, and the actual measurement value can be gained with the test of 6 groups of specimen in the same axial tension test. The result indicates that the approximate theoretical derivation value and the actual measured value are approximately equal, verifying the correctness of the proposed formula.

Keywords: *New single side full bolt connection; Elastic thin plate; Deflection approximate value ; Actual measured data*

1. Introduction

Light steel structure is a kind of structure with good seismic performance and green environmental protection. The research on the key technologies of the beam column connection has a high economic and social value for speeding up the construction of urbanization. Under the study of earthquake disaster in the past, such as The United States Northridge earthquake [1], Kobe earthquake [2], Japan and Taiwan 921 earthquake Chinese [3], It can be clearly found that most of the damage of steel structure joints occurred in node.

At present, there exist many ways to connect the steel structure, and the full bolt connection type for its specifical superiorities is being studied by more and more domestic and foreign scholars. Research on the connection of H type steel beam and rectangular tube column is less, but the cold formed rectangular square steel tube is getting more and more attention. Because of the advantages of having a large section modulus and two main axis of the same direction, reducing the amount of steel, building beautiful indoor environment [4] and so on easily. Therefore, it's more important to find a simple installation operation and good seismic performance of the node connection form.

Aiming at those issues in the research group, a new type of single side full bolt connection is developed and presented. (As shown in Figure.1): Bolts no longer need nuts, directly tapping screw on the connecting plate, accompolished to reach the designated position of beam to column connection in one step; The connection beam column method can not only connect the rectangular steel tube column and the steel beam connection, but also can be used for the whole bolt connection of the light steel structure.

In recent years, the development and testing of single side bolts in the world are supplied much in many aspects internationally. Mourad et al [5-6] had conducted two repeated low cycle loading tests of steel tubular column and steel beam joints, which are connected with single bolts and extended end plates. The hysteretic behavior and failure modes of the joints are studied. France et al [7-8] had carried out monotonic loading tests of 26 single side bolt end plate connections for steel tube concrete column and steel beam joints with Flowdrill technology and researched the mechanical properties and failure modes of the joints. Loh et al [9-10] had carried out some static tests of five cross combinations and one steel joint under negative bending moment with Lindapter Hollbolt bolts for studying the effect of partial shear connection of composite beam on the performance of the composite flat end plate. Wang Jingfeng [11] used two groups of hollobolt bolt to conduct two groups of low cyclic loading tests of steel pipe concrete column and steel girder single bolt end plate connection joints and researched the influence of end plate thickness, end plate type, column section type and bolt anchorage structure on the joint failure mode and seismic performance of the joints.

Seen from the research situation of unilateral bolts in recent years, the researchers have not explained the relationship between the bearing capacity and its influencing factors in the mechanism of the unilateral bolt. According to the research about the bearing capacity of bolts in the "Mechanical strength theory" [12] : The bearing capacity of the bolt is closely concerned with the strength and stiffness of the screw nut etc. However, because of the connection form and common connection forms presenting great differences, plate's flexure deformation will affect the structure stress. Therefore, it is necessary to study the deformation of the steel plate under the action of concentrated force applied by the bolts. Thus, the flexure deformation can be controlled more reasonably.

A preliminary study on the tensile strength of the new type of full bolt has been carried out by the research group earlier, and a formula for the ultimate tensile strength of the last lap of the screw was established [13]. In order to provide theoretical basis for further research on the connection of the new type of full bolt connection, the formula of the new type full bolt under different combination is deduced [14], according to the strength calculation formula of mechanical parts.

Scholars at home and abroad have studied further on the mathematical problems of tension on the thin plate [15-21]. M. Kadkhodayan [22] studied the elastic/plastic buckling of thin rectangular plates under various loads and boundary conditions in the in-plane loads which are placed uniformly and linearly varying in the uniaxial compression and biaxial compression/tension. Tan Fei [23] had proposed a computational procedure based on the regular hybrid boundary node method (RHBNM) to solve the thin plate subjected to a concentrated load. Zhong Yang [24] had derived that theoretical solution to the problem of elastic rectangular thin plate by using method of symplectic geometry under the condition that two pairs of edges are fixed support and other two pairs of side free. Based on Kirchhoff thin plate theory, The deflection function of the double trigonometric series is presented by Yue Jianyong [25] et al, and the exact solution of the rectangular plate with two pairs of edges is obtained by two.

The article, by using the way of a combination of experimental and theoretical derivation, made a research on the bending of the corresponding points of elastic thin plate acting as concentrated force by supplying the knowledge of elasticity. In the light of the experimental model, the approximate formula of the deflection of the corresponding point on the wall of the tube wall and the plate welded plate is derived.and the formula is verified by the test results.

2. Theoretical Research

2.1 Approximate calculation of bending deflection of thin plate under two symmetrical concentrated loads

The square steel tube specimen is provided with bolt holes and the tube wall can be simplified to two pairs of edges Fastened, and the others free. The thin plate size is a × b, and the two bolts in the test can be seen as the concentrated force (p) acting at two fixed points. (As shown in Figure.2)

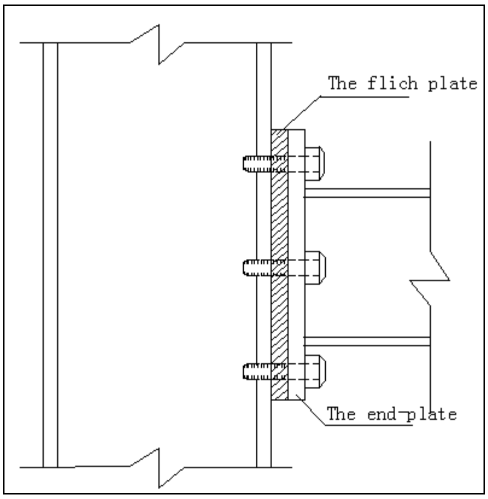

Fig.1 *Connection between rectangular steel tube column and H shape steel beam*

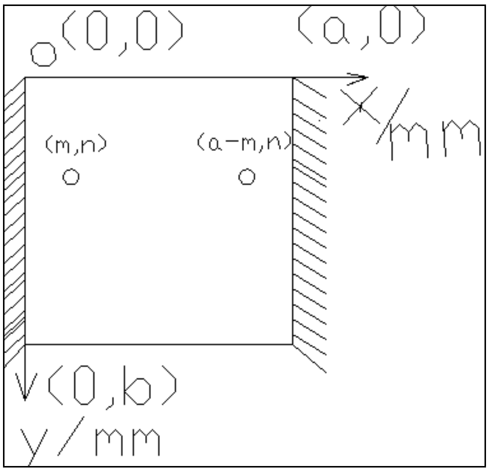

Fig.2 *Plane stress diagram*

2.1.1 Application of control differential equation

Control differential equation for thin plate bending problem can be express as:

$$D\nabla 4\varpi = q(x,y) \qquad (1)$$

Where, $\varpi = \varpi$ (x,y) is the plate deflection function, D=Et3/12（1-μ2）is sheet bending stiffness, t is the thickness of the plate, E and μ are the elastic modulus and Poisson ratio of the materials, and the plate size is a × b.

When the thin plate at two certain points（m, n）、（m+Δ ，n）be suffering from the concentration forces, q represented by delta function δ P（x-m）δ（x-n）, and the controlling differential equation becomes :

$$D\nabla^4\varpi - p\delta(x-m)\delta(x-n)=0 \qquad (2)$$

2.1.2 Approximate calculation of bending deflection of thin plate under two symmetrical concentrated loads.

Assuming that the bending deflection of thin plate is a test function as followed:

$$\varpi = C\cos\frac{2\pi x}{a}\left(1-\cos\frac{2\pi x}{a}\right)\sin\frac{2\pi y}{b} \qquad (3)$$

Where, C is defined as a function to be determined in the formula, and the test function need to meet the conditions as following [26];

$$(\varpi)_{x=0}=0;\quad \left(\frac{\partial\varpi}{\partial x}\right)_{x=0}=0;$$

$$(\varpi)_{y=0}=0;\quad (M_x)_{y=0}=\frac{\partial^2\varpi}{\partial x^2}+y\frac{\partial^2\varpi}{\partial y^2}=0;$$

$$(M_y)_{y=0}=\frac{\partial^3\varpi}{\partial x^3}+(2-\mu)\frac{\partial^3\varpi}{\partial y^2\partial x}=0$$

$$(\varpi)_{y=b}=0;\quad (M_x)_{y=b}=\frac{\partial^2\varpi}{\partial x^2}+y\frac{\partial^2\varpi}{\partial y^2}=0;$$

$$(M_y)_{y=b}=\frac{\partial^3\varpi}{\partial x^3}+(2-\mu)\frac{\partial^3\varpi}{\partial y^2\partial x}=0$$

Then the residual equation for is as:

$$R_I = D\nabla^4\varpi - p\delta(x-m)\delta(y-n) - p\delta(x-m-\Delta)\delta(y-n)$$
$$=DC[(\frac{2\pi}{a})^4\sin\frac{2\pi y}{b}(\cos\frac{2\pi x}{a}-8\cos\frac{4\pi x}{a})$$
$$+2(\frac{2\pi}{b})^2(\frac{2\pi}{a})^2\sin\frac{2\pi y}{b}(-\cos\frac{2\pi y}{a}+2\cos\frac{4\pi x}{a})$$
$$+(\frac{2\pi}{b})^4\sin\frac{2\pi y}{b}(\cos\frac{2\pi y}{a}+\cos^2\frac{2\pi y}{a})]$$
$$-p\delta(x-m)\delta(y-n)-p\delta(x-m-\Delta)\delta(y-n)=0 \qquad (4)$$

To eliminate residual equation by using the Galerkin equation for listing equation as:

$$\int_0^a\int_0^b R_I\cos\frac{2\pi x}{a}\left(1-\cos\frac{2\pi x}{a}\right)\sin\frac{2\pi y}{b}\,dxdy=0$$

Using the delta function property and integral and Eq.(5) can be obtained :

$$DC\frac{ab}{4}[(\frac{1}{a})^2+(\frac{1}{b})^2]^2\pi^4-P\cos\frac{2\pi m}{a}(1-\cos\frac{2\pi x}{a})\sin\frac{2\pi n}{b}$$
$$-p\cos\frac{2\pi(m+\Delta)}{a}[1-\cos\frac{2\pi(m+\Delta)}{a}]\sin\frac{2\pi n}{b}=0 \qquad (5)$$

Where Δ=a-2m;

$$\text{I.e. } p\cos\frac{2\pi m}{a}(1-\cos\frac{2\pi m}{a})\sin\frac{2\pi n}{b}+p\cos\frac{2\pi(a-m)}{a}[1-\cos\frac{2\pi(a-m)}{a}]\sin\frac{2\pi n}{b}$$
$$=p[\cos\frac{2\pi m}{a}-\cos^2\frac{2\pi m}{a}+\cos\frac{2\pi(a-m)}{a}-\cos^2\frac{2\pi(a-m)}{a}]\sin\frac{2\pi n}{b}$$

Thus,

$$C=\frac{P[\cos\frac{2\pi m}{a}-\cos^2\frac{2\pi m}{a}+\cos\frac{2\pi(a-m)}{a}-\cos^2\frac{2\pi(a-m)}{a}]\sin\frac{2\pi n}{b}}{\frac{5Dab}{4}[(\frac{2\pi}{a})^4+(\frac{2\pi}{a})^2(\frac{2\pi}{b})^2+\frac{1}{2}\cdot(\frac{2\pi}{a})^4]} \qquad (6)$$

Substitution of Eq.(6) into Eq.(3) can be rewritten as:

$$\varpi=\frac{P[\cos\frac{2\pi m}{a}-\cos^2\frac{2\pi m}{a}+\cos\frac{2\pi(a-m)}{a}-\cos^2\frac{2\pi(a-m)}{a}]\sin\frac{2\pi n}{b}}{\frac{5Dab}{4}[(\frac{2\pi}{a})^4+(\frac{2\pi}{a})^2(\frac{2\pi}{b})^2+\frac{1}{2}\cdot(\frac{2\pi}{a})^4]}\cos\frac{2\pi x}{a}\left(1-\cos\frac{2\pi x}{a}\right)\sin\frac{2\pi y}{b}$$

If the two level approximation calculation is used, and the deflection test function should be as:

$$\varpi=\sum_u^{1,2}\sum_v^{1,2}C_{uv}\cos\frac{2u\pi x}{a}(1-\cos\frac{2u\pi x}{a})\sin\frac{2\pi vy}{b}$$
$$=C_{11}\cos\frac{2\pi x}{a}(1-\cos\frac{2\pi x}{a})\sin\frac{2\pi y}{b}$$
$$+C_{12}\cos\frac{2\pi x}{a}(1-\cos\frac{2\pi x}{a})\sin\frac{4\pi y}{b}$$
$$+C_{21}\cos\frac{4\pi x}{a}(1-\cos\frac{4\pi x}{a})\sin\frac{2\pi y}{b}$$
$$+C_{22}\cos\frac{4\pi x}{a}(1-\cos\frac{4\pi x}{a})\sin\frac{4\pi y}{b} \qquad (7)$$

Then the residual equation for is as:

$$R_I=D\nabla^4\varpi-p\cos\frac{2\pi m}{a}(1-\cos\frac{2\pi m}{a})\sin\frac{2\pi n}{b}$$
$$-p\cos\frac{2\pi(a-m)}{a}(1-\cos\frac{2\pi(a-m)}{a})\sin\frac{2\pi n}{b}$$
$$=DC_{11}[(\frac{2\pi}{a})^4\sin\frac{2\pi y}{b}(\cos\frac{2\pi x}{a}-8\cos\frac{4\pi x}{a})$$
$$+2(\frac{2\pi}{b})^2(\frac{2\pi}{a})^2\sin\frac{2\pi y}{b}(-\cos\frac{2\pi x}{a}+2\cos\frac{4\pi x}{a})$$
$$+(\frac{2\pi}{b})^4\sin\frac{2\pi y}{b}(\cos\frac{2\pi x}{a}+\cos^2\frac{2\pi x}{a})$$
$$+DC_{12}[(\frac{2\pi}{a})^4\sin\frac{4\pi y}{b}(\cos\frac{2\pi x}{a}-8\cos\frac{4\pi x}{a})$$
$$+2(\frac{4\pi}{b})^2(\frac{2\pi}{a})^2\sin\frac{4\pi y}{b}(-\cos\frac{2\pi x}{a}+2\cos\frac{4\pi x}{a})$$
$$+(\frac{4\pi}{b})^4\sin\frac{4\pi y}{b}(\cos\frac{2\pi x}{a}+\cos^2\frac{2\pi x}{a})]$$
$$+DC_{21}[(\frac{4\pi}{a})^4\sin\frac{2\pi y}{b}(\cos\frac{4\pi x}{a}-8\cos\frac{8\pi x}{a})$$
$$+2(\frac{2\pi}{b})^2(\frac{4\pi}{a})^2\sin\frac{2\pi y}{b}(-\cos\frac{4\pi x}{a}+2\cos\frac{8\pi x}{a})$$
$$+(\frac{2\pi}{b})^4\sin\frac{2\pi y}{b}(\cos\frac{4\pi x}{a}+\cos^2\frac{4\pi x}{a})]$$
$$+DC_{22}[(\frac{4\pi}{a})^4\sin\frac{4\pi y}{b}(\cos\frac{4\pi x}{a}-8\cos\frac{8\pi x}{a})$$
$$+2(\frac{4\pi}{a})^2(\frac{4\pi}{b})^2\sin\frac{4\pi y}{b}(-\cos\frac{4\pi x}{a}+2\cos\frac{8\pi x}{a})$$
$$+(\frac{4\pi}{b})^4\sin\frac{4\pi y}{b}(\cos\frac{4\pi x}{a}+\cos^2\frac{4\pi x}{a})]$$
$$-p\delta(x-m)\delta(y-n)-p\delta(x-m-\Delta)\delta(y-n)$$

Where, C11、C12、C21 and C22 are defined as functions to be determined in the formula, and four residual equations are established as:

$$\left.\begin{aligned}
&\int_0^a\int_0^b R_I\cos\frac{2\pi x}{a}\left(1-\cos\frac{2\pi x}{a}\right)\sin\frac{2\pi y}{b}\,dxdy=0\\
&\int_0^a\int_0^b R_I\cos\frac{2\pi x}{a}\left(1-\cos\frac{2\pi x}{a}\right)\sin\frac{4\pi y}{b}\,dxdy=0\\
&\int_0^a\int_0^b R_I\cos\frac{4\pi x}{a}\left(1-\cos\frac{4\pi x}{a}\right)\sin\frac{2\pi y}{b}\,dxdy=0\\
&\int_0^a\int_0^b R_I\cos\frac{4\pi x}{a}\left(1-\cos\frac{4\pi x}{a}\right)\sin\frac{4\pi y}{b}\,dxdy=0
\end{aligned}\right\}$$

Using the delta function property and integral:

$$\left.\begin{aligned}
&\frac{5}{4}abC_{11}D\left[\left(\frac{2\pi}{a}\right)^4+\left(\frac{2\pi}{a}\right)^2\left(\frac{2\pi}{b}\right)^2+\frac{1}{2}\cdot\left(\frac{2\pi}{b}\right)^4\right]-p\cos\frac{2\pi m}{a}\\
&\left(1-\cos\frac{2\pi m}{a}\right)\sin\frac{2\pi n}{b}-p\cos\frac{2\pi(a-m)}{a}\left(1-\cos\frac{2\pi(a-m)}{a}\right)\sin\frac{2\pi n}{b}=0\\
&\frac{5}{4}abC_{12}D\left[\left(\frac{2\pi}{a}\right)^4+\left(\frac{2\pi}{a}\right)^2\left(\frac{4\pi}{b}\right)^2+\frac{1}{2}\cdot\left(\frac{4\pi}{b}\right)^4\right]-p\cos\frac{2\pi m}{a}\\
&\left(1-\cos\frac{2\pi m}{a}\right)\sin\frac{4\pi n}{b}-p\cos\frac{2\pi(a-m)}{a}\left(1-\cos\frac{2\pi(a-m)}{a}\right)\sin\frac{4\pi n}{b}=0\\
&\frac{5}{4}abC_{21}D\left[\left(\frac{4\pi}{a}\right)^4+\left(\frac{4\pi}{a}\right)^2\left(\frac{2\pi}{b}\right)^2+\frac{1}{2}\cdot\left(\frac{2\pi}{b}\right)^4\right]-P\cos\frac{4\pi m}{a}\ (1-\\
&\cos\frac{4\pi m}{a})\sin\frac{2\pi n}{b}-p\cos\frac{4\pi(a-m)}{a}(1-\cos)\frac{4\pi(a-m)}{a}\sin\frac{2\pi n}{b}=0\\
&\frac{5}{4}abC_{22}D\,\pi^4\left[\left(\frac{4\pi}{a}\right)^4+\left(\frac{4\pi}{a}\right)^2\left(\frac{4\pi}{b}\right)^2+\frac{1}{2}\cdot\left(\frac{4\pi}{b}\right)^4\right]-p\cos\frac{4\pi m}{a}\\
&\left(1-\cos\frac{4\pi m}{a}\right)\sin\frac{4\pi n}{b}-p\cos\frac{2\pi(a-m)}{a}\left(1-\cos\frac{2\pi(a-m)}{a}\right)\sin\frac{4\pi n}{b}=0
\end{aligned}\right\}$$

Thus:

$$C_{11}=\frac{P[\cos\frac{2\pi m}{a}-\cos^2\frac{2\pi m}{a}+\cos\frac{2\pi(a-m)}{a}-\cos^2\frac{2\pi(a-m)}{a}]\sin\frac{2\pi n}{b}}{\frac{5Dab}{4}[(\frac{2\pi}{a})^4+(\frac{2\pi}{a})^2(\frac{2\pi}{b})^2+\frac{1}{2}.(\frac{2\pi}{b})^4]} \tag{8}$$

$$C_{12}=\frac{P[\cos\frac{2\pi m}{a}-\cos^2\frac{2\pi m}{a}+\cos\frac{2\pi(a-m)}{a}-\cos^2\frac{2\pi(a-m)}{a}]\sin\frac{4\pi n}{b}}{\frac{5Dab}{4}[(\frac{2\pi}{a})^4+(\frac{2\pi}{a})^2(\frac{4\pi}{b})^2+\frac{1}{2}.(\frac{4\pi}{b})^4]} \tag{9}$$

$$C_{21}=\frac{P[\cos\frac{4\pi m}{a}-\cos^2\frac{4\pi m}{a}+\cos\frac{4\pi(a-m)}{a}-\cos^2\frac{4\pi(a-m)}{a}]\sin\frac{2\pi n}{b}}{\frac{5Dab}{4}[(\frac{4\pi}{a})^4+(\frac{4\pi}{a})^2(\frac{2\pi}{b})^2+\frac{1}{2}.(\frac{2\pi}{a})^4]} \tag{10}$$

$$C_{22}=\frac{P[\cos\frac{4\pi m}{a}-\cos^2\frac{4\pi m}{a}+\cos\frac{4\pi(a-m)}{a}-\cos^2\frac{4\pi(a-m)}{a}]\sin\frac{4\pi n}{b}}{\frac{5Dab}{4}[(\frac{4\pi}{a})^4+(\frac{4\pi}{a})^2(\frac{4\pi}{b})^2+\frac{1}{2}.(\frac{4\pi}{a})^4]} \tag{11}$$

Substitution of Eq.(7) and (11) into (10) and the approximate function for the deflection of thin plate bending is obtained:

$$\varpi=\frac{4P}{5Dab}\sum_{\xi}^{1,2}\sum_{\eta}^{1,2}\frac{[\cos\frac{2\pi\xi m}{a}-\cos^2\frac{2\pi\xi m}{a}+\cos\frac{2\pi\xi(a-m)}{a}-\cos^2\frac{2\pi\xi(a-m)}{a}]\sin\frac{2\pi\xi n}{b}}{(\frac{2\pi\xi}{a})^4+(\frac{2\pi\xi}{a})^2(\frac{2\pi\xi}{b})^2+\frac{1}{2}.(\frac{2\pi\xi}{b})^4}\cos\frac{2\pi\xi x}{a}(1-\cos\frac{2\pi\xi x}{a})\sin\frac{2\pi\eta y}{b} \tag{12}$$

3. Experimental Program

3.1Test Specimens

The sectional dimension of the Square steel tube (hereinafter referred to as DG) is 350mm×350mm×10mm×10mm. All specimens were made from Q345B and Q235B. Table.1 shows the specimen number and the corresponding board size. The specimen and the corresponding board adopt the way of all around welding. E50 series welding rod were used for welding seam, and welding level Reached 2 levels. All the connecting bolts adopt the friction type high strength bolt with 10.9 grades M20. The design of the test piece needs to meet the requirements of specification for structural requirements of steel structure for the connection of bolts.

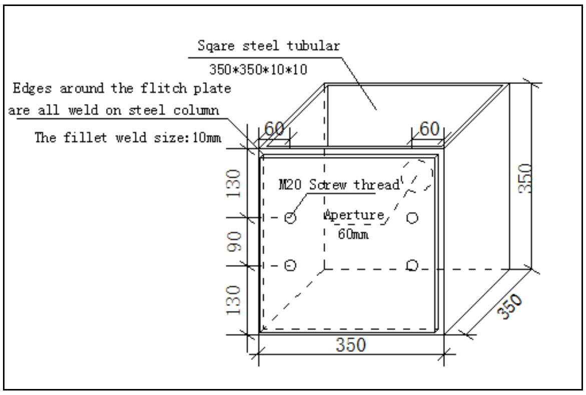

Fig.3 *Dimensions of specimen*

Table1*. Basic parameters of specimens*

Specimen	Material	Specimen size /mm	Plate size/mm	Bolt number
DG-1	Q235	350*350*10 *10	330*330* 8	2
DG-2	Q235	350*350*10 *10	330*330* 10	2
DG-3	Q235	350*350*10 *10	330*330* 12	2
DG-4	Q345	350*350*10 *10	330*330* 8	2
DG-5	Q345	350*350*10 *10	330*330* 10	2
DG-6	Q345	350*350*10 *10	330*330* 12	2

3.2 Experiment test instrument layout

The displacement meters are used to measure the bending deformation of the thin plate of the bolt location. Figure 4 shows that three displacement meters are adopted in the experiment, Two of which were used to measure the displacement of the bolts, the another was used to measure the displacement of square steel tube. What we need is the deflection of the plate corresponding to the bolt, which is the difference between the displacement and the displacement of the square steel tube was measured in the test.

Fig.4 *Arrangement of displacement meter*

3.3 Test setup and test procedure

Test loading device is shown in Figure 5. The artificial torsion custom matching wrench to load is used in this test. This experimental device needs manual loading, but considering the limited manpower, all specimens are unified only with two high strength bolts for connection. The 170KN pre tension force is applied to the bolts with the torque wrench before loading which is referred to "the code for acceptance of construction quality of steel structures"(GB50205-2001.)

Fig.5 *Test apparatus*

The whole testing process is controlled by force, each level load is increased by 15KN. Each time the load is completed, the data acquisition box for a data acquisition. Achieving one of the following conditions is deem to reach the limit state for the test:'

(1) The pipe wall steel tube is damaged;
(2) The bolt is pulled off;
(3) The bolt and the wall of the tube wall are relatively sliding or the bolt is pulled out of the tube wall.

3.4 Experimental phenomenon

By loading the specimens, a certain displacement was caused by axial tension, and the numerical value of the corresponding displacement meter is also constantly increasing. When the axial tensile loading to a certain tension value, visible cracks can be observed in the side of the tube wall and the connecting plate between the device. The gap increases with the increase of the force value. Different material and different thickness of the board will also make a difference on the size of the gap. When the tensile value reaches the extreme value, bolts will be pulled out of a certain distance from the plate, and at the same time a "bang" sound will outbreak. At this point, the measured value will be reduced, while the gap between the two plates to achieve the maximum.

4. Examples

The Q235 of the square steel pipe whose thickness of the plate is 8 mm was select, and axial tension is 120kN to calculate the change value of the bending of the plate corresponding to the elastic plate bolts. According to the experiment, the change value of the measured place in the experimental data is the deflection value of the thin plate in the place. Easy to get the actual value of the deflection here is 1.27mm. There into a=b=350mm. The value of m,n can be obtained from Figure 2

$$D=Et^3/12(1-\mu^2);$$

There into t=8mm;

$$E=205Gpa,\mu=0.3;$$

When the relative thickness of the plate is relatively large (When the aperture is the same as the thickness of the plate), considerable errors may be caused in the support of the plate or around the open hole [27]. As the Force graphics of threaded connection in "Handbook of mechanical strength calculation", the relationship between force and deformation is linear in the case of elastic deformation. because of the influence of steel plate and steel and other types of screw holes, The approximate value of the deflection of the corresponding point should also meet the following conditions.

If the steel plate material is Q235:

$$\omega=17.5\varpi+0.490 \qquad (13)$$

If the steel plate material is Q345:

$$\omega=0.16\varpi+0.625 \qquad (14)$$

Substitution of Eq.(12) and (13) into (10) it is finally yielded that the actual calculation of the approximate deflection value is 1.190 mm. The calculated values are approximately equal to the actual values. Table.2 shows the actual deflection values and the calculated values of The axial tensile force of the test being 120KN.

Table.2 *The flexure deformation of each specimen*

Specimen	Calculated value L_1/mm	Actual value L_2/mm	L_1/L_2
DG-1	1.19	1.270	0.937
DG-2	0.84	0.960	0.875
DG-3	0.805	0.900	0.894
DG-4	0.192	0.185	1.038
DG-5	0.185	0.172	1.076
DG-6	0.175	0.160	1.093

4. Conclusions

In this paper, we study the new unilateral bolt tensile connection bearing capacity of the bolt connection, In which two pieces of welding joint plate act as a nut. Through the research on the bending of the corresponding point of the thin plate, some conclusions are drawn as following:

(1) The deflection of a thin plate,t he material of the test piece, and the thickness of the plate is related to the size of the cross section.
(2) The material of the thin plate has a great influence on the deflection of the plate, and we should be reasonable and economic to choose the material of the steel plate. In this paper, we can draw a conclusion that under the same thickness Q345 in the anti-buckling aspects of the steel has a greater advantage than Q235.
(3) The bending rigidity of the thin plate is mainly determined by the thickness of the D. And the thickness of the plate is determined to take a decisive role on the deflection value.

Acknowledgements

The authors would like to express their gratitude to the National Natural Science Foundation of China for their financial support of this study through grants No.51368052.

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