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## Analysis on the setting method of tie member

G Qin<sup>1\*</sup> and G Liu<sup>1</sup>

<sup>1</sup> School of Civil Engineering, Shenyang Jianzhu University, Shenyang, China, 110168

\*E-mail: 1581011396@qq.com

**Abstract.** In order to provide a theoretical basis for the of construction scaffold design, the influence of the setting of tie member on the maximum bending moment of the scaffold under wind loads was studied. Based on the semi-rigid analysis of scaffold tube joints, the finite element ANSYS software is used to simulate and analyse the scaffold frame, and studying the change rule of maximum bending moment of scaffold upright tube when the setting of tie member is different. The maximum bending moment of the scaffold upright tube was obtained from simulation and analysis by using ANSYS. The comparison and analysis show that, when the tie member was deviated from the main node and only connected with the inner upright tube, the maximum bending moment of the upright tube was increased obviously, and the maximum bending moment of the inner upright tube increases significantly. Research has shown that the setting of the tie member should ensure the simultaneous connection with the inner and outer upright tube. According to the scaffold at different heights of building in the construction, the author proposed a value of the research for the reasonable position of the tie member and the maximum deviation from the main node.

### 1. Introduction

Scaffold is a working platform or protective frame, which is erected in engineering construction to meet the workers' operation needs. The temporary structure around the building in the construction, in order to facilitate the construction personnel up and down operation or external wall decoration work or stacking building materials is known as construction outside scaffold.

The setting of scaffold relates to the speed, quality and safety of engineering construction. Scaffold is an indispensable construction facility. With the increasing in the height of the building, the wind load role on the scaffold increases significantly. Due to structural forms or the size of the scaffold, the setting of the tie member will appear considerably different. In this paper, the key technical problems of such a as scaffold erection are analysed, when the scaffold tie member is deviated from the main node [1-3].

The research on scaffolding mainly focuses on two major aspects: a. node analysis model, b. load calculation method research. The analyses of representative works are mainly as follows:

In 2001, Professor Zongren Liu [4] the described calculation method in detail for the lower critical force limit of steel tubular scaffold with couplers. It is pointed out that in the actual construction, due to the insufficient torque of the coupler or its other factors affecting the force of the node of steel pipe joint, the "semi-rigid" node, can be simplified to the hinge contact.

In 2004, Professor Hongfei Ao and Professor Guoqiang Li [5-6] stated the fact that the ultimate bearing capacity of double row scaffolding is analysed by second-order finite element simulation.



Further considering the semi-rigid characteristics of the geometrically nonlinear beam column element and the coupler node, the rotational stiffness of the coupler is measured through experiments. Finally, the validity of the finite element analysis method is tested by two scaffold prototype tests.

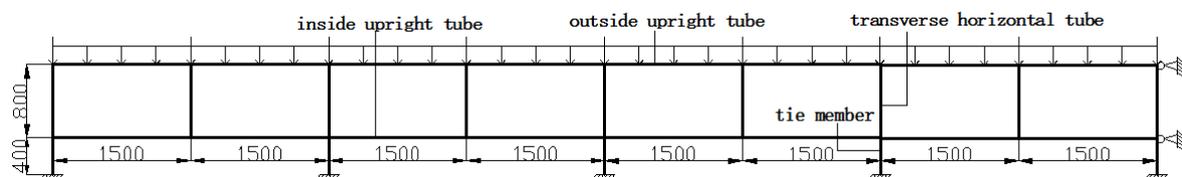
In 2015, Guijuan Qin and Jiazhi Ren [7] analysed the wind load effect of scaffold tie member in Super high-rise building construction. It is concluded that the along-wind vibration factor should be considered in the calculation of wind load characteristic value for scaffolding construction in high-rise and Super high-rise buildings. The practical calculation method of the along-wind vibration factor in the calculation of the shape factor of wind load is given, and the specific calculation method of the along-wind vibration factor and the characteristic calculation formula for the horizontal wind load of a single tie member under different arrangement methods are given.

## 2. The setting of the tie member and the calculation of the standard value of the wind load

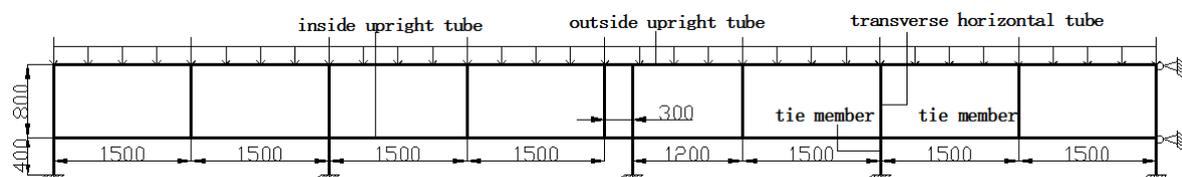
The longitudinal and transverse horizontal tubes are tightly fastened and tightly connected with the upright tube, which is called the main node. After the tie member is deviated from the main node, the right angle coupler is connected to the upright tube and the tie member. Their buckle contact point is not the main node (Deviating from the main node). The tie member is connected with the structure in construction. It is the most important force-carrying tube to transfer wind loads to the structure of the building. The reliable connection between the upright tube and the tie member, between the upright tube and the transverse tube, that can control the longitudinal and transverse deformation of the whole frame body. As the intermediate restraint of the frame body, the tie member can effectively reduce the calculation length of the upright tube and improve the bearing capacity of the frame body. The reasonable setting of the tie member can effectively increase the rigidity of the frame body, prevent the frame from overturning and ensure the lateral stability of the whole frame body [8-9].

### 2.1. Working condition analysis diagram

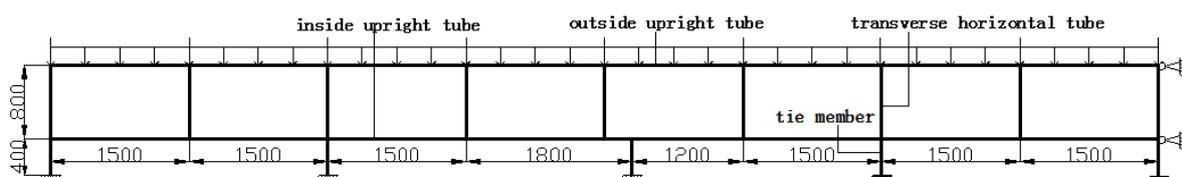
The different structure in the actual project, for example the door, window openings and other specific reasons, sometimes the tie member, cannot be connected to the upright tube and horizontal tube of the main node, but it can only deviate from the main node connection.



(a) The tie member connecting with inside and outside upright tube at the main node



(b) The tie member connecting with inside and outside upright tube deviating from the main node



(c) The tie member only connecting with the inside upright tube deviating from the main node

**Figure 1.** Working condition analysis diagram.

When the tie member is deviated from the main node connection, the tie member is divided into the tie member and the inside and outside upright tube simultaneously, and the tie member is only connected with the inside upright tube. In order to study the influence of a different setting on the frame design of the tie members of the main node under the wind load, this paper studies the influence of the bending moment of the tie member in the case of deviating from the 300mm of the main node. In this paper, the working conditions are analysed in figure 1.

## 2.2. Calculation method of standard value of wind load

The wind pressure is perpendicular to the air flow building plane on the pressure, and its expression is:

$$\omega(x, t) = \varpi(x) + \omega(t, x) \quad (1)$$

in the formula above:

$\varpi(x)$  - average wind speed static pressure,

$\omega(t, x)$  - wind fluctuating wind pressure.

Along-wind vibration is the dynamic effect caused the pulsating part of wind to the high structure.

In addition to the static effect, the high-rise building should consider the dynamic action. The dynamic action is related to the structural vibration, structural damping and structure height, and the pulsating wind pressure can be assumed to be a stochastic process of each state and deduced from the basic principle of stochastic vibration theory [10-12].

The along-wind vibration factor changes with the height of the frame body. The along-wind vibration factor is not only related to the building site, but also to the natural vibration characteristics of the structure. As for the construction scaffold of high-rise and super high-rise building, because the scaffold is connected with the structure through the tie member and based on the structure, we can only consider the effect of the first vibration mode on the structure when the structure is an equal-section structure with no change in shape and mass along the height [13, 14].

The value of the wind pressure on the building is related to the building's body size, aspect ratio and ground roughness. For the scaffold structure, the characteristic value of wind load can be simplified by static equivalent wind load. With the increasing of the structure height, the effect of the wind load is increasing, and the influence of along-wind vibration cannot be neglected. Therefore, in addition to considering the reference wind pressure value, shape factor of the wind load and exposure factor of wind pressure, the influence of along-wind vibration factor should be considered when calculating the characteristic value of horizontal wind load on scaffold. So the formula is as follows:

$$w_k = \beta_z \cdot \mu_z \cdot \mu_s \cdot w_0 \quad (2)$$

In the formula above :  $w_k$  - characteristic value of wind load (kN/m<sup>2</sup>);

$\mu_z$  - exposure factor of wind pressure;

$\mu_s$  - scaffold shape factor of wind load;

$w_0$  - reference wind pressure value (kN/m<sup>2</sup>).

The reference wind pressure value should select a 10-year recurrence period.

The rough category of the C ground:

$$\mu_z = 0.544 \times \left( \frac{z}{10} \right)^{0.44} \quad (3)$$

For the along-wind vibration factor  $\beta_z$ , the formula is :

$$\beta_z = 1 + 2g \cdot I_{10} \cdot B_z \cdot \sqrt{1 + R^2} \quad (4)$$

$B_z$ ,  $R$  quoted from reference [7].

The rough category of the C ground:  $g=2.5$ ,  $I_{10}=0.23$ .

The coefficients in formula (4) are strictly in accordance with the "Load code for the design of building structures" (GB50009-2012) [15]. For formula (2), the reference wind pressure value should select a 10-year recurrence period,  $\omega_0=0.4\text{kN/m}^2$  in the Shenyang area of China. According to the size of the analysis model frame (lift height and longitudinal spacing is 1.5m), the rough category of the C ground is taken for calculation. Taking Shenyang city of China building construction as example,  $\omega_k$  value have been given in table1.

**Table 1.**  $\omega_k$  value at different height of scaffold at the location.

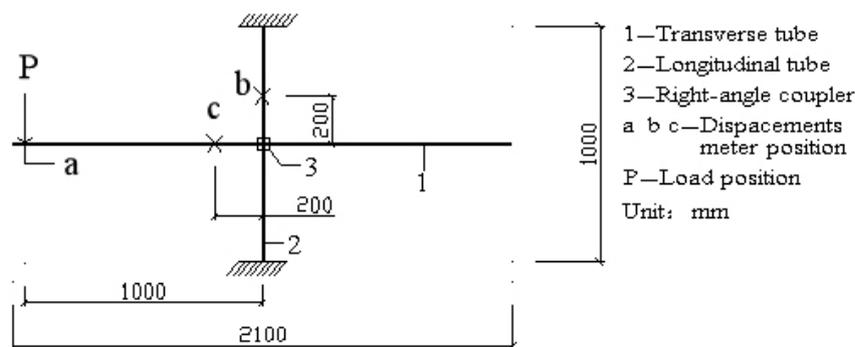
Height (m)	$\omega_k$ values at 50m-500m height above the ground									
	50	100	150	200	250	300	350	400	450	500
$\omega_k$ Value ( $\text{kN/m}^2$ )	1.53	2.01	2.33	2.56	2.75	2.91	3.04	3.16	3.27	3.30

### 2.3. Calculation method of node semi-rigidity

The right angle coupler node is neither an ideal "rigid connection" nor an ideal "articulation", but a semi rigid link between the two.

This paper further proves that the properties and stiffness of semirigid and the experimental scheme diagram and the experimental device are shown in figure 2 and figure 3. When the material and component specifications of the scaffold selected are determined, rotational stiffness value of the coupler node is directly related to the size of the coupler tightening moment, the greater the tightening torque, the greater the stiffness of the node rotation, the rotation stiffness of the coupler nodes corresponding to different tightening torques is different.

The determination of the rotational stiffness can be measured by the test method, when the tightening moment requirements are met in construction, rotation stiffness can choose according to the specified indicators.



**Figure 2.** Simplified diagram of node rotation stiffness measurement scheme.



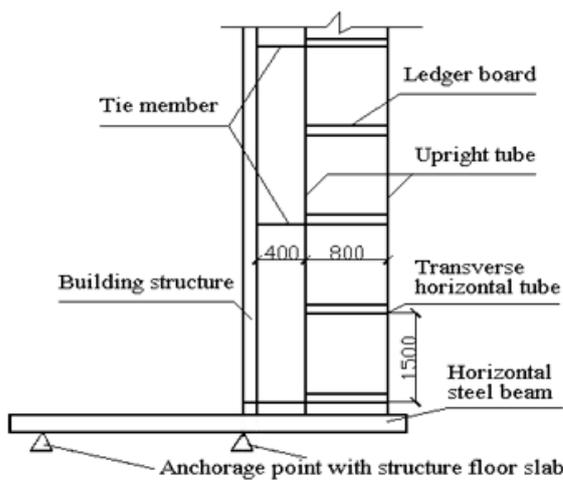
**Figure 3.** Test equipment.

### 3. ANSYS finite element analysis

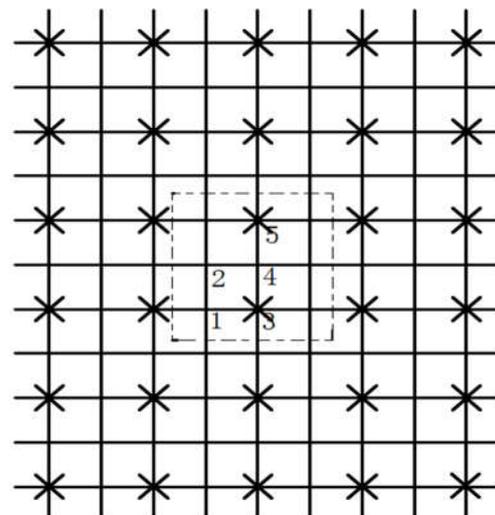
(Take two-step of height and two-span of longitudinal as an example)

#### 3.1 .Finite element analysis of at the main node

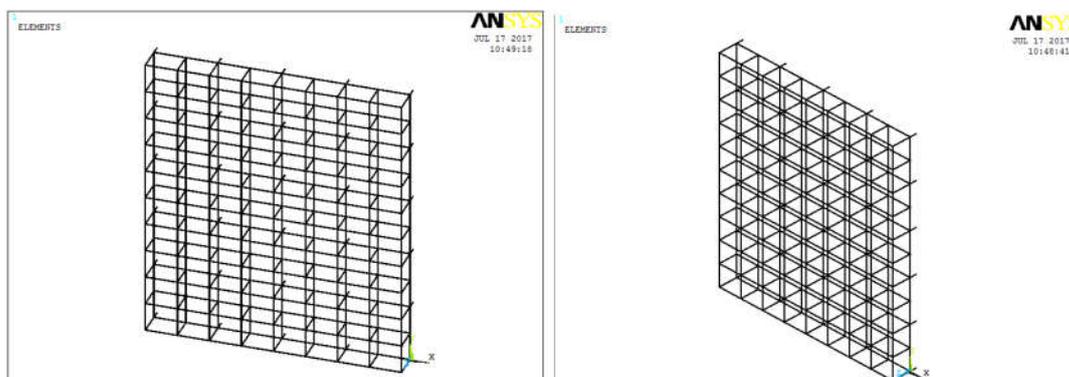
**3.1.1. The establishment of finite element model.** In this chapter, taking the analysis of tie member setting in two-step of height and two-span of longitudinal layout for the middle position as shown in figure 5, the tie member is set at the main node. Steel tube Specification Selection 48mm × 3mm, lift height and longitudinal spacing is 1.5m, distance between inside upright tube and building structure is 400mm, outside upright tube and building structure is 1200mm. Elastic modulus  $E=2.06 \times 10^5$ MPa Poisson's ratio  $\mu=0.3$ . The connection between the scaffold upright tube and steel I-Beam as articulation. The connection between tie member and the building structure is as rigid connection. In order to make the force of the fastener place better concord with the actual situation, the spring element Combin14 is introduced into the simulation process to simulate the coupler connection. The rotational stiffness between the tube and the tube through the coupler connection is 35kN·m/rad. The concrete setting of the steel tubular scaffold as shown in figure 4. The concrete arrangement of the tie member elevation as shown in figure 5. The symbol "×" represents the placement of the tie member. Number represents position number. ANSYS finite element model as shown in figure 6. Analysis of the position of the middle part of the whole frame body (figure 5 dashed section).



**Figure 4.** Cantilever steel I-beam tubular scaffold.



**Figure 5.** Elevation of tie member arrangements.



**Figure 6.** Finite element model.

*3.1.2. Analysis of finite element result.* By applying the equivalent characteristic of the value wind load of the scaffold at different heights of building, it is converted to the equivalent uniformly distributed line load and applied to the outside tube (facing wind side tube) of the frame body.

By extracting the middle part of the frame from the finite element data, the characteristic value of the moment of the scaffold at different heights is obtained. Results are shown in the table 2 and in the figures 10, 11, 12, 13, 14, 15.

**Table 2.** Bending moment characteristic value of node 1 to node 3 in figure 5 and figure 6.

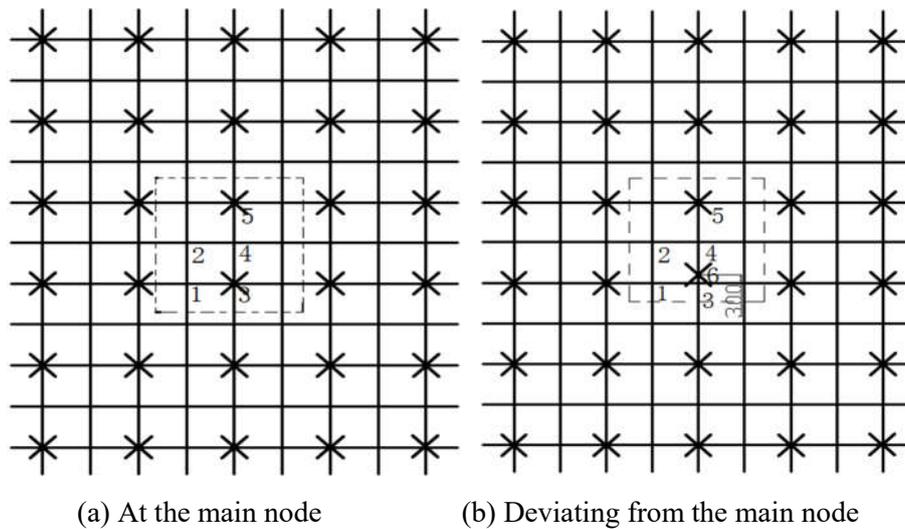
Height above the ground (m)	Bending moment of upright tube ( $\times 10^5 \text{N}\cdot\text{mm}$ )					
	position 1		position 2		position 3	
	Inside	Outside	Inside	Outside	Inside	Outside
50	3.36	1.80	-0.26	-1.81	4.3	2.92
100	4.76	2.70	-0.67	-2.73	8	6.2
150	5.67	3.29	-0.93	-3.31	10.5	8.6
200	6.34	3.72	-1.12	-3.74	13.4	10.55
250	6.88	4.07	-1.27	-4.10	13.4	13.4
300	7.33	4.36	-1.40	-4.38	13.4	13.4
350	7.71	4.60	-1.52	-4.63	13.4	13.4
400	8.05	4.82	-1.62	-4.85	13.4	13.4
450	8.36	5.02	-1.70	-5.04	13.4	13.4
500	8.45	5.08	-1.74	-5.11	13.4	13.4

**Note:** The corresponding bending moment value is positive when the stress at the upright tube of the frame body is tensile stress on the windward side.

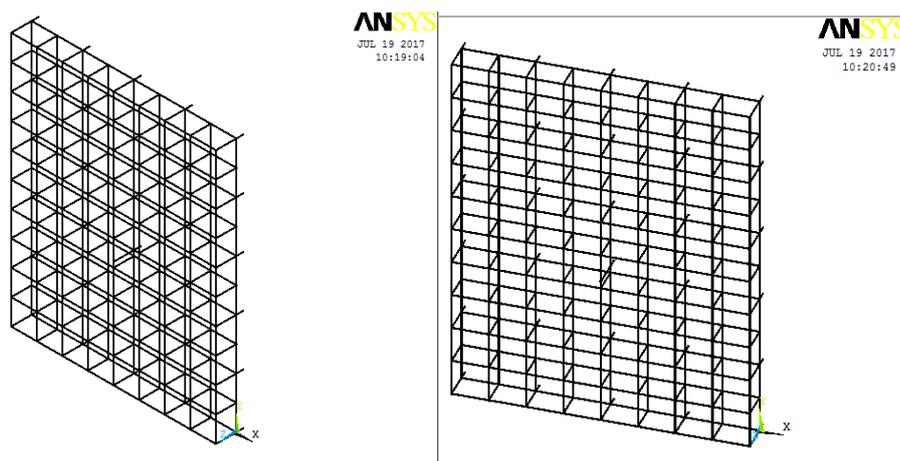
### *3.2. Finite element analysis of tie member deviating 300mm from main node*

*3.2.1. The establishment of the finite element model.* Finite element analysis of deviating from the main node connecting with inside and outside upright tube. In this chapter, taking analysis of tie member setting in two-step of height and two-span of longitudinal layout for the middle position as shown in figure 7(b), the tie member deviating from the main node.

Steel tube Specification Selection 48mm  $\times$  3mm, lift height and longitudinal spacing separately is 1.5m, distance between inside upright tube and building structure is 400mm, outside upright tube and building structure is 1200 mm. Elastic modulus  $E=2.06 \times 10^5 \text{MPa}$  Poisson's ratio  $\mu=0.3$ . The connection between the scaffold upright tube and steel I-Beam as articulation. The finite element simulation analysis of the tie member deviating from the main node is basically the same as the simulation idea of the tie member at the main node. The only difference is that the middle position of the scaffold is set on the non-main node (the tie member deviates 300mm from the main node, for simulating the actual deviation of the tie member from the main node setting in the construction project. The node is got for arrangement of the tie member elevation shown as in figure 7. The tie member in figure 7 (a), which was originally set at main position 3, deviates from the height of the upright tube to position 6 as shown in figure 7(b). In figure 7, the symbol "x" represents the placement of the tie member. Analysis of the position of the middle part of the whole frame body, finite element model is as shown in figure 8.



**Figure 7.** Elevation of tie member arrangements.



**Figure 8.** Finite element model.

**3.2.2. Analysis of finite element result.** By applying the equivalent characteristic of the value of wind load of the scaffold at different heights of building, it is converted to the equivalent uniformly distributed line load and applied to the outside tube (facing wind side tube) of the frame body.

By extracting the middle part of the frame from the finite element data, the characteristic value of the moment of the scaffold at different heights is obtained. Results are shown in the table 3 and in the figures 10, 11, 12, 13, 14, 15.

**3.3. Finite element analysis of the tie member deviating from the main node only connecting with the inside upright tube**

**3.3.1. The establishment of finite element model.** The finite element simulation analysis of the tie member deviating from the main node only with inside upright tube is basically the same as the simulation idea of the tie member deviating from the main node, the only difference is the removal of the small bar between the inside and outside of the transverse tube. This small tube cannot be set up for some reason in the actual construction project. The finite element model is shown in figure 9.

**Table 3.** Bending moment characteristic value of node 1 to node 3 in figure 7(b) and figure 8.

Height above the ground (m)	Bending moment of upright tube ( $\times 10^5$ N·mm)					
	position 1		position 2		position 3	
	Inside	Outside	Inside	Outside	Inside	Outside
50	1.95	0.4	0.72	-0.82	1.61	0.39
100	2.9	0.85	0.96	-1.08	2.13	0.51
150	3.51	1.14	1.11	-1.25	2.46	0.6
200	3.97	1.36	1.22	-1.38	2.71	0.66
250	4.33	1.53	1.32	-1.48	2.91	0.7
300	4.64	1.68	1.39	-1.57	3.08	0.74
350	4.89	1.8	1.45	-1.67	3.22	0.78
400	5.13	1.91	1.51	-1.7	3.34	0.81
450	5.33	2.01	1.56	-1.76	3.46	0.83
500	5.4	2.04	1.58	-1.78	3.49	0.84

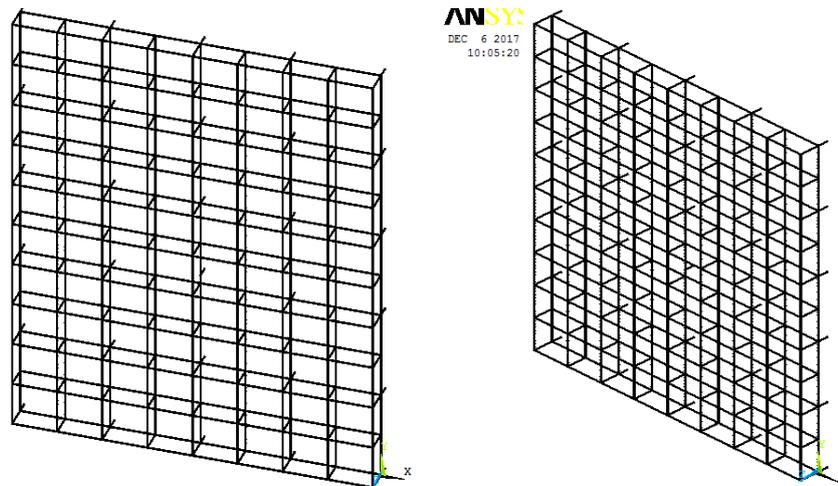
**Note:** The corresponding bending moment value is positive when the stress at the upright tube of the frame body is tensile stress on the windward side.

3.3.2. *Analysis of finite element result.* Based on the relevant data of the finite element model, the bending moment value of the joint of the tie member with the position of the inside upright tube. By extracting the middle part of the frame data, the characteristic value of the moment of the scaffold at different heights is obtained. Results are shown in the table 4 and in the figures 10, 11, 12, 13, 14, 15.

**Table 4.** Bending moment characteristic value of node 1 to node 3 in figure 7(b) and figure 9.

Height above the ground (m)	Bending moment of upright tube ( $\times 10^5$ N·mm)					
	position 1		position 2		position 3	
	Inside	Outside	Inside	Outside	Inside	Outside
50	2.87	0.51	1.4	-0.68	2.68	1.21
100	4.28	0.91	1.82	-0.87	3.54	1.68
150	5.17	1.25	2.01	-1.02	4.21	2.23
200	5.84	1.56	2.31	-1.11	4.69	2.85
250	6.37	1.62	2.55	-1.23	4.86	3.36
300	6.83	1.66	2.76	-1.37	4.97	3.92
350	7.35	1.89	2.94	-1.45	5.12	4.44
400	7.55	2.01	3.21	-1.51	5.31	5.02
450	8.75	2.11	3.33	-1.59	5.56	5.51
500	9.96	2.23	3.51	-1.63	5.67	5.89

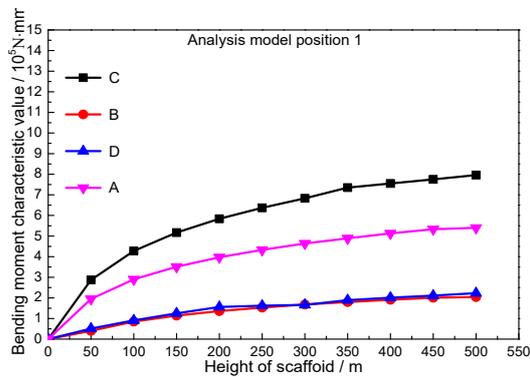
**Note:** The corresponding bending moment value is positive when the stress at the upright tube of the frame body is tensile stress on the windward side.



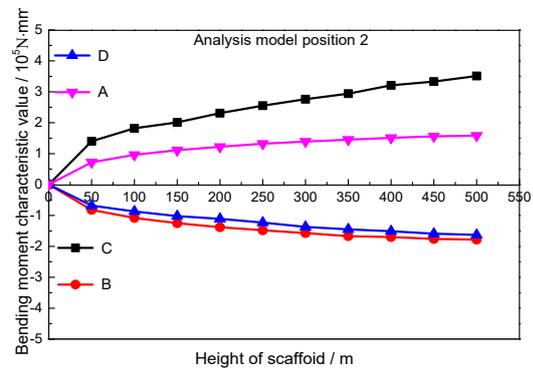
**Figure 9.** Finite element model.

Application of Originpro mapping and data analysis software, based on the above two groups of finite element analysis.

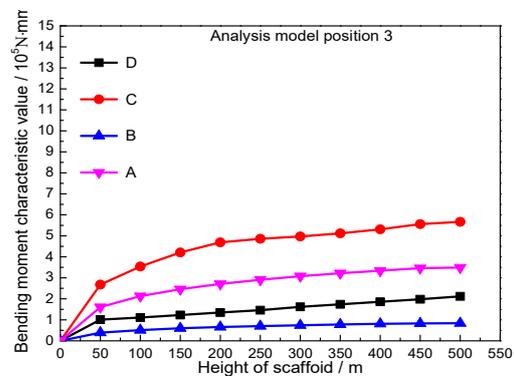
Taking the positions 1, 2, 3, 4, 5, 6 respectively to make a comparison, the bending moment characteristic changes the curve between the inside and outside upright tube, in these cases of the tie member at the main node, the tie member deviating from the main node, the tie member deviating from the main node only connected with the insider upright tube. The relation curve is as following :



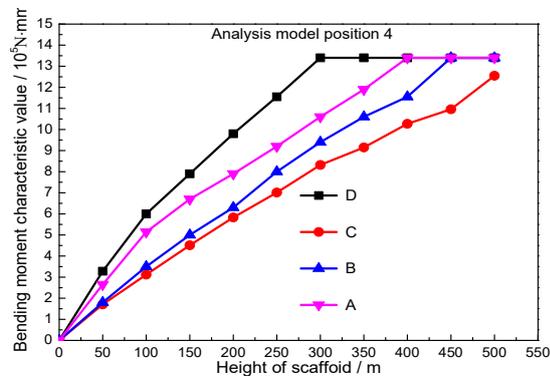
**Figure 10.** Curve of M-H at position 1.



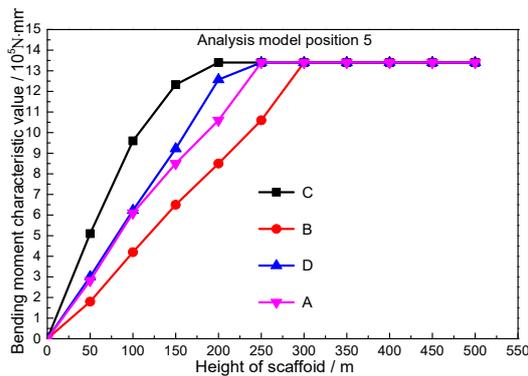
**Figure 11.** Curve of M-H at position 2.



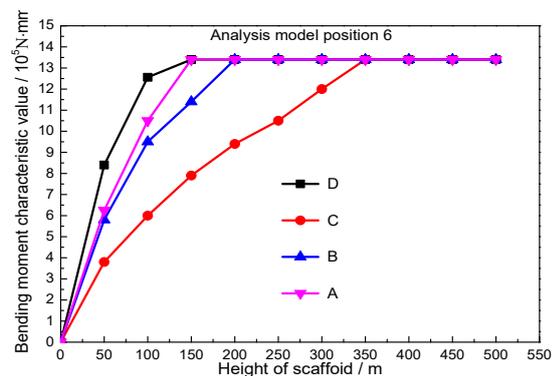
**Figure 12.** Curve of M-H at position 3.



**Figure 13.** Curve of M-H at position 4.



**Figure 14.** Curve of M-H at position 5.



**Figure 15.** Curve of M-H at position 6.

**Note:** A-The bending moment value of outside upright tube, under condition of the tie member deviating from the main node (the tie member connecting with inside and outside upright tube).

B-The bending moment value of inside upright tube, under condition of the tie member deviating from the main node (the tie member connecting with inside and outside upright tube).

C-The bending moment value of outside upright tube, under condition of the tie member deviating from the main node only connecting with the insider upright tube.

D-The bending moment value of inside upright tube, under condition of the tie member deviating from the main node only connecting with the insider upright tube.

#### 4. Result analysis

For a single upright tube, when the frame height, step distance and span are the same, the curves of the finite element model are analysed as follows:

(1) In figure 10: the maximum bending moment of the upright tube at position 1 without tie member appears in the outside upright tube, The C curve is the bending moment value of the outside upright tube at the position 1 when the tie member deviates from the main node and is connected to the inside upright tube only. The C curve above the other A, B, D curve. In figure 10, the value of maximum bending moment C is  $2.6 \times 10^5 \text{N}\cdot\text{mm}$  more than A.

(2) In figure 11: the bending moment direction of the inside and outside upright tube is different. The C curve is the bending moment value of the outside upright tube at the position 2 when the tie member deviates from the main node and is connected to the inside upright tube only, it is an absolute value, much more than in other A B D situations. The absolute value of the maximum bending moment increases and it is bad for the stability of the upright tube.

(3) In figure 12: at position 3, the longitudinal horizontal tube intersects with the upright tube, The C curve is above others in spite of the tie member being set differently. The C curve is the bending moment value of the outside upright tube at the position 3, when the tie member deviates from the main node and the maximum moment value of the C curve is double than that of A curve.

(4) In figure 13: for the position 4 between the two tie members along the step direction, the maximum bending moment of the inside upright tube increases rapidly. The maximum bending moment appears in the inside upright tube. The D curve is the bending moment value of inside upright tube under condition of the tie member deviating from the main node only connecting with the insider upright tube. Meanwhile, the maximum moment value of D curve is much larger than that in figures 10, 11, 12.

(5) In figure 14: for the position 5, the maximum moment of the frame body appears in the inside upright tube as C curve, and around 200m to reach the peak of the curve.

(6) In figure 15: for the position 6, after deviating from the main node, it can be seen from the figure that the maximum bending moment value of the outside upright tube is decreased as C curve, but the bending moment of the inner upright tube is increased obviously and around 120m to reach the peak

of the curve. The D curve is the bending moment value of the inside upright tube at the position 6, when the tie member deviates from the main node only connecting with the insider upright tube. Meanwhile, the maximum moment value of the D curve is much larger than that in figures 10, 11, 12, 13, 14.

Analysis of the figure 15: the tie member design arrangement deviating from the main node is 300mm, this design method being a feasible method. But over that size of 300 mm and the scaffold working height exceeding 100 m, that scaffold frame working is a hazardous situation. The proposed value of the maximum deviation from the main node is 200mm when the scaffold working exceeds 100m in height.

## 5. Conclusion

Based on the semi-rigid analysis of scaffold tube joints, the finite element ANSYS software is used to simulate and analyse the scaffold frame. Get the following important conclusions :

(1) The maximum moment value of the upright tube increases because of the tie member deviating from the main node, as compared with the tie member at the main node. Under construction, the tie member piece setting should be located on the main node, or around the main node, as near as possible.

(2) When the tie member deviates from the main node, the connecting with inside and outside upright tube at same time can reduce the maximum bending moment of the upright tube, which is beneficial to the stability of the upright tube. Because of the hole, etc., when the tie member could not be set at main node, the tie member should be connected with the inside and outside upright tube to reduce the maximum bending moment value of the upright tube.

(3) It is reasonable to deviate 300 mm from the main node when the scaffold using the height above the ground is less than 100m. When the using height exceeds 100m, the deviation size should be strictly limited to less than 200mm or the tie member quantity should be increased.

## References

- [1] Qin G and Zhang S 2016 Calculation and analysis of bending moment of scaffold upright tube in wind-load *Alternative translations* **S1**
- [2] Qin G, Zhang S and Zhang X 2016 Analysis of maximum bendingmoment of upright tube wind load of construction scaffold of super high-risebuilding *Journal of Shenyang Jianzhu university (natural science)* **04**
- [3] The Ministry of housing and urban-Rural Development of the People' s Republic China 2011 *Safety technical specification of construction fastener type steel pipe scaffold JGJ130-2011*(Beijing: China Architecture & Building Press)
- [4] Liu Z and Ding Y 2001 Calculation method of lower limit of critical force for steel tubular scaffold with couplers *Architectural technology* **3 ( 8 )** 541
- [5] Ao H and Li G 2003 Analysis of ultimate bearing capacity of double polesteel tubular scaffold with couplers *Construction* **25 ( 3 )** 214
- [6] Ao H and Li G 2004 Research on ultimate stable bearing capacity of double pole steel tubular scaffold with couplers *Mechanics quarterly* **25 ( 2 )** 213
- [7] Qin G and Ren J 2013 Analysis of wind load acting on the tie member of sc-affold in super high-rise building construction *Journal of Shenyang Jianzhu University* **31(2)** 306
- [8] Zhuo X and Zheng N 2005 Discussion on the Part of the Steel tubular scaffold with couplers specification *Construction technology* **34(3)** 78
- [9] Chen X 2011 Development and application of new wall fasteners of external scaffold *Construction technology* **42(8)** 714
- [10] Li Y, Xu W and Shen Q 2012 Analytical study on structural modeling for wall connector of steel pipe scaffold *Building construction* **34(11 )** 1095
- [11] Hadipriono F C and Wang H K 1986 Analysis of Causes of Formwork Failures in Concrete Structures *Const Engng Mgmt ASCE* **112(1)** 112

- [12] Hadipriono F C and Wang H K 1987 Causes of Falsework Collapses during Construction *Structure Safety* **4(3)**179
- [13] Qin G and Xu W 2015 Study on the arrangement of the steel tubular scaffold with couplers in the construction of super high rise building *Journal of Shenyang jianzhu university( natural science)* **31(6)** 1023
- [14] Siu C, Ho L and Ming G W 1994 Nonlinear Vibration analysis of steel frames with semirigid connections *Journal of Structural Engineering* **120(4)** 1075
- [15] The Ministry of housing and urban-Rural Development of the Peoples Republic of China 2013 *Load code for the design of building structures GB50009-2012* (China Architecture & Building Press)