The experimental study and finite element analysis of wheel - buckle scaffold

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Abstract. With the rapid development of the construction industry, the country has a higher demand for scaffolding engineering, so it is very necessary to develop and promote the application of wheel buckle scaffolding. Steel tube scaffold with wheel buckle has the characteristics of clear transmission and good mechanical performance. In order to study the structural performance of steel tubular scaffolding with wheel buckle, the single span three-step element frame was tested. The failure mode and ultimate bearing capacity of the frame are obtained. The finite element software Sap2000 was used to conduct 3d modeling and linear buckling analysis of scaffolds in the test. The results of experiments and finite element analysis show that the failure type of steel tubular scaffolding is the overall torsional instability failure. The connection stiffness at the joint of the diagonal brace fastener has a great influence on the wheel-buckle scaffold. The diagonal brace has obvious influence on the bearing capacity of steel tubular scaffolding body with buckles.

1 The introduction

In recent years, our country is in a stage of high-speed development of economy, construction projects are springing up and developing vigorously, construction and installation engineering of new technologies, new processes and new materials were the new, combined with the country in recent years, successively for building design, construction, supervision, quality acceptance specification and construction standards of revision, the original technical system has not adapted to the requirement of modern construction enterprise development. Therefore, the economy, practicability and safety of scaffolding are also put forward higher requirements.^[1]

Scaffolding is composed of rods or structural units and accessories through reliable connection, which can bear the corresponding load, has the function of safety protection, and provides the working conditions for the construction of the structure frame^[2]. There are several kinds of the types of scaffolding, scaffold for wheel button and disc scaffolding are similar, but due to the high price of fastener scaffold, combined with the actual use in China, the domestic production enterprises carry out technical transformation to make it more convenient at a lower cost, that round buckle scaffold arises at the historic moment. The characteristics of fast installation speed, high flexibility and low cost are quickly accepted by the market.

In this paper, based on the existing research experience, the single-span three-step steel tubular scaffolding is tested and analyzed, and the failure state,

ultimate bearing capacity and related factors are obtained through the analysis of Sap2000 finite element software.

2 experimental study

2.1 specimen design

The test was carried out in the structure laboratory of changchun institute of engineering. In the test, the unit structure test rack was composed of three steps of a single span, with a step spacing of 1.8m and a length × width × height of 2m × 1.5m × 6m. The size of each component in the specimen is shown in table 1.

table 1. Component size

Component name	Section size (mm)	The length (mm)
stud	48*3.2	1200
		1800
		2400
Horizontal bar	48*3.2	1500
		2000
brace	48*3.2	2500

Figure1. Test drawing

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2.2 loading scheme

In the test, the jack is connected to the top of the reaction frame by bolts, the reaction frame is erected on both sides of the test frame, and through the loading frame, the vertical load is applied to the top of the 4 vertical rods, with each grade of load being 10kN. This test is a destructive test, the loading end point is when the frame body appears serious deformation or the jack can no longer apply the load. Before formal loading, the vertical deviation of the opposite pole shall not exceed 1/300 of the height of the frame and shall not be greater than the diameter of the vertical pole. Preload the scaffold with a vertical load of 5kN to check whether the joints of all parts are pressed, whether the connections are tight, whether the instrument is working normally, and whether the strain distribution of the test part is abnormal. Then unmount and check that the instrument reading is zero. The loading device is shown in figure 2.

Figure2. Experimental setup

2.3 test results

The experiment was carried out in three groups and the control of other factors was consistent.

Three sets of test data were obtained respectively: the total vertical load limits were 190KN, 188KN and 180KN, respectively. The average value of the ultimate bearing capacity of each single vertical rod is 47.5KN, 47KN and 45KN respectively. The experimental phenomenon is the sudden instability of the frame body, indicating that the sensor reading of vertical load drops rapidly, indicating that the scaffold has lost the ability to continue to bear the load. On the top floor of the frame, one of the diagonal braces is damaged and the whole frame is unstable. No observable plastic deformation occurred in other bars.

Through the above tests, it can be obtained that the ultimate bearing capacity of the steel tubular scaffold model with buckles is 186kN(vertical), and the bearing capacity of a single rod is $P = 46.5\text{kn}$. The failure mode is shown in figure 3, and the load-time curve is shown in figure 4.

Figure 3. Failure pattern diagram

Figure 4. Load time curve

3 finite element model

3.1 basic assumptions

According to the parameters of the test model, the model was modeled in the finite element software SAP2000, and the rod element was adopted, and the following simplified assumptions were made:

The vertical bar is regarded as a continuous bar, that is, the connection between the vertical bar and the vertical bar is regarded as unbiased.

The vertical pole is hinged with the foundation; The vertical load ACTS on the geometric center of the vertical pole.

Considering the semi-rigidity of the node between the vertical bar and the horizontal bar, according to the connection stiffness of the node in the literature, $35\text{kN}\cdot\text{m/rad}$.^[3]

Horizontal loads such as wind load and earthquake load are not considered temporarily:

This analysis only considers the linear elastic phase, but not the nonlinear phase.^[4]

3.2 establishment of finite element model

Table 2. Model parameters

Outer diameter	Wall thickness	Cross-sectional area	Cross section moment of inertia	The cross section modulus	Radius of gyration
d (mm)	t (mm)	A (mm ²)	I (mm ⁴)	W (mm ³)	r (mm)
48	3.2	453	115857	4797	15.98

Material performance parameters: $E = 206\text{GPa}$, $f_y = 215\text{MPa}$, $f_v = 125\text{MPa}$

The horizontal distance is 2m, the vertical distance is 1.5m, and the step distance is 1.8m.

Figure 5. Finite element model

3.3 finite element calculation results

Below is round buckle type steel pipe scaffold theory forward six order buckling instability mode, from the figure of the top six order modal and buckling instability can be seen that the scaffold of the first, fourth order for XZ plane (horizontal) instability, and instability in the post buckling deformation in the same direction, present a typical framework along the size of the long side direction of structure of GuQu phenomenon, the scaffold should be paid attention to when using the actual project to strengthen the direction of the long side lateral support. The second and fifth orders are the instability of YZ plane (longitudinal). When the instability occurs, the buckling deformation direction of each vertical bar is the same. Third, six order for torsional buckling, reverse the instability in the bar after large deformation due to the effect of eccentricity of the load produced by buckling mode, generally in the wheel button type steel pipe scaffold has lost before generating torsional buckling bearing capacity, thus avoid low formation can avoid torsional buckling instability of produce, so the lateral support and bracing structure such as support for wheel button type steel tube as the stability of the die set is very important, in the practical engineering should attach great importance to the setting and the erection quality of support, this is helpful to improve the stability bearing capacity of the scaffold. [5]

Figure 6. Six order buckling instability mode

Linear buckling load P_{cr} was obtained for each order buckling mode.

	OutputCase	StepType Text	StepNum Unitless	ScaleFactor Unitless
▶	BUCK2	Mode	1	39.068902
	BUCK2	Mode	2	46.309157
	BUCK2	Mode	3	61.680589
	BUCK2	Mode	4	65.813336
	BUCK2	Mode	5	69.543488
	BUCK2	Mode	6	85.653067

Figure 7. Linear buckling loads of each order buckling mode

From figure 8 each order buckling mode of the linear buckling load P_{cr} , known wheel buckled type steel pipe scaffold single stud linear buckling load of 39.07 kN, this value is not to consider any nonlinearity and initial imperfection of the upper limit of the linear buckling load, and this value is not included in the brace model calculated, thus the value than the actual measured value is small, but differs in the normal range, so the effective data.

4 conclusion

(1) In the test, the failure of the fastener in the inclined brace part of the scaffold leads to the loss of the bearing capacity of the torsion of the scaffold; in the finite element analysis, the semi-rigid connection model is the whole buckling failure of the large wave drum.

(2) The ultimate bearing capacity of the test frame is 186KN, and the bearing capacity of a single rod is 46.5kn. Compared with other literatures, the higher the scaffold is, the less the ultimate bearing capacity it can bear. And the greater the step distance, the greater the vertical distance and the horizontal distance, the smaller the ultimate bearing capacity. Therefore, the closer scaffold should be used in the actual project as much as possible.

(3) Using sap2000 for linear buckling analysis can well simulate the failure of wheel buckle scaffold.

(4) The oblique brace has obvious influence on the bearing capacity of steel tubular scaffolding body with wheel buckle. Therefore, in the setting up of scaffolding, especially in the setting up of high support mold, must pay attention to the requirements of the oblique brace structure.

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