Influence of Scissors Support on Ultimate Bearing Capacity of High-formwork Support System

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Abstract. The influence of the setting of the scissors support on the ultimate bearing capacity of the high-formwork support system is analysed in detail by the finite element software Midas Gen. The results show that with the gradual increase of the erection density of the horizontal scissors support, the waveform of the unstable buckling mode gradually becomes slower, and the corresponding wavelength reduced, however, the horizontal scissors support imposes limited effect on increasing the bearing capacity of the high-formwork support system while the setting of the vertical scissors support is rather crucial. The ultimate bearing capacity can be lifted about 2.3 times by reasonable setting of the vertical scissors support than that by the horizontal scissors.

1. Introduction
According to incomplete statistics, although the engineering accident caused by the instability of the high-formwork support system is not high (only 5%), it is ever rising, and in the event of a collapse accident, it often comes with quite serious consequences. The results of numerous accident investigations show that the absence or lack of scissors support will greatly weaken the ultimate bearing capacity of the high-formwork support system, which is an important cause of accidents. In order to prevent the reoccurrence of such accidents, it is necessary to conduct in-depth research on the influence of the scissors support on the ultimate bearing capacity.

For the study of the bearing performance of the high-formwork support system, Chongbao Xu¹ analysed the stress of the fastener-type steel pipe by using the first-order elastic stability on the basis of the semi-rigid joint connection, and proved that the enhanced lateral stiffness is an effective method to improve its stable load. Xuefeng Zhang² proposed a multi-node continuous compression elastic buckling analysis method based on the theory proposed by Lightfoot³ and Bhula⁴. Finally, the buckling load of the node is obtained by successively applying the pressure bar theory several times. According to the force characteristics of the vertical rod of the bracket, Allen and Sholz⁵ proposed a column curve for calculating the vertical load, and the difference between the calculation result and the actual is greatly reduced by the curve.

2. Model of High-formwork support system
This paper selects a typical high-formwork support system for analysis. The model is 12 steps high, and each step is 1.5m, the vertical and horizontal are equally 9 spans, with a distance of 1.2m×1.2m,
and the bottom sweeping levers’ height is 0.2m. The top extension length is 0.2m. Therefore, the entire structure volume is 18.4 m × 10.8 m × 10.8 m. The scaffolding pipe is made of steel Q235 whose section specification is φ48.3mm×3.6mm.

The high-formwork support system uses a spatial beam element, and the basic system model contains 52,360 nodes and 26,180 cells. For the connection form of many nodes, bases and scissors supports in the high-formwork support system, it is regarded as an articulated system. According to the "Safety Technical Specification for Fastener-type Steel Pipe Scaffolding for Construction" (JGJ-130-2011), the force of the crossbar is ignored here; As to the crossbar not connected with the scissors, the beam end constraint shall be released at 40 kN/rad on each side to simulate a semi-rigid connection. The node loads in the vertical direction is -1 kN are uniformly applied to all nodes at the top of the high-formwork support system.

A nonlinear analysis that is closer to the actual situation has been taken into account, and the specific analysis method is the displacement control method, which combines the specific requirements in the technical code for safety of steel tubular scaffold with couplers in construction(JGJ-130-2011), and sets the maximum displacement of all nodes of the structure to 10mm, which is then divided into 10 levels, and each level is divided into 10 stages, which is carried out by step-by-step loading. simulation. For the high-formwork support system instability mode below, the position is defaulted to the middle row of nodes unless otherwise specified. The finite element basic model is shown in Figure 1.

This time value simulation takes into account a nonlinear analysis that is closer to the actual situation. The specific analysis method is the displacement control method, which combines the specification requirements in modeling, and sets the maximum displacement of all nodes of the structure to 10mm, and is divided into 10 levels, each level is divided into 10 stages, which is carried out by step-by-step loading. simulation. For the high-formwork support system instability mode below, the position is defaulted to the middle row of nodes unless otherwise specified.

![Figure 1 High-model model diagram with full scissors](image)

3. Results and analysis

3.1. Influence of horizontal scissors on the ultimate bearing capacity of high-formwork support system

To study the effect of horizontal scissors on the ultimate bearing capacity of the high-formwork support system, on the basis of the above system, the vertical scissors are continuously distributed in every two spans in the middle and the surrounding, and the horizontal scissors support setting conditions are shown in Table 1:
Table 1: Horizontal scissors support setting conditions and ultimate bearing capacity results

| condition | Horizontal scissors support | Vertical scissors support | Ultimate bearing capacity (kN) | Rate of change (%) |
|-----------|-----------------------------|---------------------------|-------------------------------|--------------------|
| H1        | None                        | Full set                  | 77.65                         | 0                  |
| H2        | Bottom                      | Full set                  | 77.65                         | 0                  |
| H3        | Top and bottom              | Full set                  | 80.47                         | +3.63              |
| H4        | Top and bottom +4.5m to the bottom | Full set | 80.49                         | +3.63              |
| H5        | Top and bottom +4.5m and 9.0m to the bottom | Full set | 80.50                         | +3.67              |
| H6        | Full set                    | Full set                  | 80.54                         | +3.72              |
| H7        | None                        | None                      | 32.15                         | -58.60             |

It can be seen that as the density of the horizontal scissors support is increased (the first six groups), the vertical ultimate bearing capacity of the high-formwork support system does not increase significantly. The vertical ultimate bearing capacity difference between working condition H6 and H7 is about 3kN, and the increase is less than 4%, namely, the ultimate bearing capacity of the structure does not change much. Therefore, the setting of the horizontal scissors support does not impose a significant effect on improving the vertical ultimate bearing capacity of the high-formwork support system, but merely serves to enhance the structural stability.

Comparing working condition H1 and H7, it can be found that when neither the horizontal scissors support nor the vertical scissors support is provided, the ultimate bearing capacity of the structure is quite different from that of the vertical scissors. At this time, the vertical ultimate bearing capacity of the structure plumps significantly from about 80kN to about 32kN, and the falling amplitude is 55.3%, which indicates that the setting of the vertical scissors support is significant for the ultimate bearing capacity of the high-formwork support system.
Figure 2 (a) - Figure 2 (g) shows the instability mode of vertical nodes (see Figure 1) in the middle of the high-formwork support system under the H1-H7 conditions. The analysis found that the collapse mode of the high-formwork support system under various working conditions is mainly started at the local instability, and then the entire frame is collapsed by dominoes. The unstable parts first occurred on the top side, and quickly passed from the top to the bottom, and the collapse is in a large-wave drum pattern.

By comparing Figure 2(a) and Figure 2(b) (the horizontal scissors are not set at the top) with other unstable modal patterns, it is not difficult to find that the setting of the top horizontal scissors supports not only affects the mode of instability but also the stability of the structure.

Comparing Fig. 2(c) to Fig. 2(f), it can be found that as the erection density of the horizontal scissors supports gradually increases, the waveform of the unstable drum gradually becomes slower, and the corresponding wavelength also gradually decreases.

Comparing Fig. 2(g) with other figures, it can be seen that the instability wavelength of the high-formwork support system reaches the maximum without any scissors, and the amplitude of the instability modes of all the nodes is about the same. It can be seen that the setting of the scissors support is indispensable for improving the ultimate bearing capacity of the high-formwork support system.

### 3.2. Influence of vertical scissors on the stability bearing capacity of high-formwork support system

To study the influence of vertical scissors on the same issue, and on the basis of the above basic system, the horizontal scissors are continuously distributed every three steps from bottom to top, and the vertical scissors support setting conditions are listed in table 2:

| condition | Vertical scissors support | Horizontal scissors support | Ultimate bearing capacity (kN) | Rate of change (%) |
|-----------|--------------------------|----------------------------|--------------------------------|--------------------|
| V1        | None                     | Full set                   | 35.22                          | 0                  |
| V2        | Set a circle around      | Full set                   | 51.65                          | +46.5              |
| V3        | Set a circle around + set 3.6m from four sides | Full set | 60.50 | +71.8 |
| V4        | Full set                 | Full set                   | 80.54                          | +128.7             |

It is not difficult to find that in the case where the horizontal scissors are full, the ultimate bearing capacity of the high-supporting structure is continuously increased as the density of the vertical scissors increased, and in contrast with the situation that the vertical scissors are not provided, the ultimate bearing capacity of the vertical scissors increases almost 2.3 times. Therefore, the setting of the vertical scissors support is crucial in improving the ultimate bearing capacity.
4. Conclusion

Through the analysis of the influence of the scissors support on the ultimate bearing capacity of the high-supported mold, the following conclusions are drawn:

With the gradual increase of the erection density of the horizontal scissors, the waveform of the unstable drum of the high mode is gradually slowed down, and the corresponding wavelength is gradually reduced, but the horizontal scissors support is used to improve the ultimate load of the high-supported node. Little effect;

As the density of the vertical scissors supports gradually increases, the waveform of the unstable drum gradually becomes slower. The setting of the vertical scissors support is very important for improving the ultimate bearing capacity of the high-supporting model. When the vertical scissors are supported, the ultimate bearing capacity of the high-formwork support system is about 2.3 times higher than that without the scissors.

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