Creating a node connection for scaffolding and studying its stress-strain state by means of a full-scale test

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Abstract. The article presents the results of the analysis of the stress-strain state of the developed jointing node of construction scaffolding (spatial rod temporary structures), since nodal connections are often the weakest elements of such temporary structures. The analysis of the stress-strain state of the node was performed on the basis of a full-scale experiment. The study revealed the most stressed zones in the node structure, as well as the causes of node destruction. Nodes are well known to be the weakest elements of scaffolding. It often happens that structural elements are more stable than the connections between them. Mobile spatial rod structures are very popular in construction at the present time. These structures are used for the construction of ski jumps, stands, stages and scaffolding. They are also used as support scaffolding to support the formwork of floorings. Therefore, the development of new nodal solutions, increasing the bearing capacity of nodal joints and studying their stress-strain state under various loads is a very important task.

Keywords: structures, node, stress-strain state, scaffolding, experimental study.

1 Introduction

The purpose of the work is to develop a connecting node of steel construction scaffolding of wedge type (spatial rod temporary structures) and to study its stress-strain state.

Currently, stands with a canopy, stage structures are widely used as temporary structures for sports and entertainment events [1-6]. Nodal connections are often the weakest elements of such temporary structures [7-12]. Nodal connections of scaffolding have a complex stress-strain state [13-18]. Nodes are subject to extreme deformations [19-22]. That is why the study of the stress-strain state of a newly developed nodal joint is the subject of research.

We consider the following newly developed node connection: the crossbar (horizontal element) is connected to the rack using a wedge inserted into the holes of the two flanges and the crossbar tip. This node can later be used for connecting the crossbar and the rack of mobile spatial rod structures, in particular, scaffolding. The node connection during operation must perceive compressive and tensile forces, as well as moments in the horizontal and vertical planes.

2 Methods

2.1 Node testing. Loading system. Tensometry

A cantilever test was performed to determine the actual stress state of the node, its operation and load capacity.
Figure 1. General view of the test facility.

The tested node is shown in Figure 2.

Loading was performed by two hydraulic jacks in the vertical direction. The bending moment in the node is created by the shoulder between the axis of action of the loading force and the axis of the rack in 255 mm. The stability of the bending moment shoulder when turning the node during the test was provided by centering heads on the jacks rods. The load was transmitted to the crossbar pipe via distribution plates. To avoid bending the node in the horizontal plane, guide elements were installed on both sides of the crossbar. Load values were determined by force meters installed under the jacks. The force meter readings were transmitted to a digital display and data collection system.
Figure 2. Diagram of the tested node.

The voltage measurement in the node elements was performed using BF 350-3AA (11) strain gages with a resistance of 300 Ohms. The placement of strain gages is shown in Figures 4 – 6. The strain gages were connected to the data collection system.
Figure 3. The scheme of loading system.
2.2 Measurement of movement

To assess the stiffness of the node during the test, the measurement of the rotation of the node under the action of a bending moment was performed. Determining the angle of rotation of the node was performed by two pairs of potentiometers. Potentiometers PM1 and PM4 showed the vertical movement of the crossbar at distances of 65 mm and 515 mm from the axis of the post, which determined the angle of rotation of the crossbar. Potentiometers PM2 and PM3 determined the rotation of the post through an auxiliary U-shaped element welded to the upper flange. The potentiometers were connected to the data acquisition system.
3 Results and discussion

3.1 Initial tension when driving a wedge

At the beginning of the experiment, the initial tension in the elements when driving the wedge were determined. Scoring was performed in two blows with a hammer. The tensions in the node elements are shown in Figures 8 – 13.

Figure 8. Tensions in the post.
Figure 9. Tensions in the upper flange.

Figure 10. Tensions in the lower flange.

Figure 11. Tensions at the tip of the crossbar element.
According to the readings of strain gages after driving the wedge, there are tensions of 13 MPa in the upper flange, 93 MPa in the lower flange, and 21 MPa in the wedge.

### 3.2 Cyclic loading

Since the node can experience bending moments in two directions during operation and, consequently, certain looseness may occur, a cyclic variable loading of the node with a bending moment of 1275 kg×cm, 10% of the expected load capacity, was performed before the main loading. The value of the load in the jacks was 50 kg. The graph of the node work under cyclic loading is shown in Figure 14.

### 3.3 Main loading

After cyclic loading, the node was loaded with vertical force down to destruction. The bearing capacity of the node for bending - 6350 kg×cm was determined by the moment of development of large plastic deformations in the wedge. The stresses in the node elements during loading are shown in Figures 15 – 20.
Figure 15. Tensions in the post.

Figure 16. Tensions in the upper flange.

Figure 17. Tensions in the lower flange.
Figure 18. Tensions at the tip of the crossbar element.

Figure 19. Tensions at the tube of the crossbar element.

Figure 20. Tensions at the wedge element.
4 Conclusions
As a result of the experiment, it was found that:

1) At the stage of driving the wedge, significant stresses occur in the elements: in the lower flange – 93 MPa, in the upper flange-13 MPa, in the wedge-21 MPa;

2) With the accepted sizes and materials of elements, if there is a significant margin in the other elements, the bearing capacity of the node is limited by a wedge.

For more complete use of the bearing capacity of the node, it is necessary to increase the bearing capacity of the wedge by increasing the height of the U-shaped crossbar head, increasing the strength class of steel or the thickness of the wedge.

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