The development overview of wheel-coupler type formwork support

Hang Li\textsuperscript{1,*}, Shilong Jia\textsuperscript{1, b}, Fang Zhou\textsuperscript{1, c}, Lei Zhao\textsuperscript{1, d}, Yanming Su\textsuperscript{1, e}, Bo Liang\textsuperscript{1, f}

\textsuperscript{1}School of Civil Engineering, Shenyang Jianzhu University, Shenyang, Liaoning, 110168, China
\textsuperscript{a}e-mail: 1145528455@qq.com, \textsuperscript{b}e-mail: 1054770837@qq.com, \textsuperscript{c}e-mail: 2577943038@qq.com, \textsuperscript{d}e-mail: 844240921@qq.com, \textsuperscript{e}e-mail: 302657263@qq.com
\textsuperscript{*}Corresponding author’s e-mail: cesljia@sjzu.edu.cn

Abstract: As a new type of formwork support, the wheel-coupler type formwork support has been widely used in China, but its research is not comprehensive enough. Therefore, this article introduces the structural characteristics of the wheel-coupler type formwork support and summarizes the current research status. The mechanical properties of the joints are analyzed by finite element analysis, and the analysis results are compared with the disk lock steel tubular scaffold, so as to promote the popularize and use of the wheel-coupler type formwork support.

1. Introduction
The wheel-coupler type formwork support is a new type of steel tube formwork support derived from the disk lock steel tubular scaffold, which has been widely used in China. However, as a new type of formwork support, relevant national standards have not been issued, only the association standard and the provincial standards are used as reference, such as the local standard of "Technical specification for safety of wheel-coupler type steel tubular scaffold" (DB44/T 1879-2016) formulated by Guangdong in 2016, and the "Technical specification for safety of wheel-coupler type steel tube formwork support in construction"(DBJ 43/323-2017) formulated by Hunan Province in 2017, and the association standard" Technical specification for safety of wheel-coupler type formwork support in construction" (T/CCIAT 0003-2019) formulated in 2019 by the China Construction Industry Association. At present, the requirements for the wheel-coupler type formwork support are not uniform in various specifications, and the related mechanical performance research is still lacking. Therefore, it is necessary to continue to strengthen the research on the mechanical performance to make the wheel-coupler type formwork support better popularized and used.

2. Introduction to the wheel-coupler type formwork support

2.1. Construction of wheel-coupler type formwork support
The wheel-coupler type formwork support is mainly composed of upright tube, ledger, plugs, wheel-coupler plate. In actual use, put the plug into the socket of the wheel-coupler plate, and the joint can achieve self-locking effect by manually hammering the plug. The connection diagram of the joint is shown in Figure 1.

(1) Upright tube. The upright tube is the main vertical force rod of the wheel-coupler type formwork support, which is welded with wheel-coupler plate and connect collar of upright tube, and
can be extended in the vertical direction. The standard rod with 600mm modulus, commonly used 3000mm, 2400mm, 1800mm, 1200mm, 600mm length specifications.

(2) Ledger. The ledger is the horizontal force rod of the wheel-coupler type formwork support, and plugs are welded at both ends, which has the function of transverse connection support. The rod with 300mm modulus, commonly used 1200mm, 900mm, 600mm, 300mm specifications.

(3) Plug. The plug is a wedge-shaped structure with a wide top and a narrow bottom, and the side in contact with the upright tube is a circular-arc surface. It is welded on both ends of the ledger and used to connect the upright tube and the ledger.

(4) Wheel-coupler plate. A wheel-coupler plate is welded on the upright tube every 600mm, the upright tube and the ledger are connected through the wheel-coupler plate and the plug.

![Figure 1. Schematic diagram of wheel-coupler joint connection](image)

2.2. Features of wheel-coupler type formwork support

Wheel-coupler type formwork support gradually occupy the domestic market due to its high efficiency, safety, versatility, longevity and turnover [1]. The wheel-coupler type formwork support does not have any redundant movable parts, has a simple structure, and solves the problem of component loss and storage. When installing and dismantling, workers only need a hammer to complete the work. The speed of building and dismantling is 8~10 times that of the coupler type steel tube scaffold and more than 2 times that of the cuplock steel tubular scaffolding, which greatly improves the construction efficiency. After the wheel-coupler type formwork support is connected, the joint will self-lock. The load of the ledger is mainly transmitted from the wheel-coupler joint to the upright tube. The center line of the upright tube and the ledger crosses vertically, which has high accuracy, high bearing capacity and good overall stability. The wheel-coupler type formwork support can be combined into different specifications according to the construction requirements, such as single and double row formwork support, and can also be combined with other steel pipe formwork support to build a complex support system. The wheel-coupler type formwork support is easy to disassemble and assemble, and the ledger can be disassembled in advance according to the actual project situation for turnover use, which effectively saves materials and space, and does not require accessories.

The wheel-coupler type formwork support has many advantages, but it also has certain shortcomings. Because there is no unified national standard, its production and use are restricted to a certain extent. The wheel-coupler type formwork support has a fixed modulus, which can well control the distance between the upright tubes. Compared with other supporting frames, the erection of the frame is more standard and reliable. However, in the actual project, if there is a size that does not meet the requirements of the modulus, you can only choose a coupler type steel tube scaffold to assist in the solution. When the frame is erected, it has higher requirements for the site. It is suitable for erecting on a firm base and flat ground, but cannot be erected on a soft, cracked, or easily collapsed ground.
3. Research status

3.1. Current status of overall performance research
Yang S [2] and Wang X [3] respectively used SAP2000 software to conduct the finite element analysis on the overall mechanical properties of the wheel-coupler type formwork support with different structural parameters, and obtained the bearing capacity of the formwork support under different structural parameters. They all pointed out that the setting of the bottom reinforcing tube, the step distance of the upright tube and the setting of the diagonal bracing had great influence on the stable bearing capacity of the formwork support, and suggested that the setting lift height should not exceed 1.2m.

Yang Y D [4] proposed the concept of initial equivalent defects, and carried out a full-size test on the overall mechanical properties of the wheel-coupler type formwork support, and proposed a method to approximate simulation the equivalent initial defect of the formwork support by using equivalent horizontal loads. The equivalent horizontal load is taken as 1.3%~2.1% of the ultimate bearing capacity.

Cheng Y [5] analyzed the influence of the lateral stiffness and the equivalent stiffness of the diagonal bracing on the bearing capacity of the wheel-coupler type formwork support by experiments, and compared it with that of the coupler type steel tube scaffold. They concluded that the difference between the ultimate bearing capacity and lateral stiffness of the two is mainly due to the connection defect and displacement deviation of the diagonal bracing joints, and proposed that the spring element can be used to simulate the effect of the joint connection gap on the diagonal bracing connection stiffness.

Yu Y [6] conducted experimental research on the wheel-coupler type formwork support with different longitudinal spacing of upright tube and lift height, and with no diagonal bracing, horizontal diagonal bracing, and vertical diagonal bracing, and obtained the ultimate bearing capacity and failure mode of the support under various working conditions. She proposed that longitudinal spacing of upright tube and lift height had a certain influence on the stability bearing capacity of the frame, and the setting of horizontal diagonal bracing had little influence on the stability bearing capacity. The setting of vertical diagonal bracing could improve the stability bearing capacity by 34.1%~44.2%.

3.2. Research status of wheel-coupler node performance
Bai S H [7] applied unilateral horizontal force and repeated horizontal force to the plane frame under different structural forms, and found that the plug has good pull-out resistance and the joint is safe and reliable. The mechanical properties of wheel buckle joints were analyzed by finite element method, and the damage form, force transmission path and bearing capacity of the joints were obtained.

Wang Z C [8] carried out forward bending test and reverse bending test on the joints of the wheel-coupler type formwork support respectively, and obtained the flexural bearing capacity of the wheel-coupler joints, and then calculated that its bending rigidity was 25~35kN·m/rad, finally combined with Eurocode 3 to verify the semi-rigid characteristics of the scaffolding.

Yang W J [9] carried out experimental research on applying horizontal loads to plane frames of different specifications, and found that the wheel-coupler joint is semi-rigid, and the initial rotational stiffness of the calculated node is between 30~40kN·m/rad. Compared with the joint stiffness of the fastener-type steel tube scaffolding, it is found that the stiffness of the wheel-coupler node is equivalent to the stiffness of the coupler type steel tube scaffold fastener tightening torque 40N·m.

4. Comparison of mechanical properties between wheel-coupler and disk lock scaffold
The wheel-coupler type formwork support is simplified from the disk lock steel tubular scaffold, and both belong to the socket type formwork support, but the two are different in materials and specifications, so the mechanical properties of the joints are also different. At present, some scholars have studied the characteristics of the wheel-coupler type formwork support, the material of the
member is mostly Q235 steel, and the rods specification is $\phi 48\times3.5$ steel tube.

In this paper, the rods material is Q235 steel, the material of wheel-coupler plate and plug is ZG270-500, the specification of upright tube is $\phi 48.3\times3.6$, and the specification of ledger is $\phi 48.3\times3.0$. The finite element analysis of wheel-coupler joint is carried out by ANSYS software, and the analysis results are compared with the test results of Qian X J [10], as shown in Table 1. The ultimate bearing capacity of the joint of the wheel-coupler type formwork support is weaker than that of the disk lock steel tubular scaffold, but its initial rotational stiffness is larger than that of the disk lock steel tubular scaffold.

| Name                              | Wheel-coupler type formwork support | Disk lock steel tubular scaffold |
|-----------------------------------|------------------------------------|---------------------------------|
| Node type                         | Semi-rigid joint                   | Semi-rigid joint                |
| Member specifications             | Upright tube $\phi 48.3\times3.6$  | Vertical and ledger $\phi 48.3\times3.0$ |
| Bi-directional symmetrical tensile ultimate load force (kN) | 35                                 | 44.5                             |
| Ultimate shear bearing capacity of connecting disc (kN) | 90                                 | 109.3                            |
| Initial rotational stiffness (kN·m/rad) | 32.85                             | 26                               |

5. Conclusion
The wheel-coupler type formwork support has high bearing capacity, low cost, high construction efficiency, and its advantages far outweigh its disadvantages. It is very suitable for construction use. This article summarizes the current research on the wheel-coupler type formwork support, and found that the current scholars have comprehensive experimental research and theoretical analysis on the overall mechanical properties of the wheel-coupler type formwork support, but the research on the mechanical performance of the joint is still insufficient. Most of them are limited to the performance research of the joints under unidirectional force, and the bending stiffness of the joints only studies the initial rotational stiffness in the elastic stage, and there are few studies on the stiffness of the elasto-plastic stage and the plastic stage. Therefore, in order to make the wheel-coupler type formwork support is better promoted and used, and it is particularly important for the study of the mechanical properties of the wheel-coupler joints such as multi-directional force and different force stages.

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