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ORIGINAL ARTICLE

Framework to Guide Rail type Adhesive Lifting Scaffolding in the Design and Application of High-rise Residential Buildings

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ABSTRACT As to combine with specific engineering practice, this paper presents a framework to guide rail type adhesive lifting scaffolding in high-rise residential building design and constructions well as changed the traditional characteristics of steel pipe scaffold by using new standard truss and scaffold board design All the connecting parts are connected by bolt, using electric wrench to install, and implementing the overall tools, systematic design and installation. Engineering practice proved that the frame rail type adhesive lifting scaffold can not only speed up the construction progress, control costs and improve economic efficiency, but also be popularized in similar engineering.

KEYWORDS

Frame rail type

Adhesive lifting scaffolding

Construction technology

1. Project profile

Commercial residential building 2# in Daxing District, Beijing has 29 stories above the ground and 3 stories underground. The height of above ground structure level is 2.7 m, maximum straight line span is 6.4 m, maximum liner span is 6.4 m, and maximum overhang length is 1.5 m. After overall consideration as the exterior operation protector, a framework to guide rail type adhesive scaffolding is employed. Based on the actual construction progress on site, the lifting scaffolding is scheduled to be installed after the completion of ground floor structure. The lifting scaffolding which contains 49 lifting machine positions is divided into two parts and it will be lifted in two flow work parts. No. 1 to No. 19 and No. 46 to No. 49 is one part while No. 20 to No. 45 is the other part. The machine positions arrangement are as follows.

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2. Structural plan arrangement and design

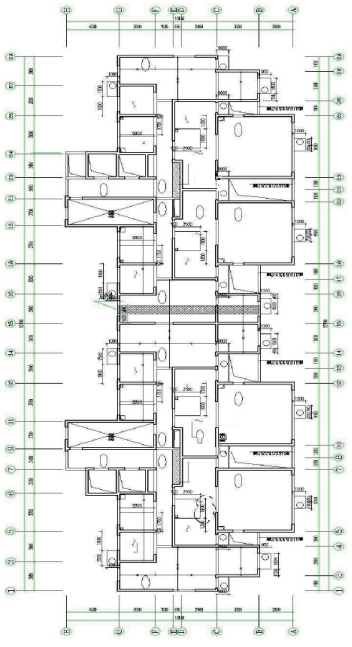

Figure 1. Structure plan and flow work division.

2.1. Location plan of lifting scaffolding segment

The scaffolding segments of Building 2 are located between the lifting machine position19# & 20# and lifting machine position 1# & 41# (Figure 2).

Table 1. Machine positions arrangement.

Building No.	Building elevation	Standard single floor area	Standard exterior eaves perimeter	Total stories	Applied stories	Standard story height	Machine position amount
2#	83.4 m	697 m^2	211 m	29	2–29	2.7 m	49

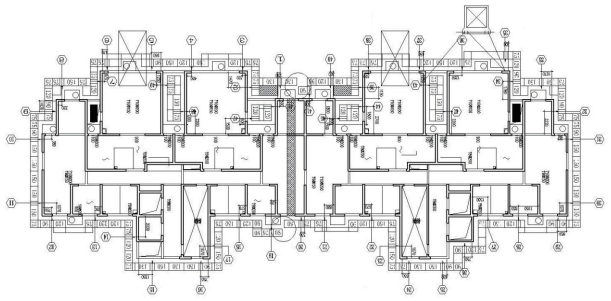

Figure 2. Location plan of lifting scaffolding segment.

3. Characteristics of adhesive lifting scaffolding

This building has a uniformed appearance which is suitable for adopting the adhesive lifting scaffolding. As the exterior operation protective framework for standard stories, WF-11 framework to guide rail type adhesive lifting scaffolding [1] is employed, in order to guarantee the construction safety, progress and on-site civilization, create good social and economic efficiency together with to meet the protective requirement of major structure construction.. In the structure construction of high-rise buildings, the adhesive lifting scaffolding will be lifted up in accordance with the construction progress [2] and it will prove protection for the structure and decoration constructor. Also it will avoid the loss of life and personal injury caused by falling gravel and sundries during construction.

3.1. Device characteristic

(1) The rail and the vertical framework formed an organic whole and double-truss parallel structure which enhances the rigidity and load of performance of vertical framework. The rail is lifted together with the framework which reduces the turnover of rail and avoids the safety risk caused by it.

(2) There is an installing hole vertically located on the rail per 100 mm and lifting synchronicity can be visually monitored anytime.

(3) There are two space restrictors on every lifting point and the load of frame was transferred to each floor. Each floor shares the load which avoids the building structure damage. There are three guide holders on each lifting point, the lower two could bear both horizontal and vertical load.

(4) The anti-falling device, guidance system and lifting system are designed separately and they are independent to each other. They separately bear the load and transfer it to the building structure directly. It solves the function series problem of most adhesive lifting scaffold. In other words, it solves the problem that once one system breaks down the rest will be affected. Also, it increases the safety performance of adhesive lifting scaffold. It is quite easy to find the faulty with the falling protective device which will facilitate the in-time maintenance and reduce the risk of falling down [3].

4. Construction design of WF-11 adhesive lifting scaffolding

4.1. Platform erection

Erect platform around the building before the erection of adhesive lifting scaffolding (Figure 3).

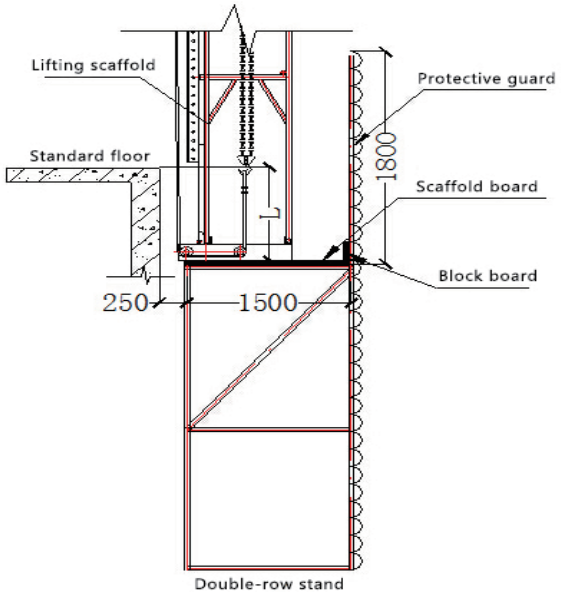

Figure 3. Schematic diagram of platform.

4.2. Embedment

4.2.1. Construction method of preformed holes

The embedded device is made by PVC plastic pipe (inside diameter >40 mm), while the length is 2 mm shorter than the thickness of wall or beam. Next, seal both end of the plastic pipes with sealing compound in case that concrete is poured into it. Fix the pipe to the fixed rebar of wall or beam with lead wire in the direction of LR. Then, embeds the pipe point by point. There should be special staff to watch concrete pouring to avoid the displacement of embedded device. Also special staff is needed for the quality inspection of preformed holes.

4.2.2. The set of preformed hole

Determine the location of preformed hole according to the arrangement plan of lift scaffolding (Figure 2). Place

the embedded holes 100 mm from the bottom of floor slab and 200 mm from the bottom of side beam. There are 2 embedded holes for each lift machine position. From center to center spacing of these two holes is 250 mm. The dimension and location of preformed holes should follow the location drawing of preformed holes (Figure 4). After the embedment of the first floor preformed hole, record the distance between preformed hole and the nearest axis to guarantee the location accuracy of the preformed holes [4].

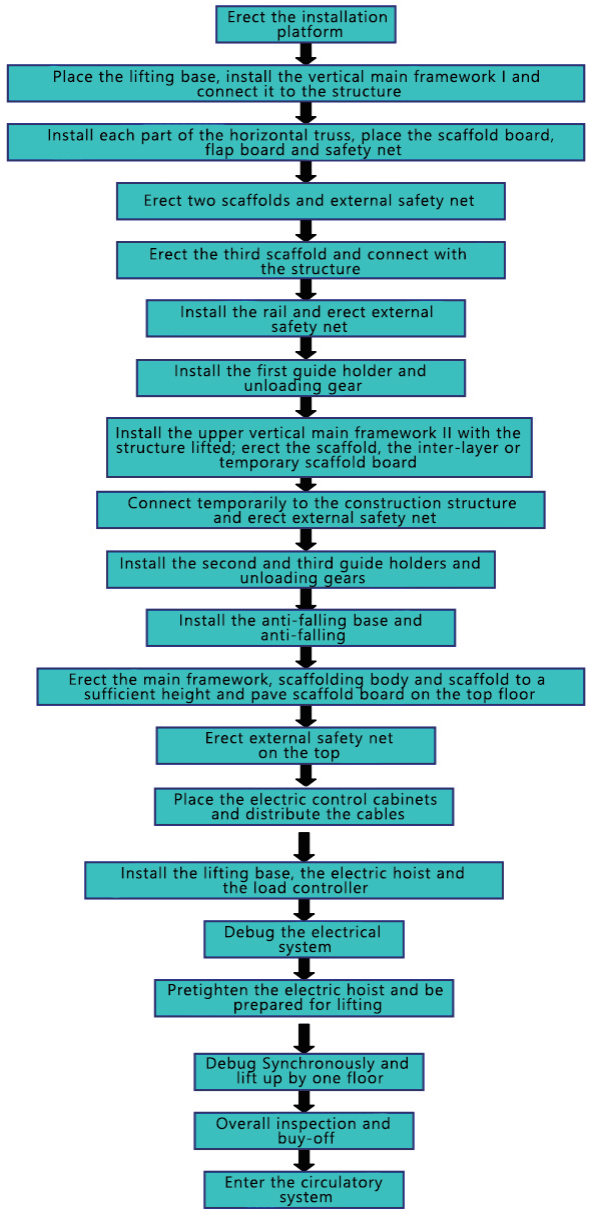

Figure 4. Location drawing of preformed hole.

4.3. Erection

During the erection make sure that each floor of the scaffolding is horizontally connected to the building to guarantee the fastness, stability and reliability of the scaffolding (Figure 5).

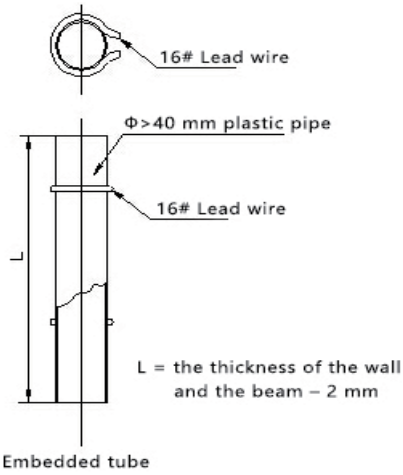

Figure 5. WF-11 lifting scaffolding installation procedures.

4.3.1. Installation of the lifting base

Place the base according to the arrangement plan of lifting scaffolding, with the base is parallel with the tangent line of external wall, strictly control the distance between vertical tube and wall. The center of vertical tube should be in alignment with that of preformed hole and the deviation should less than 10 mm.

4.3.2. Installation procedure of horizontal truss

Locate the down guide rail and external vertical tube→horizontal,framework→safety net→scaffold and board→toe boards.

4.3.3. Scaffold installation:

The horizontal tube must be staggered with ledger within two steps. The overall vertical deviation of the whole frame should be within 50 mm. The levelness of the ledger should be within 10 mm per 10 m and total horizontal height deviation should be controlled within 20 mm whereby the step height is 1800 mm, and the maximum spacing is 150 mm. The scaffolding should be rigidly connected in accordance with the structure construction to avoid the overall deformation and slant.

4.4. Crossing Bolt

Together with the installation of scaffold, install the crossing bolt, guide holder, space restrictor and the listing components [5].

4.5. Cross bridging

The external crossing birding should be erected from the bottom of the horizontal truss at the truing of lifting scaffolding. Angle of inclination is 45° to 60°. Next, erect the top of double-row scaffold by ensuring the least overlapped crossing bridges should be 1000 mm. After all, there should be at least 3 fasteners at the connection. The steel tube of cross bridging should be connected to each vertical tube. Moreover, the cross bridging angle inclination in the

same direction should be the same and ensuring the inner cross bridging is starts from the vertical tube. The angle of inclination is 45° to 60° and it should be connected to the adjacent point of main frame.

4.6. Electric control and lifting system installation

The electrical system should meet the design requirement of three-phase five-wire system (TN-S requirements). Electric control cabinet and cable should be installed on the third or fourth floor of the scaffold. Fix the cable to the external ledger with rubber or plastic brace. There should be PEN, leakage protection, rainproof device and waterproofing device. There are two AC contactors and circuit breakers in the electric control cabinet. The maximum amount of the transfer box series connected to each AC contractor and circuit breaker is 15. In case of special circumstances, the maximum amount of the transfer box series connected to each AC contractor should be 17.

4.7. Protection design

4.7.1. Grab rail

There is streak of grab rail around the edges and ends of the operation level of the scaffold, and it is 900 mm from the scaffold board. Each scaffold was covered by fine mesh safety net.

4.7.2. The distance between scaffold and wall

The inner gap distance of scaffold should be less than 200 mm and it must meet the requirement of scaffold lifting and framework forming [6].

4.7.3. Scaffold board and large mesh

The top, middle(the fourth level)and bottom scaffolds are composed of wood board, while the rest are composed of welded steel mesh or large mesh. Also there should be a layer of safety net before the paving of bottom scaffold board.

4.7.4. Flap board

The inner side block of scaffold should employ wood flap board and it should be set on the bottom level of the scaffold. The flap board should be overlapped to the scaffold board by at least 100 mm and it also should be overlapped to structure by at least 150 mm. The flap board is connected to the scaffold board by multi-strand iron wire and set safety assurance bracing wire hook on the top of flap board. When the scaffold is lifted and the flap board is turned over, the bracing wire will hook the flap board to the inner vertical tube. Generally, the flap board is made of plywood and connected by standard device self-manufactured hinge. Make the flap board piece by piece according to the shape of building and next the flap board should be placed consistently. The joint gap and distance between scaffold board and building should both be less than 100 mm. The horizontal that contained angle of flap board should be 30° to 60°. The flap board should be overlapped to scaffold by at least 100 mm and could be installed at the lifting [7].

4.7.5. Protection erection of the scaffold segment edges

(1) Fully large mesh is paves to the two each segments of the scaffold in case of falling objects break down the overlapped board and warning tube is added. The tube on both side of the warning tube is 1400 mm and rotary buckle is used for connection. Before lifting and turning the warning tube, the warning tube is removed into one side by 90°. After lifting, the original condition is returned.

(2) In case of falling objects or workers during the lifting and the use of segment, there is a large mesh at the three layer overlapped board with the length of a signal floor height is H + 1. The hanging net should be reliably tied to the tube on both sides.

(3) Erect two protective handrails 0.6 m and 1.2 m away from the operation segment. The protective rails and small

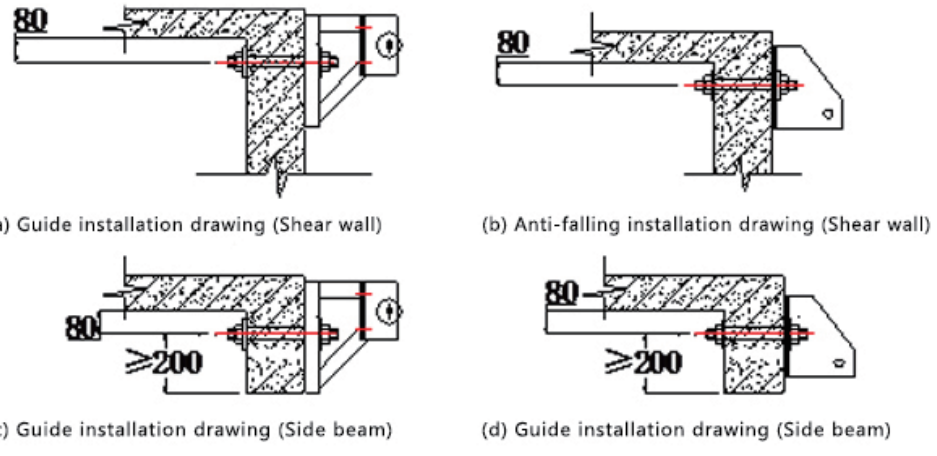

Figure 6. The crossing bolt at the coupling beam.

horizontal tube should at least be 200 mm from the building. Close it immediately after lifting. Fine mesh is pave next to the segment.

(4) Install a handrail between the operation levels of scaffold in the same way as operation level. Enclose it with dense mesh from top to bottom. Add two steel tubes to the exterior framework of operation level.

4.7.6. The striking toe boards also function as mark plate

It is made of 180 mm high plywood and painted with red and white each 500 mm wide.Also they are installed outside safety net of first floor, fourth floor and seventh floor.

4.8. Installation requirement of anti-pitch

(1) The wall adhesiveness that support between the external wall and external coupling beam should be installed 80 mm under the floor slab. Make sure that the crossing bolt at the coupling beam is at least 200 mm from the bottom of beam (Figure 6).

(2) If it cannot be guaranteed that the crossing bolt at the coupling beam is at least 200 mm from the bottom of the beam, straight steel beam is needed to install the wall adhesive support on the steel beam (Figure 7).

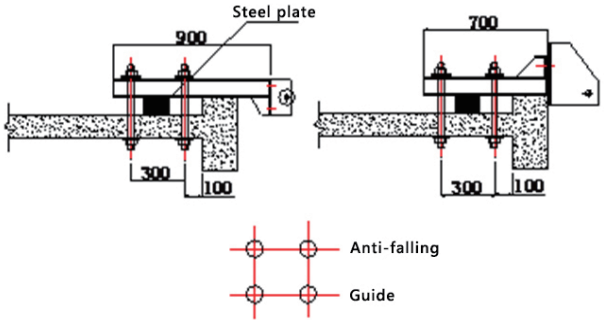

Figure 7. The straight steel beam which is installed the wall adhesive support on the steel beam.

(3) If the point is located on the air-conditioner board, triangle steel beam is needed and the wall adhesive support should be installed on the tri-angle steel beam (Figure 8).

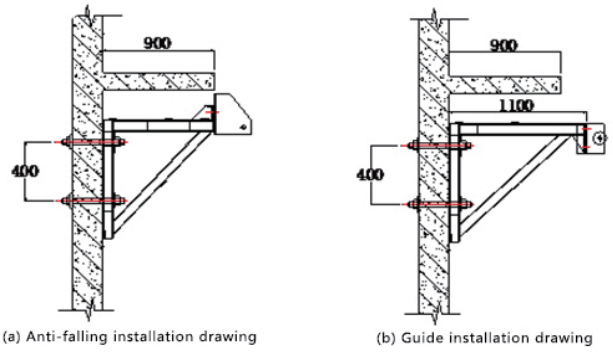

Figure 8. The wall adhesive support which is installed on the tri-angle steel beam.

(4) If the point is located on the air-conditioner board and beam is behind the board, straight steel beam is needed and the wall adhesive support should be installed on the steel beam (Figure 9).

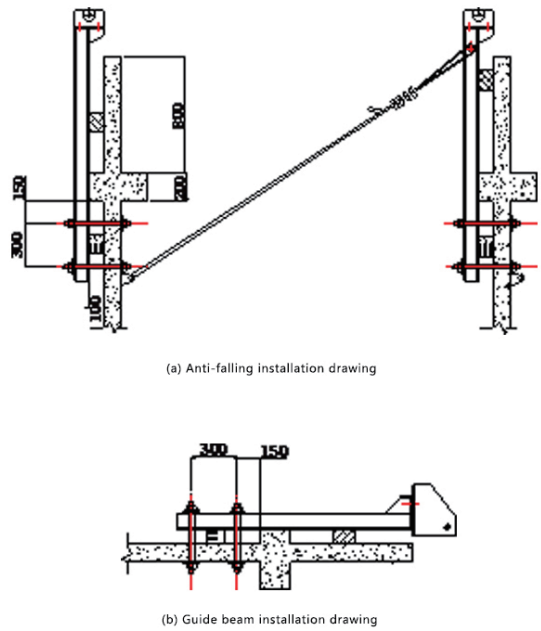

Figure 9. The wall adhesive support which is installed on the steel beam.

(5) The vertical deviation of rail installation should be smaller than 2.2 and the guide wheel should move smoothly in the race. Guide holder should be firmly connected to the building structure.

4.9. Installation requirements of falling protector

The falling protector device and lifting device must be installed on two adhesive supporting structures respectively; if one of the structures breaks down, the other must support all the falling loads independently. Connecting the components of the falling protector should be installed on the building structure to ensure prompt braking. Thus, the scaffold can be instantly locked on the anti-falling suspender in accidental loss of loads. The anti-falling suspender should be freely moved in the holes of falling protector.

4.10. Measures for ensuring synchronous lifting of the scaffold body

A synchronous control system for load should be installed on each lifting point. The automatic alarm is used when the load is 15% over the default and automatic shutdown is used when the load is 30% over the default until the trouble is cleared. Overload and big loss of loads with potential risks should be avoided to ensure safety of the scaffold body. Erection platform of scaffolding should be installed around the building before erecting adhesive lifting scaffolding. The levelness of scaffold board on the erection

platform should be limited between 20 to 50 mm in order to ensure that the scaffolding body is lifted at the same horizon. The power of the lifting system and the electric hoist of the scaffolding should be the same to ensure the same lifting pace at each point and the synchronous lifting of the scaffold body. On-site technical disclosure should be conducted before each lifting. In the process of scaffold lifting, instant alarm for shutdown and trouble clearing should be raised when the scaffold body is out of synchronization. The lifting cannot be run until the trouble is cleared.

5. Treatment of special parts

5.1. Attached wall of the tower crane

Attached wall of the tower crane should not interfere with the lifting machine and tube of the scaffolding body. However, when erecting the scaffolding body, the ledger and cross bridging should be short while the vertical tube and lifting mechanism should be kept off the support of the attached wall. Next, when lifted to the tube of the attached wall, the adhesive lifting scaffolding should be stopped in which a horizontal tube (diagonal tube) should be added first and then the obstructive horizontal tube (diagonal tube) should be removed. After the lifting, the removed horizontal tube (diagonal tube) should be returned to the original position instantly. During the lifting, special staff should be arranged for monitoring, removal and erection to ensure the safety and integrity of the scaffolding [8].

5.2. Discharging platform

Due to the need of material transition, the position of the discharging platform should be located in accordance with construction requirements. Besides, the space for installing the discharging platform should be reserved and should not be connected to the adhesive lifting scaffolding.

6. Removal

6.1. Removal technology

The staff should remove each unit from the top in accordance with the removal plan. The scaffolding should be kept in the status of unloading through connecting with the attached wall and adjusting the suspension of wire-rope. Remove from the lifting center to the lifting point. Remove the lifting point from top to bottom through window opening with thick string.

6.2. Removal method

(1) Device removal method: Tie the anti-falling rope, remove according to sequence drawing and transit to each floor by labor. (2) Main frame removal method: Operating staff should wear safety harness and stand on firm objects. Then hang the main frame with thick string, and then the operating staff will release the main framework and bolts. Then transit them to each floor with thick string. (3) Horizontal load framework removal method: Remove the whole frame work from top to bottom and when it comes to horizontal frame, start removal from the center of lifting point. Operating staff should also wear safety harness and then remove the bottom scaffold board. Next transit them to each floor by labor and unbolt the bolts between frameworks. The next frame must be connected firmly before everything is well prepared.

7. Secure measures for construction safety

Strictly follow the construction management plan. Stick to the idea of safety first when safety conflicts with quality and efficiency. Strengthen the safety education and personnel management. Safety harness and safety helmet are needed during the erection of scaffold. Tools and spare parts should be stored in the work bag. Besides, Anti-skid shoes are needed as well as tighten the cuff and leg opening. Stop high scaffold erection when the bad whether affect the construction safety. Template, welder, steel tube, steel bar and other material are forbidden to be stored on the scaffold. When welding in high scaffold, non-ignitable fire holder should be used and windshield is needed in windy days. Scaffold erection should be stopped in thunderstorm weather or wind of force 5 weather. At the same time it is necessary to reinforce the scaffold. After that, check all the devices and safety net of the scaffold. The external scaffold must be covered by dense mesh safety net. The bottom must be enclosed by protective device and also the bottom safety net is also needed. The scaffold should be firmly connected to the wall by flap board. Within 6m around vertical ground projection, warning line is needed in which no personnel are allowed to stay in or enter the warning area during lifting.

8. Conclusion

Compared with traditional ground-mounted steel pipe scaffold, framework to guide rail type adhesive lifting scaffold is a more scientific and rational external protective method. This is because, it is providing a safe and sufficient protective platform and embodying the advantages of safety, efficiency and cost saving. Framework to guide rail type adhesive lifting scaffold can not only accelerate the construction progress, control the costs and ensure safety, but also help achieve considerable economic and social benefits.

Conflicts of interest

These authors have no conflicts of interest to declare.

Authors' contributions

These authors contributed equally to this work.

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