LOAD-CARRYING CAPACITIES OF ISOLATED TOWER SCAFFOLDS USED IN CONSTRUCTION

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ABSTRACT

During the construction stage of a building with high clearances, large spans and thick slabs, the isolated tower scaffolds which have higher load-carrying capacity are often considered to serve as the falsework and meet the load demand of the building. Because isolated tower scaffolds served as temporary supports are immediately removed after finishing the construction stage, the importance is often neglected. Up to now, the information on the structural design of isolated tower scaffolds has been rather scarce, and the assembly of isolated tower scaffolds on construction sites still relies mainly on the experienced workers. This phenomenon results in a high risk of collapse in actual application of isolated tower scaffolds on construction sites. This study explores the critical loads and the failure models of isolated tower scaffolds in various setups by testing actual installations of isolated tower scaffolds based on construction sites. The research results show that the base screw jack has a limited effect on the overall load-carrying capacity of isolated tower scaffolds. When isolated tower scaffolds are set up on ground with different elevations or on ground under an inclined top slab with varying elevations, the load-carrying capacity is not affected evidently if the elevation is less than half meter. On construction sites, when assembled in multiple layers, the isolated tower scaffolds are often installed with steel tube shores on the top layer. However, this combined shoring structure substantially reduces the load-carrying capacity of isolated tower scaffolds. In this case, directly extending the top screw jacks of the isolated tower scaffolds is better than using a combined shoring structure. As to the depreciation of repeatedly used tower scaffolds, this study conducts a repeated loading test to simulate the lower bound strength of isolated tower scaffolds on construction sites.

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1. INTRODUCTION

High headroom, large spans and thick slabs are often found within structures like factory buildings, warehouses or gymnasiums. During the construction of these building structures, it is not suitable to use door-type steel scaffolds or tubular steel adjustable shores as falsework because they have lower load capacity. Instead, it is more desirable to adopt isolated tower scaffolds which have higher load capacity. Up to now, there is no specific design code that can provide design references for isolated tower scaffolds used in Taiwan. Therefore, it is not possible to effectively control the variation of the load carrying capacities of various setups of isolated tower scaffolds. This phenomenon leads to a higher risk of collapse in actual application of isolated tower scaffolds on construction sites.

Many construction falsework studies have been investigated up to now. Yu (Yu 2004) explored the load capacities of modular door-type steel scaffolds. Huang et al. (Huang et al. 2000) conducted numerical analysis and loading tests on door-type steel scaffolds to confirm the relationship between load capacity and number of layers. Peng et al. (Peng et al. 1997) conducted theoretical analysis and experimental study on door-type steel scaffolding systems with different setups and number of layers. Kuo et al. (Kuo et al. 2008) explored the effect of various loading paths and loading patterns on the load capacities of door-type steel scaffolding systems. Liu et al. (Liu et al. 2010) conducted experimental study on full-scale large-sized tube and couple scaffolds without X-bracing. Zhang et al. (Zhang et al. 2010) explored the variability of parameters related to the use of steel scaffolds.

As shown in the above-mentioned previous studies which on isolated tower scaffolds are comparatively fewer. The previous falsework-related studies can only serve as references and cannot be directly applied to isolated tower scaffolds. Therefore, it is necessary to conduct research on the load capacities of isolated tower scaffolds.

2. TEST PLANNING

This study aims to explore the load carrying capacities of isolated tower scaffolds by comparing the loading test results of various setups of isolated tower scaffolds used on construction sites. The tests are planned for the following 5 key points: (1) the increase of load capacity provided by the stiffness of base screw jacks of isolated tower scaffolds, (2) the effect of top slope and inclined ground on the load capacity of isolated tower scaffolds, (3) the effect of extension of top screw jacks on the load capacity of isolated tower scaffolds, (4) the effect of steel tube shores added at the top of isolated tower scaffolds on the load capacity of the scaffolds, (5) review of lower limit value of the load capacity of reusable scaffolds.

2.1. Two-layer setup with and without base stiffness

This test aims to explore the load capacities of two-layer basic setup of isolated tower scaffolds. The results of this test can be used to compare with those of other setups used in this study. For the

two-layer setup with jack base, the height of each layer is 150 cm and the height of both top and base screw jacks is 20 cm. The scaffolds are reinforced with plane braces, as shown in figure 1.

In order to understand the effect of the stiffness of base screw jacks, another test adopts a two-layer setup with the base plates of the base screw jacks being cut off, so that the base screw jacks would not provide additional bending moment stiffness.

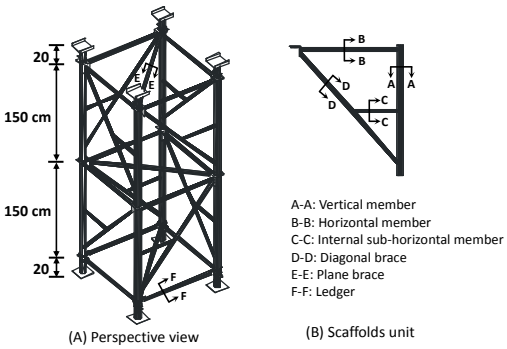

Figure 1: Test configuration of two-layer isolated tower scaffold.

2.2. Ground and top differences in elevation

The scaffolds sometimes have to be setup on ground with difference in elevation since the driveways and stairways often are designed in a building. This test explores the effect of ground with difference in elevation on the load capacities of the isolated tower scaffolds. Two ground differences in elevation, 33.2 cm and 56 cm, are applied in the test, as shown in figures 2(A) and 2(B).

During the construction stage, in order to cope with the height of roof beams or slabs, the top of scaffolding structure often has difference in elevation. In the lab, it is very difficult to configure the scaffolds with top difference in elevation. To solve the problem, we put the scaffolding structure upside down as shown in figures 2(A) and 2(B) to simulate the top difference in elevation of the scaffolds.

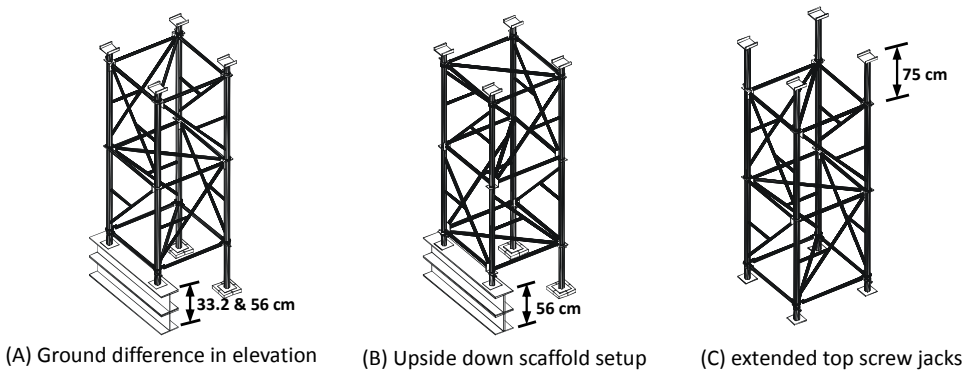

Figure 2: Test configuration of two-layer setup with ground differences in elevation and with extended top screw jacks.

2.3. Extension of top screw jacks

Since the total height of multiple-layer isolated tower scaffolds often cannot fill up the headroom of the interior of a building. It is advisable to extend the top screw jacks to full up the gap. The top screw jacks of the scaffolds are extended to 75 cm as shown in figure2(C).

2.4. Addition of steel tube shores without and with enclosed restraint on top of scaffolds

Regarding the problem of the gap between the scaffolds and slab, steel tube shores added on top of the scaffolds is often used to fill up the gap. Sometimes, these steel tube shores are reinforced by horizontal enclosed restraint with stringers. Test configuration of the scaffolds reinforced with steel tube shores without and with enclosed restraint as shown in figure 3(A) and 3(B) respectively.

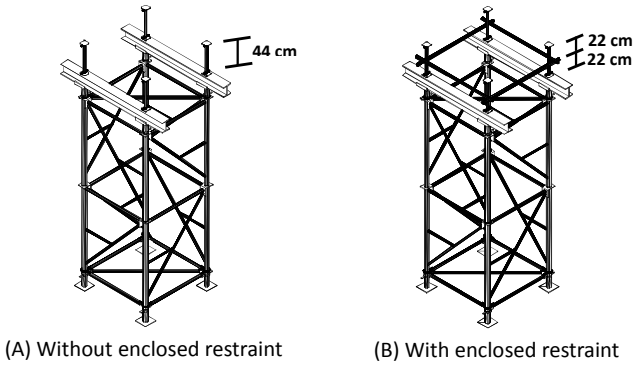

Figure 3: Test configuration of the scaffolds reinforced with steel tube shores.

2.5. Reusable scaffold strengths

On construction sites, there are usually assembled with reusable scaffolds. In order to obtain the load capacity of these reusable scaffolds at worst condition, it is advisable to reload the scaffolds. The second loading is a reload after finishing the first loading and readjusting the scaffolds. The load capacity of the second loading can be considered as the lower limit value of reusable scaffolds.

3. DIMENSIONS AND MATERIAL PROPERTIES

The measurements of cross-sections in figures 1 are as follows: A-A: D (diameter) = 76.5mm, t (thickness) = 3.2mm; B-B: D = 40.2mm, t = 2.1mm; C-C: D = 33.4mm, t = 2.0mm; D-D: D = 33.4mm, t = 1.8mm; E-E: D = 42.3mm, t = 1.9mm; F-F: D = 42.4mm, t = 2.4mm. The average value of elastic modulus was 19,982kN/cm^2, which is close to the nominal value 20,012.4kN/cm^2.

4. RESULTS AND DISCUSSIONS

4.1. Two-layer setup with and without base stiffness

Two tests were conducted for the two-layer setup. The average maximum load capacities of the first and second loading are 907.346 kN and 470.925 kN respectively.

The tests of the scaffolds with non-stiffness base screw jacks were conducted in three tests. The average maximum load capacities of the first and second loading are 858.373 kN and 527.552 kN respectively. The additional bending moment stiffness provided by the base screw jacks is not big.

4.2. Ground and top differences in elevation

The tests of 33.2 cm ground difference in elevation were conducted in twice. The average maximum load capacities of the first and second loading are 886.967 kN and 527.619 kN respectively. Similarly, two tests were conducted for 56 cm ground difference in elevation. The average maximum load capacities of the first and second loading are 890.252 kN and 642.688 kN respectively. The tests of top difference in elevation were conducted in two groups. The average maximum load capacities of the first and second loading are 940.872 kN and 608.252 kN respectively. These results show that the effect of ground difference and top difference in elevation are insignificant.

4.3. Extension of top screw jacks

There are four tests in this case. The average maximum load capacities of the first and second loading are 841.027 kN and 561.087 kN respectively. This result shows that it has small effect on the load capacity of the isolated tower scaffolds.

4.4. Addition of steel tube shores without and with enclosed restraint on top of scaffolds

Two tests were conducted for the tests of addition of steel tube shores without enclosed restraint on the top of scaffolds. The average maximum load capacity is 232.747 kN. Due to the severity of failure of the 4 steel tube shores on the upper layer, it was not easy to readjust and restore the original position of the scaffolds, hence not possible to conduct the second loading. This result shows that the load capacity of the scaffolds will be seriously reduced.

Two tests were conducted for the tests of addition of steel tube shores with enclosed restraint on the top of scaffolds. The average maximum load capacity is 214.108 kN. This result shows that the strength is slightly lower than that of without enclosed restraint tests. Because one of the four steel tube shores tilts, the other 3 shores will be pulled together due to the enclosed restraint.

4.5. Reusable scaffold strengths

The quotient obtained by dividing the maximum load capacity of the second loading by that of the first loading is the depreciation factor of the strength of the reusable isolated tower scaffolds. The mean value of depreciation factors $\mu = 0.629$, and the standard deviation $\sigma = 0.113$. Figure 4 shows the distribution of 1~3 fold standard deviation. The depreciation factor 0.516, 0.403 and 0.29 are respectively obtained by subtracting 1-fold, 2-fold and 3-fold standard deviation from the mean value. When using the reusable isolated tower scaffolds, the contractors and designers may choose appropriate depreciation factors to make design based on the need for construction safety.

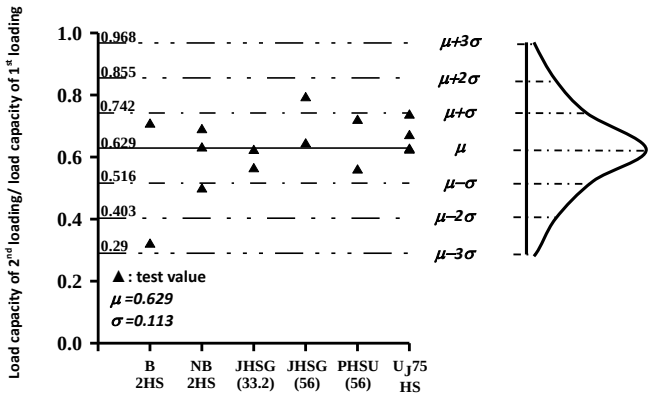

Figure 4: Distribution of 1~3 fold standard deviation of load capacity of reusable scaffolds.

5. CONCLUSIONS

The isolated tower scaffolds which have higher load capacity are often used as the falsework during the construction stage. This study explores the critical loads of isolated tower scaffolds in various setups. The results show that the bending moment stiffness provided by the base screw jacks is insignificant. When isolated tower scaffolds are setup on ground difference or on top difference in elevation, as long as the difference in elevation is less than 56 cm, the load capacity will not be affected evidently. The load capacity of isolated tower scaffolds assembled with single material is much higher than that of the combined scaffolding structure. For the strength design of the reusable isolated tower scaffolds, the depreciation factors presented in this study can be used as a design reference.

6. ACKNOWLEDGEMENTS

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