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TECHNICAL DEVICES FOR ACCESSING RESTORED HISTORICAL AND CULTURAL MONUMENTS OF TOWER TYPE

Svetlana G. Sheina (a)*, Deni K.-S. Bataev (b), Said-Alvi J. Murtazaev (c),
Petimat D. Bataeva (d)
*Corresponding author

(a) Federal State-Funded Educational Institution of Higher Education Don State Technical University, Department of Urban Construction and Economy, 344000, Rostov region, Rostov on Don, Gagarin square, 1, Russian Federation, sheina_gs@mail.ru
(b) Department of Materials Science Kh. Ibragimov Complex Institute of the Russian Academy of Sciences, 21a Staropromyslovoe hw., Grozny, 364051, Russian Federation, kniiran@mail.ru
(c) Department of Materials Science Kh. Ibragimov Complex Institute of the Russian Academy of Sciences, 21a Staropromyslovoe hw., Grozny, 364051, Russian Federation, murtazaev_saj@mail.ru
(d) Department of Materials Science Kh. Ibragimov Complex Institute of the Russian Academy of Sciences, 21a Staropromyslovoe hw., Grozny, 364051, Russian Federation, bataeva_p@mail.ru

Abstract

In order to increase the reliability and safety of the repair and restoration work in confined conditions, a mast being a lifting device, a support, a means of access to repaired structures, etc. has been recommended. Based on the principle of this device, the authors proposed a manually operated pantograph, pull-out scaffold and mechanical arm. An improved design of the mounting mast has also been developed. The proposed device can be used for installing and dismantling means of access to the structures under repair, mainly in confined spaces, while repairing, restoring and reconstructing cultural heritage sites (historical and cultural monuments) of the tower type. In the developed and proposed devices, a block-and-tackle system being unique in its technical solution and functioning as a part of the lifting mechanism is used. In the extended position the mast lifts and lowers the load using a hoisting tackle fixed on the console. The proposed devices are dismantled in the reverse order. Thus, the proposed devices are superior to the known technical solutions in simplicity and efficiency. The technical advantages are as follows: rejection of auxiliary cranes and other lifting means that install the device, avoiding work at height and the device's potential to be used in confined spaces and inaccessible sites implementing repair, restoration and reconstruction works

Keywords: Block-and-tackle system, cultural monuments, mechanical arm, pantograph, towers, technical solution

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1. Introduction

Technologies for mounting (dismantling) structures and technical means of access to repaired and restored structures amid confined spaces and inaccessibility are inextricably intertwined with materials during repair and restoration of historical and cultural monuments (Bataev et al., 2017; Bataev, 2020; Bazhenov & Bataev, 2021). It is insufficient to develop a certain material, an effective delivery means (method), provide access to the part of the structure under restoration, etc. Practically, in most cases when repairing and restoring cultural heritage objects, there occurs the need to mount or dismantle various structures and means of access to structures for optimal work in confined spaces. Due to the lack of appropriate methods and means, builders-repairmen-restorers use ineffective engineering solutions.

Domestic research and design institutes have developed and studied methods, techniques and means of the main types of installation and construction work in capital construction, and little attention is paid to the study of repair and restoration work. Therefore, due to the lack of scientifically grounded technologies and means of repair and restoration work, the level of reliability and safety is rather low. Installing and dismantling the means of access to structures being a complex and dangerous type of work has not been studied either (Mele, 2022; Nikulin, 2023; Rawel, 2022).

Practically, using existing methods and means of installation and dismantling the means of access to repaired structures amid new construction is dangerous, and in some cases technically impossible or economically unfeasible. Therefore, further study of repair and restoration work in confined spaces aimed to develop new methods and means to increase the level of reliability, safety and labor productivity is relevant and has an important national economic importance (Collet-Sabé, 2023; Manakbayeva, 2023; Sheveleva, 2024).

At present, the rational methods and means of mounting and dismantling structures are chosen based on the availability of lifting, organizational and technical means at a specific object and criterion indicators of the methods being compared, specifically, reduced labor costs, duration of work.

The confined spaces, reliability and safety caused by the lack of a scientifically grounded methodology for choosing methods and means of repair and restoration work are not taken into account.

Traditional methods of analyzing confined space and reliability (safety) are not acceptable due to the following shortcomings and imperfections:

i. the methods are developed for narrow areas of technology and cannot be applied to assess the level of reliability and safety of installing and dismantling the means of access to repaired structures;
ii. the results of assessments obtained using these methods are expressed in points, percentages, coefficients and other indicators that are incomparable with each other;
iii. the methods do not always take into account the complex of the main factors affecting the level of reliability and safety, and are inapplicable at the stages of choosing rational methods of installation and dismantling.

Thus, the main goal of the authors' research is to develop devices, mechanisms and means of access to the restored and repaired structures of historical and cultural sites (Gumba, 2007; Mazaeva, 2014, 2019) amid confined spaces and inaccessibility.

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2. Problem Statement

Many works are devoted to the issue of improving the existing methods and means of assembling structures in the conditions of new construction.

At the same time, not enough attention is paid to the development of methods and means for dismantling and installing structures in confined spaces and assessing the level of their reliability and safety.

When choosing rational methods of installing and dismantling structures, the reduced costs, labor costs and duration of work are currently used as an optimization criterion. The level of reliability and safety of work is not regarded due to the ineffectiveness of the existing methods. The level of constraint is also not taken into account. This leads to great social and material damage (over 30 billion rubles over the past 10-15 years) as a result of accidents (Giza, 2024; Mambetova et al., 2024; Mascareno & Chavez, 2024).

3. Research Questions

Stairs, scaffolds, mobile towers, bridge cranes and other means used in practice to provide access to structures, in most cases, especially in confined spaces, fail to provide repair and restoration opportunities to be exploited from the closest and most convenient distance.

4. Purpose of the Study

The level of reliability and safety of the listed technical means is significantly reduced when used in confined spaces.

5. Research Methods

Mounting mast. Mounting masts belong to the main means of rigging when repairing tower structures, and working in confined spaces and inaccessible sites. They are the only means of access to the areas under repair and restoration. Mounting masts with rigging equipment are large and heavy. Therefore works on their installation and dismantling have a significant share in total equipment installation and are dangerous. This indicates the relevance of improving the construction of mounting masts. It should also be noted that it is technically impossible to use sectional lattice masts for assembly and disassembly in a built-up area during the repair and restoration of historical and cultural monuments in confined spaces and inaccessible conditions.

6. Findings

In order to increase the level of safety and ergonomics of rigging during the dismantling and installation of access means, several lifting devices, including a self-erecting mast are proposed in this work (Bataev, Isakov, et al., 1988; Bataev, Panov, et al., 1988; Bataev, Krivonos, et al., 1989; Bataev, Merzhueva, et al., 1989).

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Figure 1 shows a general view of the mast, figure 2 – its initial position, figure 3 – its intermediate position and figure 4 – its design position. The self-erecting mast in this case has the form of a device containing a base 1, a load-holding device 2, a toggle-lever system 3, a stabilizing mechanism 4 and a bracing structure 5.

The base 1 includes a back-up shoe 6, installed on the foundation, and a ball pivot 7, which is connected to the support truss 8. The stabilizing mechanism 4 in this case has the form of struts 9 and shoes 10. Some ends of the struts 9 are connected to the supporting truss 8 with a toggle, and others abut against the protrusions of the shoes 10. The ends of the struts 9 freely slide along the guides of the shoes 10 when moving to the support shoe b and cannot move in the opposite direction.

The load-holding device 2 is a mast head, made in the form of a spatial truss 11, carrying a fixed block 12 and a drain block 13 of the hoisting tackle 14. The movable branch of the hoisting tackle 14 is brought out to the drum of the hoisting winch (not shown in the figure). On the spatial truss 11, a bracing device 5 is fixed, which has flexible rods 15.

The toggle-lever system 3 consists of sections 16, pivotally connected to each other.

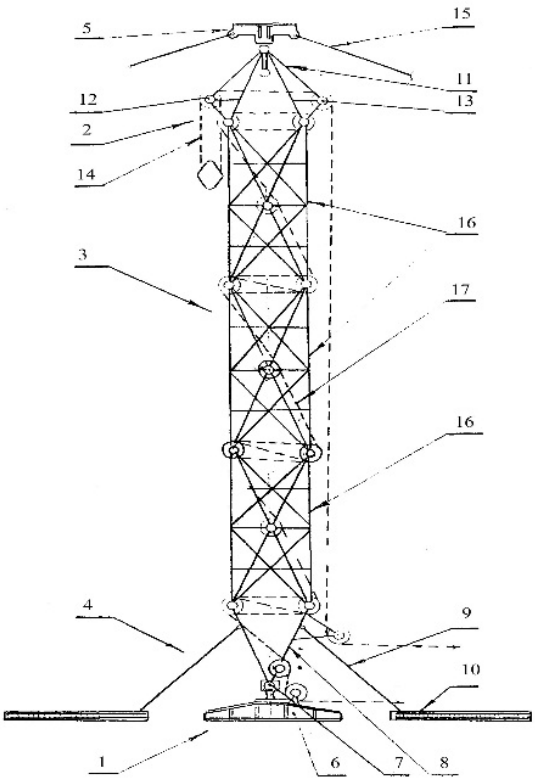

Figure 1. General view

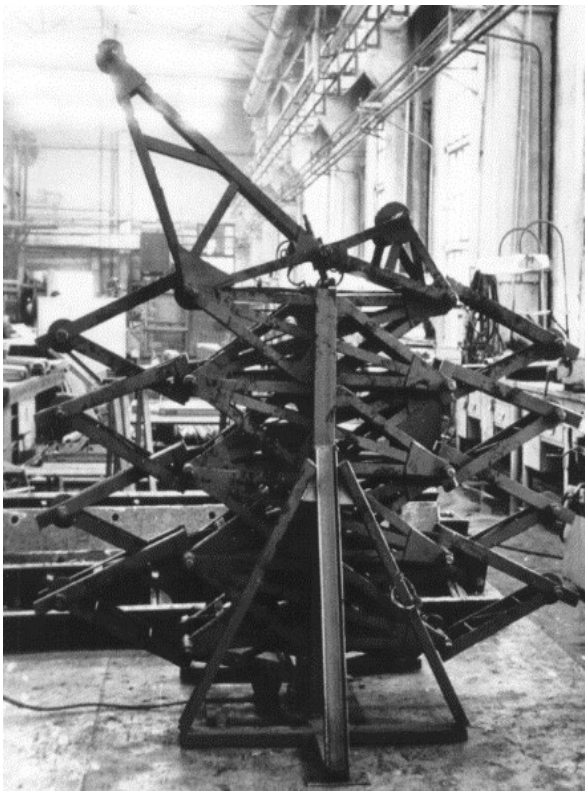

Figure 2. Device in initial position

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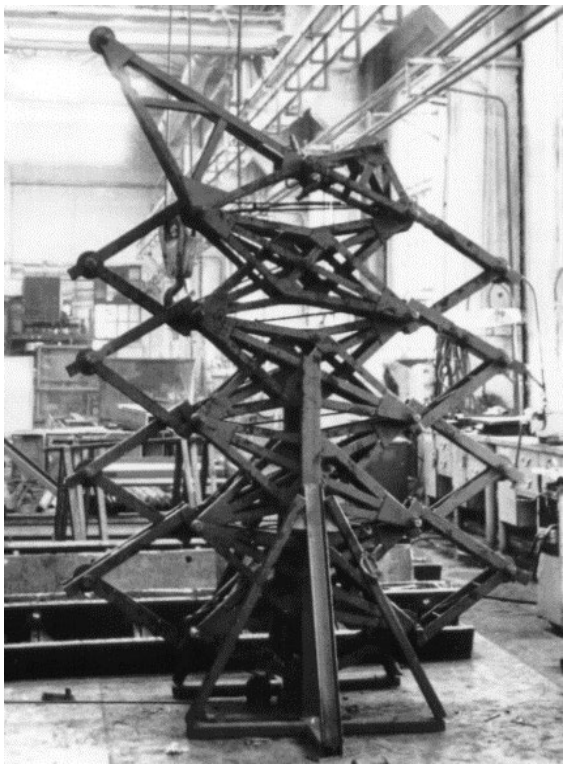

Figure 3. Device in intermediate position

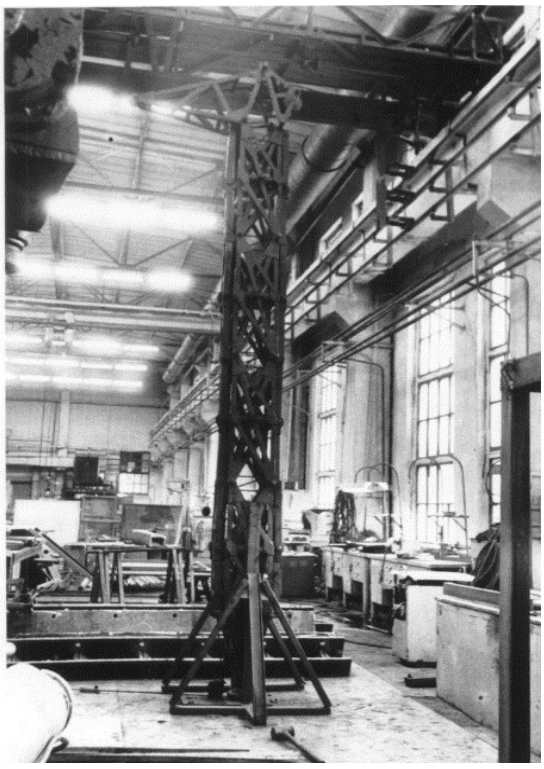

Figure 4. Device in design position

The mast is raised to the design position in the following way.

The folded mast is installed at the equipment installation site. The back-up shoe 6 of the base 1 and the shoes 10 of the stabilizing mechanism 4 are fixed to the foundation using, for example, anchor bolts. They include traction mechanism. When tensioning the movable branch of the block-and-tackle system, the rope 17 pulls out, pushing up the toggle-lever system. After extending the mast to the design position, the traction mechanism of the block-and-tackle system is locked. Due to the fact that the mast is loaded only by its own weight during lifting, it is sufficient that stability is provided by the stabilizing mechanism 4. After lifting the mast, the flexible rods 15 are pulled, bracing the mast and the ends of the struts 9 are disconnected from the support truss 8. The stability is provided by the usual method.

In the extended position, the mast serves as a lifting device, lifting and lowering the load using a hoisting tackle 14.

The mast is dismantled in the reverse order.

The economic effect of the proposed design of the mast in comparison with the base design is as follows: rejection of auxiliary cranes used to install the mast, the possibility of using it in confined spaces and on inaccessible sites. The social effect is lack of necessity to work at height. The estimated annual economic effect is 5.5 million rubles.

Improved design of the mounting mast. The proposed device can be used for installing and dismantling access means, mainly in confined spaces, during the repair and restoration of historical and cultural monuments of the tower type.

Figure 5 shows the device in an extended position and figure 6 shows the device in an intermediate position.

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The lifting device in this case has the form of a mounting mast containing a base 1, a load-holding device 2, a toggle-lever system 3 and a bracing device 4. The base 1 includes a back-up shoe 5 installed on the foundation, a ball pivot 6 and a pivot joint 7, which connects the lower section of the mast with a back-up shoe. The load-holding device 2 is a mast head, made in the form of a console 8, on which the hoisting tackle is suspended. Flexible rods 9 are fixed on the bracing device 4.

The mast, consisting of sections 10–12, connected by hinges 13 and 14, is supplemented by levers 15–20 located on both sides of the sections, which are flat trusses. The levers 15–20 are connected in pairs with each other by the axes 21 and 22. Through the hinge axes 7, 23 and 24, the sections 10–12 are connected to the levers 15–20, forming a hinge-lever system. In each of the sections 10–12, locks 25 and 26 are mounted for rigid connection between them.

On the axis of the pivot joint 7, a branch unit 27 of the block-and-tackle system is installed, and on the opposite axes of the joints 13 and 21, 14 and 22, working blocks 28–32 are installed. Rope 33 is inserted in blocks 28–32 forming the loops. The details of rope 33 insertion into blocks are shown in Fig. 4.26. The movable branch of the rope 33 is connected to the traction mechanism 34.

The mast is raised to the design position in the following way. The folded mast is installed on site. The support shoe 5 of the base 1 is fixed to the foundation using, for example, anchor bolts. The section of the mast 10 is installed and fixed in the pivot joint 7. When the traction mechanism 34 is turned on, the rope 26 pulls out and brings the axes 13 and 21, 14 and 22 closer together. After the sections 10–12 occupy the design vertical position, the locks 25 and 26 and the traction mechanism 34 is locked. During lifting the mast is loaded only by its own weight. Thus, it is sufficient that its stability is ensured by the simultaneous release of the flexible rods 9. After lifting the mast, the flexible rods 9 are fixed on specially arranged anchors and stability is provided by the usual method. The block-and-tackle system functions as a part of the lifting mechanism.

The mast in the extended position functions as a lifting device lifting and lowering the load using a hoisting tackle attached to the console 8. The mast is dismantled in the reverse order.

Based on the principle of this device, the authors proposed a manually operated pantograph, pull-out scaffold and mechanical arm.

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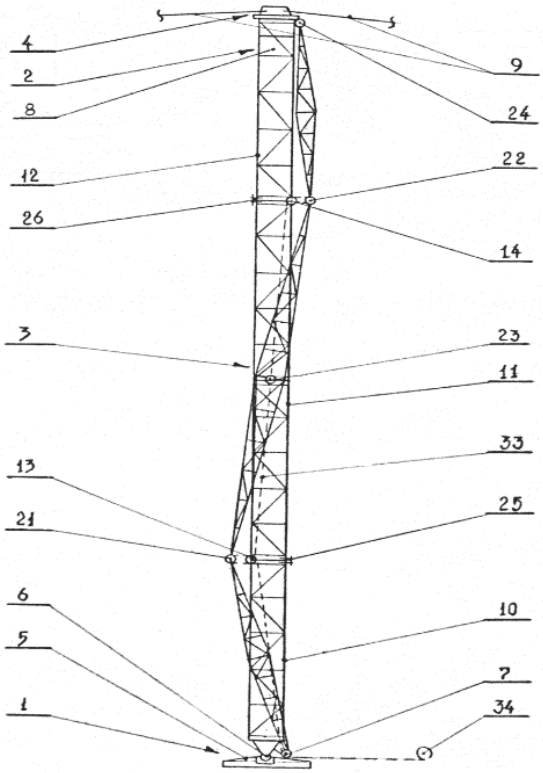

Figure 5. Device in extended position

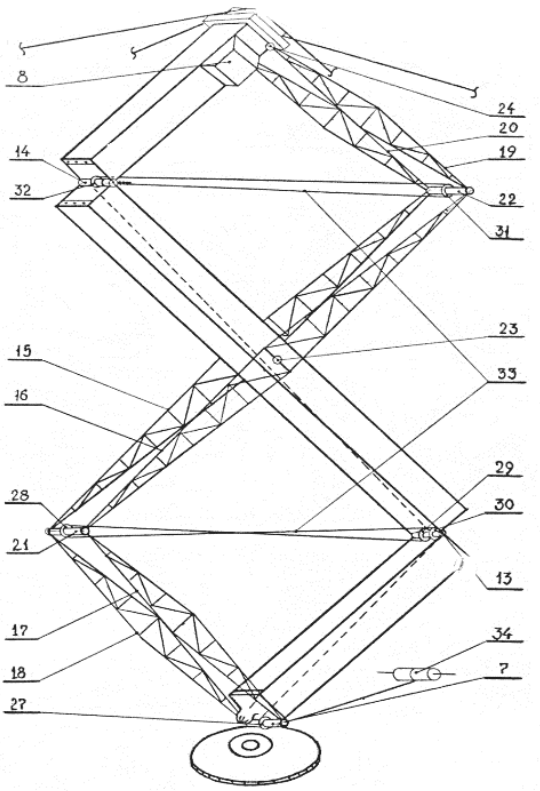

Figure 6. Device in intermediate position

7. Conclusion

Russian specialists have made a significant contribution to the development of technology and the creation of new technical means for repair and restoration. However, not all inventions used in practice meet the requirements of the construction site with regard to repair and restoration works of cultural heritage objects of the tower type. Thus, it is appropriate to analyze the existing methods of providing access to the structures under repair in terms of reliability and safety and the possibility to use these methods in repair and restoration work in confined spaces on inaccessible sites.

Practically, in most cases when repairing and restoring cultural heritage objects, there occurs the need to mount or dismantle various structures and means of access to structures for optimal work in confined spaces. Due to the lack of appropriate methods and means, builders-repairmen-restorers use insufficiently effective engineering solutions.

In this regard, it is useful to study the experience of mechanical assembly work with the objective to adopt it to this task, and the technical devices developed and proposed in this work are the most acceptable for repair and restoration of historical and cultural monuments.

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