Stability of Ladders when Working at heights and Safety while performing this type of work

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Abstract. The analysis of industrial injuries when working at heights is conducted. Statistics show that a fall from a height takes more than 30% of the total number of accidents. Operations with the help of ladders are the most common type of works at heights. However, the ease of installation and use of ladders often leads to the fact that the persons performing the work do not pay enough attention to safety. The aim of the work was to improve the safety in operation at heights with the use of ladders inclined to the horizontal surface. An important prerequisite for the safe use of ladders is to ensure their stability. There were analyzed the most common devices used to increase the stability of ladders. The issue of applying a lifeline system attached to a ladder (if the ladder is affixed to a building or other structure), when working with a ladder at heights of more than 1.8 m, is considered. The inferiority of this issue is shown in the current regulatory documents. It was proposed to revise the relevant requirements in the regulatory documents on the possibility of using a lifeline system attached to the ladder, requirements for the durability of the ladders and methods of their testing.

Keywords: work at heights, ladder, anchor point, safety system, personal protective equipment, vertical lifelines.

1. Introduction
Operations at heights have become an important part of human production and economic activity. At present, they are found in construction, operational tasks of buildings and structures, in large companies, at ports and at oil and gas complex facilities, as well as in various structures, such as wind turbines or cell towers [1-5]. At the same time, safety in this area of work performance remains the most popular issue. At the moment, this sector of work has not the best statistical indicators with regard to labor protection. If we consider the statistics of accidents, then a number of sources [6-13] give the following data: occupational injuries statistics as to the number of accidents while performing work at heights is in the first place in the Russian Federation, accidents due to a person's fall from a height, occupy more than 30% of all heavy and "lethal" statistics, and if we consider only fatal cases, more than 35%. The main regulatory document regulating the area and safety while working at heights is the Order of the Ministry of Labor of Russia dated March 28, 2014, No. 155n (as amended on December 20, 2018) “On the Approval of the Rules on Labor Protection When Working at Heights” [14]. In accordance with the Order [14], works at heights, in particular, includes types of works where there are risks of a worker’s falling from a height of 1.8 m or more, as well as when a worker
ascending to a height of more than 5 m or descending from a height of more than 5 m by means of a ladder inclined to a horizontal surface more than 75°.

Operations with the help of ladders are probably the most common type of work at heights. Installation and electrical work at heights, installation, and repair of advertising structures, construction and repair work, installation and repair of electrical lighting equipment, ascent or descent to various platforms and wells, as well as many other works are performed with the help of ladders. However, the ease of installation and use of ladders often leads to the fact that the persons performing the work are not paid enough attention to safety. An important condition for the safe use of is to ensure their stability, i.e. exclusion of possible shifting or overturning during their operation.

The aim of the work is to improve the safety in operation at heights with the use of ladders inclined to the horizontal surface 75°. In order to achieve this goal, the following tasks are set: To analyze the most common devices used to improve the stability of ladders, as well as to consider the issue of safe access to height with their use. Of all types of activities at heights in accordance with the Order [14], this work will consider the safety of performing work at heights with the use of ladders. This paper does not consider fixed and suspended ladders. The term "Fixed" should already imply their reliable stable fixture to structures or supports [15-18]. The main issue of the safe operation of suspended ladders is the strength and reliability of their hooks, grips and structural elements or supports on which they are suspended.

2. Analysis
The main causes of the buckling failure of ladders are:

- an insufficiently reliable surface of the installation site – soft soil, a slope of the base surface, slippery surfaces;
- lateral sliding, falling to the side – loosening of the safety clamps or unsecured fixing of the upper part of the ladder to the installation site;
- adverse weather conditions – wind, torrential rain, snow, ice;
- incorrect installation – incomplete expansion angle of two – and three sectional ladders;
- installation in dangerous places – next to doors, windows, roadway;
- wrong choice of the type of ladder – inappropriate size of the ladder, type of activity.

When installing the ladder on the ground, the base of the ladder should be equipped with ladder spikes (figure 1). If the ladder is installed on smooth support surfaces (for example, concrete, tile, parquet, asphalt, metal, etc.), foot plugs made of rubber or other materials should be installed at the base to prevent them from slipping along the support surface (figure 2). In cases where it is impossible to fix the ladder when installing it on a smooth floor, one employee should stand in a helmet at its base keeping the ladder and preventing it from possible shifting in its lower base part. In other cases, it is not allowed to keep the ladder with your hands at the foot.

![Figure 1. Foot plugs.](image1)

![Figure 2. Ladder spikes.](image2)
The stabiliser can be installed at the base of the ladder to increase the stability and preventing overturning of the ladder by increasing the footprint (figure 7), as well as to balance small level difference on uneven and inclined surfaces (figure 3).

![Figure 3. Stabiliser.](image)

In order to balance large level difference on uneven surfaces and on flights of stairs or platforms, edges of sidewalks, etc. side rail extensions (figure 4) and cross rail levellers (figure 5) are used. It is worth noting that the Order [14] prohibits the installation of ladders on the steps of the flights of stairs and it recommends the use of scaffolding to perform work in such conditions.

![Figure 4. Side rail extensions.](image)  ![Figure 5. Cross Rail levellers.](image)

Outriggers (figure 6) provide additional lateral support for the ladder, also by increasing its footprint (figure 7). Stepless adjustment of the outriggers allows you to use them on a variety of surfaces. It is worth noting that during operation of the ladder in its non-self-supporting version, outriggers cannot be used to balance a missing support surface (for example, walls), they can only be used for additional support and fixation.
When installing a ladder under conditions where it is possible to displace its upper end and to prevent it from falling due to wind pressure or accidental jolts, the top must be securely affixed to stable structures. The top of the ladder leaning against the pipes or wires are supplied with special ladder hooks (figure 8).
A mast claw (figure 9) or all-purpose mast castors (figure 10) can be installed on the top of the ladder leaning against a pole (mast) with a diameter of 100 to 250 mm, the delay can also be used when leaning the top of the ladder against flat vertical surfaces, against a wall for example. Both types of attachments prevent lateral movement of the ladder. Specialists have also designed a more cross-functional attachment on the top of the ladder based on the mast claw against sliding off for any type and size of supports, posts, trees and flat surfaces that do not require adjustment [19].

Affixing a ladder can be accomplished by tying it to reliably fixed points (figure 11). The base is tied and pulled to the sides opposite to its possible slippage along the horizontal support surface. The top and middle part of the ladder is tied and pulled away from a possible lateral movement or overturning.
3. Discussion
R. 153 Labor protection regulations… [14] indicates that: When working with a ladder at a height of more than 1.8 m, a lifeline system should be applied that is affixed to the construction of the structure or to the ladder (provided that the ladder is affixed to a building or other structure).

At present, many manufacturers propose a rigid anchor lifeline, the structural anchors of which are attached to its crossbar as an anchor device of a lifeline system, attached to the ladder (figure 12).

Another common lifeline system for climbing the ladder is the using of scaffold hooks (figure 13). These scaffold hooks comply with A class anchor connecting elements according to GOST R EN 362-
2008 “Occupational safety standards system (OSSS). Personal protective equipment against falls from a height. Connectors. General specifications. Methods of Testing”.

Figure 13. Using scaffold hooks.

But the problem is that there are no requirements for the durability and reliability of the ladders so that the ladders and/or its elements can serve as an anchoring point. In accordance with GOST EN 795-2014 “Occupational Safety Standards System (OSSS). Personal protective equipment against falls from a height. Anchor devices. General specifications. Methods of Testing” each anchor point of fixation in a lifeline system for a single person must withstand without breaking a static load of at least 10 kN. While the requirements for durability against the effects of static loads for ladders in the existing GOST 24258-88 “Means of scaffolding. General technical conditions” and GOST 26887-88 “Platforms and ladders for construction and installation works. General technical conditions.”, are much less at the moment. This means that even if the ladder is securely affixed to a building or other structure, the use of a lifeline system attached to the ladder does not guarantee the safe stopping of a fall in the event of an accident.

4. Conclusions
Based on the analysis, special attention should be paid to the ladders’ installation in a stable position in order to improve the safety of work at heights with the use of ladders as a scaffold.

But even in case of a reliable and stable installation of a ladder in a proper way, the issue of applying lifeline systems attached directly to the ladder remains unsolved. In this regard, we propose to revise the relevant requirements in the regulatory documents:
– The issue of applying a lifeline system attached to a ladder (if the ladder is affixed to a building or other structure), when working with a ladder at heights of more than 1.8 m in the Order [14];
– requirements for the durability of ladders and their test methods in GOST 24258-88 and GOST 26887-88 in which the ladder and/or its elements could serve as an anchor point and/or attachment point for other anchor devices of lifeline systems.

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