Research on Risk Prevention Measures for Working at Heights in Maintenance and Repair of Port Equipment and Facilities

Zhiyan Zhao[1], Weiwei Sun[2*]

[1]Shuikeyuanda Traffic Design Institute (Beijing) Co., Ltd., Beijing, 100088, China
[2]China Waterborne Transport Research Institute, Beijing, 100088, China

*Corresponding author's e-mail: sww@wti.ac.cn

Abstract. This study identifies potential risk events in maintenance and repair activities involving working at heights for port equipment and facilities, and analyzes the risk factors contributing to such events. Based on the process management methods for working at heights, key on-site safety risk prevention measures are proposed for critical stages. These measures provide practical control methods for ensuring on-site safety in working at heights for port enterprises.

Keywords: working at heights; port enterprises; maintenance and repair; risk control

1 Introduction

Working at heights is common in the port industry and is characterized by a high frequency and likelihood of accidents. It poses significant risks of personal injury, including falls from heights, being struck by objects, mechanical injuries, and electric shocks, which can lead to severe consequences. Managing safety during such activities is one of the critical and challenging aspects of port enterprises' safety production efforts. At present, domestic and international scholars have done a lot of research on accident cause analysis by using different data sources, variables and sample sizes. Lu Yu [1] proposed to use 24Model-AHP to analyze the causes of the falling accidents from high places, and concluded that the preventive measures and countermeasures of falling accidents in building construction from height in the construction sector. Jia Xiaoshan [2] proposed to use FTA to analyze the causes of falling accidents from high places, and concluded that the main causes of falling accidents from high places are unsafe factors of things and unsafe behaviors of people. Liu Haozhen [3] used accident tree analysis to analyze the accident of falling from a height, clarified the accident mechanism and made clear the accident prevention measures. Filipa Pereira [4] used PRISMA methodology to analyze the risk of falling, and introduced the new technologies to predict the risk of a fall in real time. To reduce accidents during work at heights and safeguard lives and property, this paper discusses strategies for strengthening risk control in maintenance and repair activities involving working at heights for port equipment

G. Zhao et al. (eds.), *Proceedings of the 2025 8th International Conference on Traffic Transportation and Civil Architecture (ICTTCA 2025)*, Atlantis Highlights in Engineering 39,
https://doi.org/10.2991/978-94-6463-793-9_73

and facilities and proposes preventive measures to mitigate safety production risks for port enterprises.

2 Overview of Working at Heights in Maintenance and Repair of Port Equipment and Facilities

The national standard Classification of Work at Heights (GB/T 3608-2008) [5] defines working at heights as operations performed at an elevation of 2 meters or more above the reference surface where there is a risk of falling. Based on the height of the operation, work at heights is classified into four levels: Level 1, Level 2, Level 3, and Special Level. Related equipment and facilities for working at heights include scaffolds, ladders, elevating work platforms, temporarily installed suspended access equipment, personal fall protection systems, and safety nets. Working at heights is characterized by its high-risk nature, which involves limited spatial positioning, significant elevation above ground, overlapping vertical work areas, and complex construction techniques [6].

According to survey data, a certain port group conducted up to 50 instances of working at heights for equipment and facilities maintenance and repair within a single month across its subsidiaries. Compared to working at heights in loading and unloading production, where standard procedures and work instructions are available, working at heights in maintenance and repair lacks fixed operational guidelines. Besides, it is marked by its sporadic timing and arbitrary locations, which result in a higher risk of accidents.

3 Risk Identification for Working at Heights

3.1 Identification of Risk Events

For maintenance and repair work involving working at heights in port equipment and facilities, risk events were identified across different operational phases: before, during, and after the work. Drawing on daily safety production management practices and considering the occurrence of historical risk events, potential risk events for each phase are summarized in table 1.

Table 1. Potential risk events for each operational phase.

Operation name	Operational phase	Risk events
Working at Heights	Before work	Other injuries
	During work	Falls from heights
		Being struck by objects
		Mechanical injuries
		Electric shock
		Fire and explosion

	After work	Poisoning and asphyxiation
		Vehicle-related injuries
		Collapse
		Falls from heights
		Being struck by objects

3.2 Analysis of Risk Factors

For the potential risk events associated with working at heights, a risk factor analysis was conducted based on the Classification and code of hazards and harmful factors in the production process (GB/T 13861) [7]. This analysis examined four categories of contributing factors: personal factors, material factors, environmental factors, and management factors in Table 2.

Table 2. Risk factors contributing to potential incidents.

Category	Risk factors
Personal factors	1. Workers suffer from medical conditions or physiological defects (e.g., hypertension, heart disease, anemia, epilepsy) that impede working at heights. 2. Workers experience excessive physical or mental fatigue, leading to distraction, slowed reactions, increased errors in movement, or misjudgment. 3. Stepping into voids or onto non-load-bearing surfaces, edges, or areas. 4. Failure to promptly attach safety harness hooks after moving to a new position. 5. Throwing or dropping tools, materials, or other objects from heights; stacking slippery or rolling tools and materials, leading to being struck by falling objects. 6. Losing balance due to accidental collisions with structural elements while bending or turning. 7.Lack of knowledge about safe operation techniques or habitual rule violations, such as improper use of personal fall protection systems, failing to secure hooks to sturdy points, or working under the influence of alcohol.
Material factors	1. Instability, collapse, or overloading of scaffolds, ladders, or elevating work platforms. 2. Defective or weak scaffold materials, sudden breakage, or use of severely corroded steel pipes and fasteners. 3. Damaged safety nets, inadequate spacing or width, or absence of safety nets. 4. Lack of protective measures or damaged protective facilities at edges or openings. 5.Defective personal protective equipment, such as counterfeit or aged personal fall protection systems and safety ropes.

Environment factors	1. Gusts with wind speeds exceeding 8.0 m/s (Force 5 wind or above). 2. Working environments with an average temperature of 5°C or lower. 3. Exposure to cold water at 12°C or lower. 4. Slippery work surfaces due to ice, snow, frost, water, or oil. 5. Insufficient lighting or poor visibility at the work site. 6. Operating within unsafe proximity to electrically charged components. 7. Unstable or minimal standing surfaces that prevent workers from maintaining proper posture. 8. Presence of toxic gases or oxygen levels below 19.5% in the air. 9.Hazardous environments prone to accidents or emergencies requiring sudden rescue operations.
Management factors	1. Absence or inadequacy of safety management systems, including operational guidelines for equipment, safety measures, and protective gear. 2. Incomplete risk identification leading to ineffective implementation of control measures. 3. Lack of on-site safety technology disclosure or inadequate communication with all workers involved. 4. Poorly planned work approvals, resulting in overlapping operations or overtime work. 5. Assigning workers with contraindications for working at heights. 6. Uncertified workers or those lacking essential safety training. 7. Failure to provide appropriate equipment, facilities, or personal protective equipment for working at heights. 8. Absence of designated monitoring personnel at the work site. 9.Lack of warning signs or the establishment of safety zones at the work site.

4 On-Site Safety Risk Prevention Measures

Based on safety process management across the phases of before, during, and after the work, and utilizing risk-based management principles while accounting for the dynamic complexity of on-site work, risk factors in each operational stage are identified to establish a comprehensive safety management model for working at heights. The on-site safety management process for working at heights includes five key stages: safety analysis, approval, safety technology disclosure, safety inspection, and site recovery.

4.1 Risk Prevention Measures for Before Work Stage

4.1.1 Prevention Measures for the Safety Analysis

(1) Clearly define the scope of work and break down tasks into discrete steps or phases.

Conduct safety analysis involving key construction management and technical personnel to identify potential safety risks and establish control measures.

4.1.2 Prevention Measures for the Approval

The approval before work includes environmental safety, personnel qualification, personal protective equipment, tool safety, work platform safety confirmation and on-site approval.

(1) Environmental safety confirmation:

1) Suspend work in adverse weather conditions, such as wind speeds at or above Level 5, heavy fog, or storms. For operations during rain or snow, ensure reliable anti-slip and cold-weather measures. After extreme weather events such as storms, typhoons, or heavy rains, inspect safety facilities and eliminate hazards before resuming work.

2) When working near areas emitting toxic or hazardous gases, dust, or fumes, establish prior communication with local production personnel and implement effective safety measures.

3) Avoid overlapping vertical operations along the same fall direction. If such operations are necessary, install safety barriers. For operations exceeding a fall height of 24 meters, double-layer protective barriers must be installed.

4) Ensure adequate lighting equipment is available to meet operational requirements.

5) Set up warning zones or barriers around the work area, place warning signs, and ensure proper isolation of the operational zone. For night work or incomplete tasks where the site cannot be restored, install additional warning lights (use explosion-proof lights in explosion-proof areas).

(2) Personnel qualification confirmation:

1) Individuals with contraindications for working at heights must not participate. Workers must obtain and carry the appropriate qualification certificates.

2) Site supervisors, safety monitors, workers, and emergency rescuers involved in working at heights must undergo specialized safety training. Monitors must be certified to perform their roles.

(3) Personal protective equipment confirmation:

1) Verify that fall protection equipment such as personal fall protection systems, safety nets, and fall protection equipments meet current national standards for material, specifications, physical properties, fire resistance, and flame retardance. Equipment that is defective or beyond its service life must not be used.

2) Workers must correctly wear personal protective equipment compliant with Specification for the provision of personal protective equipment – part 1: General requirement (GB 39800.1) [8]. During nighttime operations, reflective clothing or vests must be worn.

(4) Tool safety confirmation:

1) Ensure tools such as scaffolds, lifting machinery, welding (cutting) tools, and handheld power tools comply with operational safety requirements. Handheld or portable electric tools exceeding safe voltage must be equipped with individual circuit breakers and power switches.

2) For work above 30 meters, communication tools must be provided.

3) For construction in explosion-proof areas, it is necessary to check and confirm the use of explosion-proof tools, the presence of explosion-proof safety labels, and relevant inspection reports. In addition, proper fire prevention measures should be implemented.

(5) Work platform safety confirmation:

1) The work platform, temporarily installed suspended access equipment, ladders, toe boards, bridging boards, etc., should be equipped according to actual needs and meet safety requirements. They should be put into use only after inspection and acceptance. The erection, dismantling, and use of scaffolds should comply with relevant standards, such as the General code for scaffold in construction (GB 55023) [9]. The requirements for edge-near, opening, climbing, hanging, cross operations, and safety nets installation should comply with relevant standards.

2) Aerial work platforms and lifts must meet safety requirements and be operated by trained personnel. Substituting cranes or forklifts for these purposes is strictly prohibited.

3) Personnel engaged in high-altitude operations should not work on unstable structures. When working on lightweight materials such as color steel roofing, asbestos tiles, or corrugated fiberboard, sturdy scaffold boards should be laid and fixed in place, with anti-slip measures on the boards. Operations or passage should not be carried out on components or pipes that are not fixed or lack protective facilities.

(6) On-site approval:

1) Approval must be completed at the work site.

2) Verify that the approval level of the safety work permit aligns with the levels specified in the enterprise management system. Ensure all approval steps comply with corporate management requirements.

3) Confirm that all identified risks and control measures in the safety work permit have been thoroughly implemented.

4.1.3 Prevention Measures for the Safety Technology Disclosure

(1) Provide a safety technology disclosure on the primary procedures, potential hazards, harmful factors, specific safety measures, and emergency response plans for the task.

(2) Organize work personnel to visit the site, familiarize themselves with the environment, verify the reliability of safety measures, and locate emergency rescue equipment.

(3) Clearly define the roles and responsibilities of work personnel and specify emergency duties based on the on-site emergency response plan.

(4) All personnel must sign off on the disclosure, and the records should be archived for future reference.

4.2 Risk Prevention Measures for During Work Stage

The risk prevention measures for the safety inspection during work are detailed as follow.

(1) Work personnel safety confirmation:

1) On-site inquiries should be made to determine whether workers have a history of sudden illnesses such as heart disease or hypertension, and to confirm that their physical and mental condition meets the requirements for the job.

2) Verify the number of workers, their identities, and credentials in accordance with the safety work permit.

3) Supervisors should wear clear identification and hold a valid training certification to be on duty.

(2)Tools safety confirmation:

1) Ensure all tools meet the requirements for safe operation at the site.

2) Count and record tools and equipment used during the operation.

3) Tools, materials, and parts used during operations should be placed in tool bags. Workers should not carry items in their hands when moving up or down, and tools, materials, or other objects should not be thrown. For tools and materials that are slippery or prone to rolling, fall prevention measures should be taken during storage.

(3) Communication safety confirmation:

When communication at the worksite cannot be conducted through visual signals or shouting, communication devices such as walkie-talkies should be used. A unified communication signal should be established to facilitate communication between workers on-site.

(4) Personal protective equipment safety confirmation:

Workers should wear personal protective equipment that meets the requirements of Specification for the provision of personal protective equipment — part 1: general requirement (GB 39800.1) [8]. The carrying of flammable or explosive items such as cigarettes or fire-related materials is strictly prohibited.

(5) Emergency supplies confirmation:

Verify the availability of emergency gear, such as personal fall protection systems, safety ropes, first aid kits, fire extinguishers, and emergency lighting equipment.

(6) Work environment safety confirmation:

1) The electrical power supply on equipment that requires maintenance should be reliably disconnected, with the power switch locked and a safety warning sign placed at the switch. The safety distance for electrical work should comply with the relevant requirements of Safety code of electric power industry - part of electric lines (GB 26859). Work tools used near live equipment and power lines should be properly grounded multiple times.

2) For hot work operations, any surrounding flammable materials should be dealt with, and combustible materials, mechanical equipment, cables, gas cylinders, etc., underneath should be cleared or reliably protected. Safety measures should also be taken to prevent sparks from splashing or falling. Hot work should not be carried out simultaneously with operations such as cleaning with flammable solvents or anti-corrosion spraying beneath the work area.

3) For confined space operations, a portable gas detection alarm device should be installed at the worksite. It should continuously monitor flammable gases, toxic gases, and oxygen levels within the confined space, recording data every 2 hours. If gas concentration exceeds the limit, work should immediately stop, personnel should evacuate, and the site should be handled accordingly. Work can only resume after re-testing and confirming safe levels.

4) When painting indoors with coatings containing volatile solvents, forced ventilation measures should be implemented.

(7) Supervision of work process:

1)Work is strictly prohibited on structures that are unstable, insecure, or under demolition.

2)Work or passage is prohibited on components or pipelines that are not secured (movable or rotating) or lack protective facilities.

3)Workers should not rest at the work site.

4)During cross operations, vertical work should not be conducted up and down. When working in layers, isolation measures should be in place between layers.

5)Workers should ascend or descend along designated passages or ladders, not by climbing ropes, protective frames, or guardrails.

6)If abnormal conditions occur at the work site, work should be stopped immediately, and appropriate emergency measures should be taken. In case of violations by workers, the violations should be promptly stopped, and in severe cases, the safety work permit should be revoked, and operations should be suspended.

4.3 Risk Prevention Measures for after Work Stage

The risk prevention measures for the site recovery after work are detailed as follow.

(1) When dismantling work platforms, temporary ladders, or protective sheds, a warning zone should be set up. Both upper and lower areas should not be worked on simultaneously, and a designated person should be assigned for supervision.

(2) Walkways, passage boards, and climbing equipment used during the work should be cleared in a timely manner.

(3) The removal of temporary electrical lines should be done by electricians with special operation certificates.

(4) The work acceptance personnel should verify the safety of workers, check tools and equipment, and ensure that safety protection facilities have been restored before signing off on the safety work permit.

5 Conclusion

To enhance on-site safety management for working at heights and minimize the likelihood of accidents, enterprise supervisors, safety monitors, workers must strictly adhere to the preventive measures outlined for before, during, and after the work phases in the maintenance and repair of port equipment and facilities. Comprehensive safety inspections should be conducted, and appropriate records of the operational process should be maintained.

The safety risk prevention measures proposed in this paper are intended for enterprises to reference and adapt based on their specific circumstances. This approach provides fundamental on-site safety support, ensuring the effective operation of the enterprise's safety management system. By integrating these measures with their safety management protocols for working at heights, enterprises can gradually develop a safety culture tailored to their unique characteristics.

References

1. Lu Yu, Zhichao Shao and Jin Xu (2024) Cause Analysis and Countermeasures of Falling Accident in Building Construction.Journal of Safety Science and Engineering, 2024(1): 25.
2. Jia Xiaoshan, Dong Yu, Zhang Yu&YuAnqi (2017) Analysis of falling accidents in construction based on FTA and AHP.Building Safety, (10): 37-40.
3. Liu Haozhen & Xu Lanjuan (2019) Study on prevention countermeasures of common accidents in construction site based on fault tree analysis. Sichuan Cement, (05): 272+348.
4. Filipa Pereira, María de las Nieves González García and João Poças Martins (2024) An Evaluation of the Technologies Used for the Real-Time Monitoring of the Risk of Falling from Height in Construction—Systematic Review.Buildings 2024,14(9): 1-3.
5. AQSIQ and SAC (2008) *Classification of work at heights GB/T 3608-2008*. SPC, Beijing. pp. 1.
6. Sang X M (2018)Countermeasures for On-site Safety Management in High-altitude Operations. Chemical Management,2018(01):108-109.
7. SAMR and SAC (2022) *Classification and code for the hazardous and harmful factors in process GB/T 13861-2022*. SPC, Beijing. pp. 1-11.
8. SAMR and SAC (2020) *Specification for the provision of personal protective equipment – part 1: General requirement GB 39800.1-2020*.SPC, Beijing. pp. 1-11.
9. MOHURD and SAC (2022) *General code for scaffold in construction GB 55023-2022.* SPC, Beijing. pp. 10-14.