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Safety Management at Tower Crane in Construction Site

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Abstract: Tower cranes are critical in high-rise construction but present significant safety risks due to their structural characteristics and operational complexity. This study analyzed 73 serious tower crane accident cases reported to the Korea Occupational Safety and Health Agency between July 2012 and July 2020. A mixed-methods approach was applied, combining quantitative accident data analysis with surveys and expert interviews. Statistical proportions were calculated to identify high-risk factors. Lifting operations accounted for the highest proportion of accidents (45.3%), with falls being the most common disaster type (35.8%). The leading cause of accidents was non-compliance with safe work procedures (38.8%). Survey and interview findings highlighted insufficient training, lack of standardized signal protocols, and limited on-site safety supervision. Strengthening training programs, standardizing signal operations, and enforcing systematic safety management can significantly reduce tower crane accidents. Policy recommendations and a framework for continuous monitoring are proposed.

Keywords: construction site; disaster case; safety accident; securing safety; tower crane

1 INTRODUCTION

Tower cranes are indispensable for modern high-rise construction, enabling the lifting and transportation of heavy materials where mobile cranes are impractical [1, 2]. However, their unstable superstructure and operational hazards contribute to a persistently high accident rate. According to the Korea Occupational Safety and Health Agency (KOSHA), an average of 6.55 fatalities occur annually in tower crane operations [3]. Although tower cranes offer high work efficiency and excellent operability on construction sites, they continue to be associated with frequent major accidents each year, becoming a persistent social issue. This is largely due to the inherent difficulty for safety personnel, such as safety managers and on-site supervisors, to easily access and systematically manage the entire lifecycle of tower crane operations—from installation to dismantling. Recent research highlights that current safety management practices remain fragmented across the pre-construction, construction, and post-construction phases. A comprehensive study emphasized the need for integrated safety technologies, including proactive planning tools, anti-collision systems, and stability control mechanisms, to address these persistent safety gaps and improve the overall management of tower crane operations [4, 5].

The scope of this paper is to identify the type of accident by analyzing serious accident cases related to tower cranes (2012-2020). In addition, it is intended to investigate the safety and work status of tower cranes through analysis by referring to external data that conducted surveys and interviews with tower crane drivers. As a result, we would like to suggest ways to improve safety management for tower crane work in domestic construction sites.

The research methods are as follows.

1) It identifies research trends on safety management of tower cranes through domestic prior papers and literature.
2) The type is identified by analyzing the current status of major disasters related to tower cranes from 2012 to 2020.
3) By analyzing through Excel by referring to external surveys and interview results, the work environment and problems of the site are identified.
4) Through the analysis of the current status of major disasters in tower cranes and the survey results of workers, measures to improve the parts necessary for systematic safety management of tower cranes are presented.

2 THEORETICAL BACKGROUND

2.1 Literature Review

The review of previous studies in this study is as follows. Jeon (2013) presented basic data for safe equipment operation by evaluating risks through investigations of accident cases that occurred at the site and presenting accident cases by grade to reduce accidents caused by construction equipment with a Study on Risk Assessment for Reduction of Safety Accidents in Construction Equipment [6].

Lim (2012) analyzed whether users related to power cranes used in the field acquired national qualifications and their influence through empirical analysis of tower crane disaster prevention factors, and suggested ways to improve national qualifications by analyzing the effect of tower crane qualifications on site disaster prevention [7].

Shim (2011) establishes a model for the safety diagnosis management system by analyzing the disaster factors of the tower crane with <a study on the domestic construction site tower crane safety diagnosis management system model> and confirms the effectiveness and efficiency generated through the system development. In addition, a case was presented to check the state of the tower crane through a remote system and to establish the field situation as a real-time monitoring diagnosis system [8].

Park (2012) is a Study on the Development of Algorithm Model for the Stability Review of Upward Tower Crane [9]. When installing a tower crane, an appropriate crane can be selected through data analysis of the crane, and through this data, the person in charge of installation can relieve anxiety about the crane and secure stability. And through this method, the expected effect of reducing construction costs and securing the crane installation person in charge directly reviewing the crane's equipment appropriateness was presented [10].

While prior studies have addressed mechanical safety and risk assessment domestically, there is limited research integrating operational, managerial, and training factors, particularly in the context of international safety standards. This study addresses this gap by analyzing accident cases and surveying industry stakeholders to identify key areas for safety improvement.

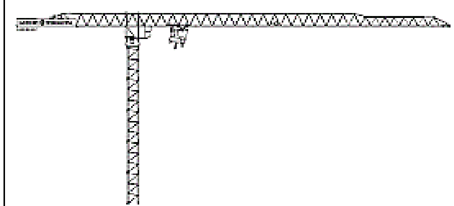
T-type Tower Crane	Luffing Crane	Topless Crane
		

Figure 1 "T-type" and "L-type tower crane", Topless crane

2.2 Overview of Tower Crane

A tower crane is a construction equipment belonging to a construction machine crane, and it is a crane with the characteristics of a three-dimensional exercise work that moves up and down, moves forward and backward along the trolley, moves forward and backward, and rotates the upper part to move the salvage to the desired location [11]. In general, a tower crane can adjust the height of the tower, providing the convenience of double work that is continuously required in places where it is difficult to construct structures and use mobile cranes that change the height of the workplace as the field work process progresses. Depending on the model, it is widely used for narrow space work and high-rise construction work in urban areas. Tower cranes are designed to be used appropriately according to the purpose of use and are generally classified according to their appearance. Tower cranes are largely divided into three categories: T-type, L-type (LUFFING JIG), and Topless cranes, as shown in Fig. 1. The "T-type" tower crane is the main form of the tower crane, and the jib is fixed and is mainly used when there are no obstacles within the working radius. In the event of interference with other buildings during construction, the "L-type" tower crane can move work like a mobile crane by moving the jib up and down with the selected equipment. A topless crane is a crane without a top and is used for lifting heavy objects or when there are problems such as altitude restrictions.

2.3 Safety Rules for Tower Crane Work

Safety rules form the foundation of safety management activities. True safety can only be achieved when both employers and workers fully comply with these rules. In the context of crane operations, safety protocols can be categorized into several core areas: general work rules, rules for operation in strong winds, tower crane electric shock prevention measures, driving safety protocols, and signal safety procedures [12]. Recent studies also emphasize the importance of incorporating dynamic environmental factors—especially wind forces—into crane safety management. Wind-induced pressure can significantly affect the crane's operational stability, control accuracy, and lifting torque. Therefore, real-time control adjustments are essential to prevent tipping and ensure safe load handling [13].

Based on these categories and engineering insights, the following safety rules are recommended for crane work:

1) Observe the matters specified in the safety rules, such as overload and limitation of inclination angles
2) Ensure transition and take necessary action in case of user replacement
3) To lift the crane, use the designated ladder
4) Check wire ropes, clutches, controllers, brakes, etc. every day before starting work
5) When driving the crane, illuminate the horn or horn to notify
6) Safety signs must be attached during repair inspection
7) In case of winding, work is carried out by keeping the cargo straight at the center of the hook
8) Care must be taken to ensure no workers are on board the cargo
9) Crane users must drive in accordance with the signal of the signal count
10) No rapid movement while driving
11) If it stops while driving, place the controller in the stop position and lower the main switch to check the stop
12) Prohibited inspection, feeding oil, etc. while driving
13) Do not leave the driver's room. If you leave, make sure to lower the switch to stop.

Integrating environmental considerations—such as wind gusts, load swing dynamics, and torque control—into these procedural rules enhances crane safety and performance. Such an approach is especially important for high-risk conditions often encountered in large construction or offshore environments [13].

2.3.1 General Working Rules

1) Crane users and signal numbers are checked for daily safety checks before work and recorded in the log for maintenance (reported to the management supervisor if abnormalities are confirmed)
2) Check the signal between the crane user and the signal number and operate the equipment when there is no abnormality
3) Crane users wear prescribed safety helmets, clothing, seat belts, and safety shoes
4) Management supervisor checks the health status of the crane user and reflects it in the work arrangement
5) Stretching before work, and strict eating and resting time to prevent accumulated accidents from occurring due to work fatigue.

2.3.2 Rules for Strong Winds

1) During work, crane users and signal numbers are frequently checked for weather changes, decelerate in the event of strong winds, and be careful not to push the work in the direction of the wind
2) Crane stops working at wind speed of 15m/sec or more
3) Operate according to the instructions of the person in charge of management during the emergency process
4) Refer to the weather information in advance and take measures in accordance with the safety manual in the event of a bad weather.

2.3.3 Tower Crane Electric Shock Prevention Rules

1) Distribution panel box for managing the electrical ground wire of the crane, main line installed on the fixture and avoiding connections to places where there is frequent movement
2) Double installation of the electrical ground wires of the tower crane, avoid installation in rusting areas and painting areas, and attach classification stickers
3) When installing or disassembling the electric ground wire of the tower crane, it must be requested to the person concerned with the electricity to carry out the work.

2.3.4 Safety Rules for Tower Crane Operation

1) Crane operation must be operated only by licensed authorized persons, and it is prohibited to operate arbitrarily without the signal of the number of signals
2) Stop operation and report to the administrator if there is an abnormality in the overload protection device or machine room during operation
3) Prohibition of rapid operation, such as rapid acceleration and sudden acceleration when driving
4) When driving and turning cranes, check for obstacles in the direction of movement of cranes and conduct driving and turning
5) Avoid unidentifiable levels of tinting in the driver's compartment, such as coffee pots, DMBs, radios, laptops, etc., which can interfere with operations.

2.4 Risk of Tower Crane Work

Tower crane work is used to move objects that need to be moved to other places. Such tower crane work is repeatedly performed by a user or a signal number who hooks directly, hangs heavy objects, raises them vertically, and puts them back down at the point after moving. The types of disasters that occur when moving heavy objects within a certain space are mainly falling objects and stenosis disasters. Tower cranes lift not only mold materials, rebar, and general materials, but also large mold members for external work that are affected by wind or outside air, and because they are not controlled during lifting, falling accidents and stenosis accidents can occur. If an unspoken external force, such as a hook on the tower crane or colliding with nearby obstacles, is applied instantaneously, it can lead to a fall and collapse accident of the entire tower crane. Tower crane disasters are more often known as large accidents and personnel accidents in the event of an occurrence than general disasters, and are often known to the media, which causes social issues and criticism [14].

In order to prevent serious accidents in tower cranes, a clear plan, inspection, and training must be preceded before work, but there are many accidents because the conditions at the current domestic site do not meet this. Unlike general industrial sites, due to the nature of construction sites, it is difficult to manage personnel because a large number of various personnel of the type of construction are used in a short period of time and workers are replaced frequently [15]. In the case of dismantling the tower crane installation, it is necessary to install it as soon as possible because it receives a limited amount of money, but it tends to be rushed because it is more profitable. In addition, because employment is unstable, frequent personnel changes and unskilled workers are sometimes put in. Drivers and signal drivers who use tower cranes after installation also have a social problem that their employment is not constant [16].

3 CASE OF TOWER CRANE DISASTER

To analyze tower crane accidents, the study was conducted in the following four stages.

1) Data Sources: Accident data were obtained from the Korea Occupational Safety and Health Agency's official casebook of serious accidents (2012–2020), comprising 73 major tower crane incidents.
2) Survey Design: A structured questionnaire was distributed to installation/dismantling workers, crane operators (signalers), and safety managers. The questionnaire covered accident causes, safety training adequacy, and operational procedures. Responses were measured on a 5-point Likert scale.
3) Expert Interviews: Semi-structured interviews with three industry experts were conducted to validate survey findings and explore improvement measures.
4) Analysis: Proportions were calculated for each accident

cause category. No probabilistic inference was performed; instead, descriptive statistics were used. Survey and interview data were analyzed separately to distinguish quantitative and qualitative findings.

3.1 Method of Analysis of Tower Crane Disaster Data Sources

In order to analyze the case of tower crane accidents, the case of major accidents related to tower cranes among industrial accidents of the Korea Safety and Health Agency was investigated.

In the past 9 years, 73 serious accidents occurred, and they were analyzed by accident cause. When analyzing disaster cases by cause, the classification criteria were prepared according to the criteria of the Korea Safety and Health Agency.

Accident data were obtained from the Korea Occupational Safety and Health Agency’s official casebook of serious accidents (2012–2020), comprising 73 major tower crane incidents.

3.2 Results of Analysis of Tower Crane Disaster Case

3.2.1 Analysis by Job Type

Tab. 1 is the result of analyzing accident cases by work type. During the work, 35 accidents (47.9%) occurred in 'nurturing work', and when it comes to the cause of accidents that appeared during the lifting operation, it was found that there were more accidents that caused the number of signals with the task manager than the driver's carelessness, and it is thought that thorough management of the task manager is necessary to prevent such accidents. In addition, in the installation, elevation, and dismantling work, 35 accidents occurred despite repeated work by professional workers, which is thought to be the cause of safety insensitivity due to repetitive work progress, so work-related education is considered necessary.

Table 1 Analysis of disaster cases by job type

	Installation & Dismantling	Maintenance	Upward	Reclamation	Etc.	Sum
The number of disasters	17	2	18	35	1	73
Ratio	23.2%	2.7%	24.6%	47.9%	1.6%	100%

1) **Accident case analysis:** Lifting operations were responsible for 45.3% of accidents, followed by installation/dismantling (23.2%) and climbing operations (24.6%). Falls were the most frequent disaster type (35.8%). The leading contributing factor was non-compliance with safe work procedures (38.8%).
2) **Cause of accident during installation and dismantling operation:** The main causes of accidents in installation and dismantling work were 10 cases of non-compliance with safety rules (58.8%), 5 cases of non-compliance with work processes (29.4%), and 2 cases of inexperience (11.8%).
3) **Cause of accident during salvage operation:** The cause of the salvage operation was 14 cases (40%), 10 cases of unidentified line hooks (28.5%), 5 cases of non-compliance with the signal (14.2%), 4 cases of unidentified lifting (11.4%) and 2 cases of equipment (5.9%), and the control around the tower crane is exclusively managed by the signal number.
4) **Cause of accident during ascending operation:** The causes of accidents in ascending work were 12 cases (67%) of non-compliance with the work process and 6 cases (33%) of non-compliance with safety rules, and it is thought that the thorough management of the work manager is necessary to prevent accidents.

3.2.2 An Analysis of the Cause of Work Accident

As a result of analyzing the cause of the tower crane accident as the cause of the physical accident and the cause of the human accident, 10 physical factors (13.6%) and 63 (86.4%) human factors such as unsafe behavior of workers and non-compliance with the work order among the functions of the tower crane.

3.2.3 Analysis by the Type of Disaster

As a result of the analysis by type of tower crane disaster, 27 falls (36.9%), 23 falls and rain (31.5%), 11 falls and falls (15%), 9 stenosis (12.3%), and 3 falls (4.3%) were found. The risk of falls was high during installation, assembly, and dismantling, and the risk of falls and rain was high during the salvage operation. This is judged to reflect the characteristics of the work and should be focused on preventing accidents from falling by establishing countermeasures.

3.3 Tower Crane Disaster Risk Assessment

Risk factors were derived through analysis by work type through accident cases, and 73 cases of major tower crane accidents provided by the Korea Safety and Health Agency for risk calculation occurred between 2012 and 2020. Since the proportion of occurrence per one out of 73 major accidents was 1.4%, it was assumed as the lower limit that it hardly occurred, and the largest number of accidents was assumed to be 19.2%, with 14 cases occurring due to poor control during the salvage operation. Risk assessment was conducted based on the frequency of occurrence by simply dividing 1.4% to 19.2%.

The rating calculation for the proportion of occurrence of a risk, and the proportion of occurrence is shown by dividing the total number of accidents of tower cranes by the number of accidents by risk factor for each type of work in the tower crane work where the disaster occurred. As a result, it was shown in Tab. 2.

As a result of calculating the risk level through the analysis of the probability of occurrence of a serious accident by risk factor, the most dangerous risk factor among the entire tower crane work was investigated as 'bad peripheral control', followed by 'non-compliance with the work process' and 'bad line-up'. Therefore, it is judged that the role of the signal numbers that control the surroundings is important.

Table 2 Proportion and risk calculation of major disasters

	Cause	Number of serious accidents	Proportion (%)	Ranking	Grade
Lifting	Poor control	14	19.2	1	1
	Unidentified line hook	10	13.7	3	2
	Failure to comply with the signal	5	6.8	6	3
	Unidentified salvage material	4	5.5	8	3
	Defects in equipment	2	2.7	9	4
Installation & Dismantling	Non-compliance with safety rules	10	13.7	3	2
	Non-compliance with the work process	5	6.8	6	3
	inexperience in the work	2	2.8	9	4
Upward	Non-compliance with safety rules	6	8.2	5	3
	Non-compliance with the work process	12	16.4	2	1
Maintenance		2	2.8	9	3
Etc.		1	1.4	12	4
	Sum	73	100%		

4 SURVEY
4.1 Survey Overview
4.1.1 Survey Method

The survey was conducted from September 2020 to October 2020, centered on the sites of large domestic construction companies, and the responses of the questionnaire were a total of 250 people, of which a total of 193 copies were conducted, excluding unfaithful and unclear respondents. The survey results conducted by external literature were used and analyzed through Excel. In addition, expert interviews are conducted to derive opinions on safety management improvement measures and additional alternatives, and to determine whether the improvement measures are appropriate.

4.1.2 Survey Contents

This questionnaire was composed by reflecting the analysis results of serious accident cases in Chapter 3. It was largely classified into general (common) and tower crane work. Tower crane work items were prepared according to the work characteristics of the installation/demolition person, user, and safety manager, and each item was constructed based on items that affect safety work, such as the cause of accidents, education system, work command relationship, and contract business format related to tower crane work. Using a 5-point scale, the questionnaire was marked with 5 points for "very yes", 4 points for "yes", 3 points for "normal", 2 points for "not very much", and 1 point for "not very much". Each detail is shown in Tab. 3.

Table 3 Details of the installation/demolition worker/user/safety manager

Area	Item	Details
General	Common	Age
		Carrier
Tower crane work	Installation and Demolition worker	Investigation of the necessity of education (Safety and Health Agency)
		The Impact of the Wage System on Safety
		Examination of the importance of work conditions in the field
		Investigation of Safety Violators
		Survey on the Quality of Field Training
	User	Investigation of the necessity of education (Safety and Health Agency)
		Survey of the importance of education
		Investigation into the need for education
		Necessity of Qualification Specialization
		Examination of the safety knowledge level of work
		Investigation of Safety Violators
		Investigation into the need for specialized knowledge
	Safety manager	Investigation into the need for specialized knowledge
		Survey of the level of expertise
		High-risk process investigation
		Investigating the necessity of improving signal receiver quality
		Investigation of key items of disaster prevention activities
		Effectiveness of the Construction safety plan

4.2 Survey Results
4.2.1 Age

According to the survey respondents' age distribution, many safety managers (62%) were aged 31 to 40 at the site, many were aged 41 to 50 (50%) who played a control role when using tower cranes, and many elderly people were older than 50 (44.4%) who were engaged in practical risk processes such as complaint work.

Table 4 Ages in workers

Age	Installation / dismantling worker		Crane operators (Signalers)		Safety managers	
Under 25	0	0.0%	1	1.2%	1	1.4%
26~30	0	0.0%	1	1.2%	2	2.8%
31~40	5	13.9%	17	20.2%	44	62.0%
41~50	15	41.7%	42	50.0%	16	22.5%
Over 50	16	44.4%	23	27.4%	8	11.3%
Sum	36.0	100.0%	84.0	100.0%	71.0	100.0%

4.2.2 Career

Safety managers were able to receive realistic responses as 60% of them had more than 6 years of experience, and workers were evenly distributed by experience. On the other hand, installation and dismantling workers were found to be in the dangerous process, with few new workers and a large number of skilled workers for more than 6 years.

Table 5 Career in workers

Career	Installation / dismantling worker		Crane operators (Signalers)		Safety managers	
Under1yr	0	0.0%	14	16.7%	9	12.5%
1~3	3	8.3%	16	19.0%	14	19.4%
4~5	1	2.8%	15	17.9%	6	8.4%
6~10	15	41.7%	16	19.0%	19	26.4%
Over11yr	17	47.2%	23	27.4%	24	33.3%
Sum	36.0	100.0%	84.0	100.0%	71.0	100.0%

4.2.3 The Primary Cause of Tower Crane Accidents

A survey on the primary cause of tower crane accidents revealed that safety managers, crane operators (signalers), and installation/dismantling workers all cited "errors in work methods and behavior during work."

Regarding the response to the question, "What is the primary cause of tower crane accidents?", a chi-square test was performed across safety managers, installers and dismantlers, and crane operators (signalers), revealing a significant difference (p = 0.047). Overall, errors in work methods and behavior during work were identified as the most common cause of accidents. Installers, dismantlers, and safety managers identified defects in the equipment defects as the second most common cause, while crane operators (signalers) identified defects in the lifting material defects as the second most common cause.

Table 6 Analysis of variance by respondent on the main causes of tower crane accidents

Cause	Installation / dismantling worker		Crane operators (Signalers)		Safety managers		χ^2	p-value
	Number	%	Number	%	Number	%		
Equipment defects	7	21.21	3	3.80	10	14.49	12.78	0.047
Errors in work methods and behavior during work	22	66.67	60	75.95	47	68.12		
Lifting material defects	0	0.00	10	12.66	7	10.14		
Surrounding environment, including climate	4	12.12	6	7.59	5	7.25		

4.3 Expert Interview Review

4.3.1 Review Overview

Expert interviews were conducted through e-mail from October 11 to October 13, 2023. The interviewees were a safety manager and a total of two construction site unloading workers. The questionnaire data was conducted using official form, and through the analysis of the survey results, opinions on the improvement plan and additional alternatives were derived, and the appropriateness of the improvement plan was determined.

4.3.2 Expert Interview Results

Experts emphasized the ineffectiveness of purely theoretical safety training, advocating for participatory, hands-on education. They also highlighted the lack of standardized signal protocols and insufficient staffing as recurring safety risks.

4.4 Discussion

As a result of combining the survey and interviews, the survey was conducted on installation and dismantling workers, use (signal number) workers, and safety managers. As a result of the survey, 68% of safety managers thought it was "unsafe work" and 45% of use (signal) workers thought it was "safe," and 30% of installation and dismantling workers were divided into "unsafe" and "safe," respectively. In addition, in the case of users, the more experience they had, the higher the safety. The main cause of the tower crane accident was "error of work method and behavior during work" in all three groups.

Whether workers who have been installed and dismantled have experienced violations of safety rules, "Work rules" 54.3% of them said they had experience of violation, more than half of them. Currently, new workers who are installed and dismissed are entitled to work after completing one training session in accordance with the "Rules on the Restriction of Employment in Hazardous and Dangerous Works" and there is no follow-up management. Therefore, in order to prevent accidents, it is considered that regular maintenance training is conducted in addition to new training to minimize safety symptoms, and regular management and training such as the characteristics of equipment by manufacturing company and job descriptions of new equipment is necessary.

This study confirms that human factors, particularly procedural non-compliance and inadequate training, are the dominant causes of tower crane accidents. These findings align with international research, which also identifies training quality, communication protocols, and supervision as critical safety determinants. Integrating hands-on, scenario-based training and enforcing standardized signal operations could bridge current safety gaps. Furthermore, aligning domestic safety regulations with international best practices could enhance both compliance and accident prevention.

5 CONCLUSION

The Tower crane is a dynamometer crane mainly used in high-rise building construction and is a high-risk work. Therefore, this paper attempted to identify problems with tower crane work through an analysis of major accident cases related to tower cranes over the past 13 years and a survey of tower crane-related workers, and to suggest improvement measures accordingly.

The analysis of tower crane accidents in Korea highlights the urgent need for structured safety interventions. Key recommendations include: (1) institutionalizing participatory safety training; (2) mandating certification for signalers through public institutions; (3) enhancing safety managers' expertise through specialized curricula; and (4) enforcing continuous monitoring and supervision.

Limitations include the reliance on domestic accident data and self-reported survey responses. Future research should incorporate international comparative analyses and longitudinal tracking of safety interventions.

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