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Research on the Application of Emergency Management of Construction Engineering Enterprises in Flood Season Based on Dual-Control System

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Abstract: The building construction industry, recognized as one of the eight high-risk sectors, also serves as a crucial pillar of the national economy and a key source of employment. Major project advancements typically concentrate between April to June and September to November each year. However, construction progress tends to slow down during July and August due to increased rainfall associated with the flood season. The impact of the flood season on construction projects is primarily reflected in areas such as civil works, machinery and equipment, and temporary power supply. By establishing a dual-control emergency management system for the flood season, construction enterprises can enhance their emergency response capabilities, effectively reduce management challenges, and improve the overall efficiency of emergency handling.

Keywords: Flood season; Emergency management; Dual-control system

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1. Introduction

As one of the eight high-risk industries, the building construction industry is also a crucial part of supporting the national economy and employment. In recent years, China has increased its efforts to manage safety in the construction industry, but the situation of construction safety is still severe, and the safety management of building construction is still facing great challenges [1]. In addition, the construction industry is prone to extreme weather such as high winds, snowstorms, and floods during the full construction cycle due to its long construction period, which poses new challenges and dilemmas to the traditional safety management model. Usually, safety management focuses on after-the-fact treatment, lacks systematicity and foresight, and is difficult to effectively prevent and control safety risks under extreme conditions.

In China, the annual progress of the project is concentrated in April-June and September-November, and the construction progress is slower in July and August due to more precipitation in the flood season. Risk has always accompanied construction progress. During periods of increased rainfall, the working environment changes significantly where the surfaces become unstable, and hot, humid conditions can affect workers' awareness and mental state. Therefore, greater attention must be given to safety and emergency management during the flood season to ensure project stability and worker well-being.[2].

Table 1 presents the number of building construction accidents from 2014 to 2023. The data indicates that both the number of accidents and fatalities increased annually from 2014 to 2017, a period marked by policy relaxation. During this time, China explicitly called for deepening the reform of the construction industry's "management and service," improving the regulatory system and mechanisms, and strengthening accountability for quality and safety. These policy initiatives laid a foundation for the industry's standardized development. The standardized development of the industry provides a policy guarantee. As a result, the accident rate gradually declined following the implementation of stricter regulations. However, a surge in accidents occurred in 2020 due to a nationwide rush to resume construction activities. The downward trend resumed from 2021 to 2023. Overall, the accident rate in the construction sector remains high, and the consequences of such incidents are often severe [3].

Table 1. Building construction accident statistics from 2014 to 2023

Year	Number of construction accidents in China	Death toll	Year-on-year change rate (number of cases)	Year-on-year rate of change (deaths)	Accident rate
2014	1185	2123	——	——	0.18
2015	1232	2344	4.00%	10.40%	0.2
2016	1336	2749	8.50%	17.30%	0.22
2017	1419	2810	5.50%	2.20%	0.23
2018	1382	2394	-18.80%	-15.50%	0.2
2019	1372	2443	-7.90%	1.90%	0.21
2020	4183	5413	198.40%	121.60%	0.31
2021	4397	5135	5.10%	-5.10%	0.3
2022	4180	4736	-5.00%	-7.80%	0.28
2023	3900	4300	-6.70%	-9.20%	0.26

Table 2 presents the main types of accidents in the construction engineering field. Based on the distribution of accident types, falls from height, being struck by objects, mechanical injuries, and electrocution are the four most frequent types of accidents in the construction industry [4]. Based on the climatic conditions during the flood season, most types of construction machinery are largely out of service, and work at heights is generally suspended. Therefore, the types of accidents most likely to result in casualties during this period are primarily object strikes, electrocution, structural collapses, and incidents involving poisoning or asphyxiation.

Table 2. Distribution of main types of accidents

Type of accident	Rate	Key reasons
Drop to height	30%	Insufficient edge protection, safety belts not standardized use
Object strikes	25%	Falling objects from heights, inadequate safety precautions
Mechanical damage	20%	Improper operation of machines, inadequate education, and training
Electrocution	15%	Temporary power violations, leakage protection failures
Fire	5%	Improper stacking of flammable materials, electrical short circuits
Collapse	3%	Unstandardized pit support, improper earth stockpiling
Poisoning, asphyxiation	2%	Poor ventilation, toxic gas leakage in confined space operations

In 2021, the Work Safety Law was amended to strengthen the main responsibility of enterprises, and the National Safety Committee explicitly proposed the construction of a dual prevention mechanism [5]. All production and operation units are required to strictly comply with work safety laws and regulations, and must establish a comprehensive system of safety risk classification, control, and hidden danger investigation and management. This means that enterprises must not only identify potential safety risks but also categorize and manage these risks and conduct regular hidden danger inspections to ensure that all hidden safety risks are dealt with in a timely manner.

2. The current situation of emergency management in construction enterprises

China has clarified the requirements of the main responsibility of the relevant construction enterprises in recent years by continuing to improve. For example, the laws and regulations on construction safety management, such as the Regulations on the Safe Production Management of Construction Works, have been supervised on this basis. To enable a rapid response in the event of an accident, enhance the speed and coordination of emergency rescue efforts, effectively prevent and control secondary disasters, minimize injuries, protect employee safety, maintain orderly production, and reduce property losses. An emergency management system is developed in accordance with relevant laws, regulations, and corporate policies. At present, it seems that the emergency management of China's construction enterprises mainly covers the formulation of plans, exercises and training, emergency equipment, online monitoring, and coordinated scheduling in several aspects [6].

Plan development serves as the foundation of emergency management. In the construction engineering field, a wide range of emergency plans are required, covering incidents such as daily fires, electrocution, and fall-related injuries, as well as emergency responses tailored to special periods. Due to the complexity and diversity of personnel within construction units, these emergency plans are further subdivided into specific implementation programs to ensure clear responsibilities and effective execution. This is especially important during the flood season, when the emergency plan includes a designated flood control team and outlines a specific response process and disposal procedures for emergency events. **Table 3** presents some of the foundational elements used in the development of these emergency plans. However, analysis of inspection data reveals that many current emergency plans in construction projects suffer from excessive duplication and lack adaptation to actual conditions, resulting in insufficient practical effectiveness during real implementation.

Table 3. Basis for the preparation of the emergency plan

Number	Laws, regulations, and institutional norms
1	Work Safety Law of the People's Republic of China
2	Law of the People's Republic of China on Emergency Response
3	Measures for the Management of Emergency Response Plans for Production Safety Accidents
4	Enterprise Production Safety Management System
5	General Provisions of the Emergency Response Plan for Production Safety Accidents in Enterprises

Plan rehearsals are a critical component of effective emergency management. Experience from past accidents shows that early-stage damages are often limited. If personnel consistently follow the content and procedures practiced during regular disaster prevention drills, the severity of accident-related destruction can be significantly reduced. Typically, drills are conducted for the entire project, involving the participation of all staff members. This approach helps to improve the construction personnel's familiarity with emergency response procedures, enhancing overall preparedness. When work is halted or construction cannot proceed due to adverse weather conditions, it presents an ideal opportunity for personnel training and education. However, many building construction enterprises fall short in this area due to insufficient emergency management awareness and weak risk control consciousness. As a result, some construction workers and even management staff lack clear emergency response procedures, making it difficult for them to respond calmly and effectively during accidents.

Emergency equipment is an important tool for carrying out emergency management and a necessary means to ensure that the emergency plan can be carried out smoothly. Common emergency rescue materials on construction sites mainly include first aid kits, fire extinguishers, safety ropes, protective equipment, search and rescue tools, etc. **Figure 1** shows some of the emergency equipment. Although some units have equipped their sites with an adequate amount of emergency rescue equipment, maintenance and regular servicing are often neglected. This oversight can lead to emergencies, as the effectiveness and safety of the equipment cannot be guaranteed, posing a risk of malfunction or failure. At the same time, daily management should enforce strict control over emergency equipment by establishing a rigorous system for warehouse entry and exit. Corresponding records must be maintained for each piece of emergency equipment, documenting its receipt, deployment, scrapping, and consumption to ensure full accountability and compliance with emergency preparedness requirements.

Figure 1. Emergency equipment

The online monitoring program is an important means of managing the whole process of emergency management, which can not only make real-time forecasts before the occurrence of disasters or accidents, but also monitor the dynamics of accidents after the occurrence of accidents, to ensure that no secondary disasters occur as well as the safety of rescuers' lives. Online monitoring system in a broad sense consists of two parts, one is the perception layer composed of sensors and transmission equipment, and the other part is the application layer composed of the operation center. At this stage, construction companies primarily rely on online monitoring equipment such as cameras, temperature sensors, wind speed sensors, and dust particulate monitors to track behaviors and meet environmental protection requirements. However, these systems mainly serve to assign responsibility after violations occur, making it difficult to implement effective preventative measures beforehand.

Coordination and scheduling are central to emergency management, requiring the establishment of a command department responsible for emergency response. This department communicates with various departments and functional groups to make timely and effective decisions. Generally, the emergency command consists of an office and a rescue team. The rescue team is further divided into the rescue group, repair group, alert group, and comprehensive protection group. The detailed organizational structure is illustrated in **Figure 2**.

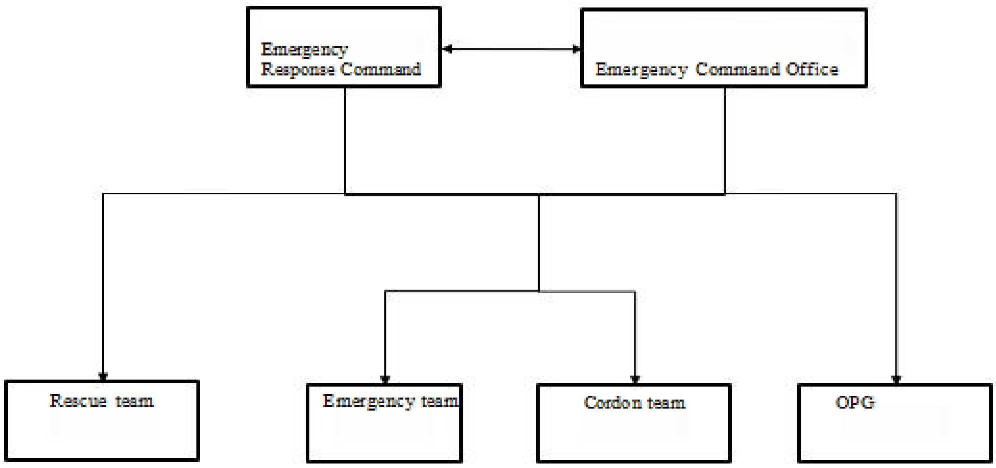

Figure 2. Organizational framework for integrated movement control

The primary functions of coordination and dispatching in emergency management include receiving instructions and mobilization orders from the government, group companies, and higher-level units; organizing and formulating the accident emergency rescue plan; defining and implementing the responsibilities of personnel at all levels during emergency situations; collecting and analyzing issues reported by each rescue team to inform decision-making based on the current situation.

Additionally, coordination and dispatching oversee real-time updates to the command center during critical rescue operations; facilitate collaboration with external rescue forces and manage personnel evacuation; allocate personnel and resources within the operation area; mobilize emergency response teams; designate on-site commanders; coordinate all activities related to the accident site; approve the activation and termination of emergency plans; ensure protection of relevant data following an incident; report accident information; and organize emergency response drills. The efficiency and comprehensiveness of coordination and dispatching directly determine the overall effectiveness of emergency management.

3. Flood season characteristics and main impacts

In China, the annual flood season typically occurs from June to September and is often characterized by heavy and sustained rainfall. The sharp increase in precipitation during this period leads to elevated surface water levels and rising river stages, significantly impacting infrastructure and public safety. For instance, during the

2025 “Dragon Boat Water” period, Shenzhen experienced precipitation that accounted for nearly 20% of its annual total, with some areas recording unprecedented levels reaching 996.4 millimeters. At the same time, the flood season is often accompanied by secondary natural disasters such as flash floods, mudslides, and severe convective weather. While these hazards may have limited direct impact within urban centers, the overall increase in rainfall and prolonged hot, humid conditions can significantly affect workers’ physical and mental well-being. This is particularly true in the southern coastal provinces, where typhoons are more frequent during this period. These environmental stressors not only pose safety risks but also reduce operational efficiency and increase the likelihood of accidents. The following is a brief analysis of how the flood season impacts the construction engineering industry.

3.1. Civil construction

The impact of flood season on civil construction operations mainly exists in the following aspects [7]:

(1) Construction progress is affected

Increased rainfall during the flood season leads to water accumulation and muddy conditions at construction sites, resulting in construction site vehicles, personnel, and other mobility difficulties, equipment and materials transportation difficulties. At the same time, for some dangerous projects, such as deep foundation pit, high supporting mold, and other construction operations, need to be completely suspended during the flood season, the rainfall changes the ground soil conditions, increasing the probability of accidents such as collapses and landslides.

(2) Construction quality is affected

During the flood season, even if the corresponding construction materials are sealed and preserved, the high water retention in the air is not conducive to the preservation and utilization of certain materials, such as cement and wood. At the same time, the flood season construction site environment is complex, and the construction process standard is difficult to meet the standard, greatly affecting the quality of the project.

(3) Increase in project cost

During the flood season, construction sites must implement various flood prevention and control measures, such as reinforcing flood barriers with sandbags, ensuring communication equipment is in place, and preparing for the relocation and resettlement of personnel. These preparations are reflected in increased project costs. Additionally, the prices of raw materials often rise during this period, further driving up overall construction expenses.

3.2. Mechanical equipment

The impact of flood season on mechanical equipment is mainly reflected in the two factors of high winds during strong convective weather and water accumulation after precipitation storms. Whenever there is a typhoon, the mechanical equipment and the boarding house at the construction site should be additionally reinforced, which is done to effectively resist the wind load brought by the gusty weather. At the same time, equipment such as tower cranes, mobile cranes, and reinforcement materials are vulnerable to tipping or causing injuries during strong winds. For example, during a typhoon in Shanghai, two tower cranes collapsed at a construction site. Investigations revealed that wind speeds reached 26.5 m/s at the time, 1.72 times the equipment’s design load. The excessive pressure not only caused the collapse but also destroyed the cranes’ safety components [8]. Therefore, during the flood season, especially in windy conditions, all mechanical equipment should be stopped, and appropriate protective measures must be taken. These include securing protective covers, fastening steel cables, lowering suspended platforms to the ground, and evacuating personnel from temporary structures such as site dormitories.

3.3. Temporary electricity

Temporary electricity is one of the most frequent safety hazards on construction sites due to its wide distribution and complexity. During the flood season, electrical equipment must be elevated above ground level, as sudden rainfall can cause water to enter power equipment, leading to short circuits or equipment failure. Additionally, water's conductivity increases the risk of electrocution, making proper protection and elevation of electrical systems essential for safetyAdditionally, common switch boxes and distribution boxes on construction sites are often of low quality and lack permanent reinforcement. This makes them prone to falling over in strong winds, which can accidentally turn switches on or off. More seriously, falling boxes can pull or damage cables, exposing worn rubber insulation. In humid environments, high voltage combined with damaged insulation increases the risk of non-contact electric shocks, leading to injuries and property damage [9]. Therefore, it is essential to strictly control the operating voltage of power and lighting systems, ensuring a safe voltage level of 24V in humid environments.

4. Dual-control system of flood emergency management points

In order to improve the flood emergency management capacity, in the construction project to carry out the establishment of dual-control system can effectively reduce the difficulty of management to improve the efficiency of emergency response. The following analysis will focus on key aspects of construction engineering emergency management based on the dual-control system.

4.1. Hazardous source identification and risky operation type

Based on on-site inspections and research, the primary hazardous sources that may cause harm to personnel on site are mainly classified as first-level hazards, with objects being the most common contributing factors. The sources of danger and types of risky operations on site are listed in **Table 4**.

Table 4. Flood season construction site hazard sources

Number	Risk points	Risk factors or potential events	Inherent risk rating
1	Trench collapse	Accumulated rainfall ≥ 50mm, and the slope of the pit top interceptor drainage < 1% The rate of rise of groundwater level > 15cm/h, resulting in a 30% decrease in soil shear strength.	IV
2	Landslide	Expansion rate of surface cracks > 2cm/h Cumulative displacement of deep displacement monitoring point ≥ 20mm	III
3	Collapse of boarding house	Depth of water on the foundation floor > 30cm, soaking time ≥ 6h The proportion of concrete compressive strength of steel column foundation < C20 > 10%	III
4	Tower crane overthrow	Depth of water in foundation > 50cm Deviation of verticality of pre-embedded foot bolt > 3‰.	IV
5	Temporary Electricity System leakage	Distribution box height from the ground < 80cm (when the depth of water ≥30cm) Cable immersion time > 2h resulting in insulation resistance < 0.5MΩ	III
6	Material yard landslide	Height of stacking of bagged cement > 10 layers (moisture-proof liner is missing) Slope of stacking of square logs > 1:1.5 and no earth blocking facilities	II

4.2. Hierarchical risk control

The higher the risk level, the higher the level of control required [10]. Based on the actual situation of the construction enterprise, company-level leaders are responsible for the entire process control of "significant risks", department-level leaders are responsible for the entire process control of "general risks", and team-level leaders are responsible for the entire process control of "low risks". The entire process should be controlled step by step, with specific measures implemented. There are various measures for risk control, including engineering and technical measures, such as elimination or reduction, substitution, closure, isolation, removal, or redirection etc. In terms of management measures, a range of safety management systems and operating procedures can be established. These include developing a comprehensive and effective emergency rescue plan, implementing self-inspection and internal reporting reward mechanisms for identifying hidden hazards, enforcing strict safety permit requirements for operating procedures, adjusting working hours to reduce exposure based on seasonal factors, and setting up warning signals, among others.

Education and training should begin by introducing employees to the basic risks and their classifications, helping them to correctly understand potential hazards. This foundation is followed by professional safety training aimed at improving employees' emergency response abilities. Practical exercises should be incorporated to teach methods of self-help and mutual aid, and to train employees to remain calm and effective under stress.

Additionally, employees must be made aware of the specific safety risks associated with their positions and the corresponding prevention and control methods. Strengthening individual protection is crucial—each worker should be provided with protective clothing, ear muffs, safety glasses, insulated gloves and shoes, and convenient respirators. Staff should be trained on the correct use of this equipment both before and during work. Safety management personnel must regularly inspect the effectiveness of personal protective equipment (PPE) and emphasize to employees that PPE is the last line of defense, not a cure-all.

When risks become uncontrollable, emergency response measures should be activated, which include collecting and reporting key site information, implementing emergency plans, coordinating response actions and material supply, and enhancing pre-training to improve the preparedness of all relevant personnel.

4.3. Hidden danger investigation and management

First, focus on high-risk areas by establishing a ledger for key parts. Then, develop an inspection plan to conduct regular hidden danger inspections, documenting findings in inspection records and hidden danger rectification notification forms. Hidden dangers should be classified and graded, with regular public announcements made, and major hazards reported promptly.

Construction sites can use the following methods for hidden danger investigations: (1) Daily inspection; (2) Special inspection; (3) Seasonal inspection; (4) Holiday inspection; (5) Technical monitoring; (6) Employee self-inspection; (7) Expert diagnosis; (8) Double-blind rehearsal inspection; (9) Cross-checking each other; (10) Accident review inspection.

Based on the identified hidden dangers, develop a targeted rectification plan that clearly defines the corrective measures, responsible personnel, and a timeline for completion. Ensure that the rectification process is properly managed and its effectiveness verified. Once the rectification is completed, conduct a timely acceptance inspection and evaluation to confirm that the hazards have been eliminated. The enterprise should document this typical hazard handling process as part of an effective governance experience. Additionally, all hidden dangers should be recorded and maintained in a ledger for regular analysis. Relevant reports and materials should be prepared to support future risk prediction and prevention efforts.

5. Conclusion

The building construction industry faces numerous risks, and the flood season's climate and hydrological conditions add further challenges to construction site safety. Safety management personnel in construction enterprises must clearly understand the characteristics of each project and combine this knowledge with flood season features to carry out thorough risk identification and control measures. By effectively applying a comprehensive dual-control system, all potential risk points can be managed, and hidden dangers eliminated to minimize the likelihood of accidents. Continuous improvement in hazard investigation and management is essential to ultimately achieve fundamental safety.

Disclosure statement

The authors declare no conflict of interest.

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