Analysis of Safety Risk Management in Construction Engineering Projects

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Abstract: With the acceleration of China's urbanization process, the scale of construction engineering continues to expand. Characteristics such as complex construction environments and numerous work procedures have led to a surge in safety risks and hidden dangers. Frequent construction safety accidents not only threaten the lives of construction personnel but also cause huge economic losses and negative social impacts. This article analyzes the importance of safety risk management in construction engineering projects and proposes specific safety risk management strategies. It aims to provide reliable guidance for construction engineering, ensuring safety during the construction process and the smooth progress of the project.

1. Introduction

As a pillar industry of the national economy, the construction industry has always played a key role in promoting social development and improving infrastructure construction. In recent years, China's construction projects have clearly shown a development trend of being "taller, larger, more difficult, and newer." The number of projects such as super high-rise buildings, large bridges and tunnels, and complex venues continues to increase. This also leads to a significant increase in high-risk links involved in the construction process, such as work at height, deep foundation pit excavation, and lifting operations. The complexity and uncertainty of safety risks subsequently rise. Against this background, in-depth analysis of the importance of safety risk management in construction engineering and exploration of scientific and effective management strategies are of great practical significance.

2. The Importance of Safety Risk Management in Construction Engineering Projects

2.1 Ensuring the Safety of Construction Personnel

Construction personnel are the core force of construction engineering projects. Their life safety is not only the primary prerequisite for carrying out engineering construction activities but also directly reflects social fairness, justice, and humanistic care in the construction field. The construction environment itself is obviously complex and dangerous. For example, during work at height, if the scaffolding is not set up according to specifications or personal protective equipment (PPE) is incomplete, it can easily lead to fall risks. During deep foundation pit construction, if slope support measures are inadequate, collapse hazards may occur, threatening the personal safety of construction personnel. These potential risks constantly threaten the life and health of workers. Safety risk management, relying on systematic workflows, can comprehensively investigate dangerous links throughout the construction process in advance, accurately identify various safety hazards, and formulate corresponding protective measures for different risk types[1]. Measures such as providing PPE that meets safety standards for workers at height, setting up protective facilities in dangerous areas, and conducting dynamic monitoring of key construction links can effectively reduce the probability of safety accidents and build a strong protective barrier for the lives of construction personnel.

2.2 Ensuring Smooth Project Progress

Construction engineering projects are inherently characterized by long cycles and numerous complex links. Once a safety accident forces a work stoppage, it inevitably leads to serious schedule

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delays and cost overruns. From the perspective of schedule progress, after a safety accident occurs, the company must cooperate with relevant departments to investigate the cause and determine liability. The downtime varies according to the severity of the accident, potentially affecting local construction progress in the short term or causing the entire project to stall in the long term, ultimately disrupting the original construction plan[2]. From a cost control perspective, even during a work stoppage, the company still bears fixed costs such as equipment rentals and personnel salaries, and may also face claims from the owner due to delays. Furthermore, rescue efforts, medical treatment for the injured, compensation for property losses, fines imposed on the company, and subsequent rectification costs all add to the total project cost, creating an unnecessary economic burden. A sound safety risk management system can identify safety hazards in construction in advance and ensure monitoring and control throughout the construction process, preventing safety accidents from the source. This ensures the project proceeds orderly according to the established plan and reduces various unnecessary cost losses, providing strong support for achieving the project's economic benefits.

3. Strategies for Safety Risk Management in Construction Engineering Projects

3.1 Conduct Comprehensive Risk Identification and Establish a Dynamic Risk Register

Risk identification is the primary link in safety risk management and the foundation for subsequent work. Only by accurately identifying various risks existing in all links of construction can construction companies ensure that subsequently formulated control measures are truly targeted and effective, avoiding superficial risk management. Construction companies should, based on the actual scale, type, and construction environment of the project, shift from the past model of a single department responsible for risk identification to a method involving full participation and multi-dimensional investigation. Personnel from different positions, such as technical staff, construction workers, and safety management personnel, should participate in identifying potential hazards from their professional perspectives to ensure no omissions in risk identification. Before the official start of the project, the company should lead professionals from fields like technology, safety, and construction to systematically sort through and analyze the entire construction process based on core documents such as engineering drawings, geological survey reports, and construction plans, identifying potential risks[3]. For example, geological aspects like insufficient bearing capacity of soft soil foundations or unclear distribution of underground pipelines; technical aspects like high operational difficulty of complex processes or poor adaptability of new technology applications; environmental aspects like heavy rain causing water accumulation or typhoons affecting work at height; and management aspects like insufficient personnel allocation or imperfect safety systems—all need to be identified one by one. After entering the construction phase, risk identification cannot be interrupted. It can be conducted through daily on-site inspections by safety managers, daily pre-shift meetings reminding of risks by various teams, and regular special actions for hidden danger investigation, to timely discover dynamic risks arising during construction. Examples include component wear due to long-term use of lifting machinery, aging of temporary power lines due to environmental influences, or violation of operating procedures by construction personnel for convenience, all of which must be captured in real-time. Simultaneously, the company should establish a "Dynamic Risk Register," recording all identified risks by category, clearly marking each risk's name, specific location, initially determined risk level, potential accidents and consequences, and clarifying the department and personnel responsible for control[4]. The company should also regularly update the register content based on construction progress and environmental changes. For instance, before the rainy season, add seasonal risks like foundation pit water accumulation and slope landslides; during the main structure construction phase, focus on updating and highlighting high-frequency risks like falls from height and being struck by objects. Having a dynamic risk register ensures that various risks during construction are not omitted and provides a well-organized and clear basis for subsequent risk assessment and control.

3.2 Scientifically Implement Risk Assessment and Implement Graded Control Responsibilities

Risk assessment is a key link after risk identification. Based on the identified risks, it involves quantitative analysis of the likelihood of risk occurrence and the degree of harm, clarifying the risk level to provide a scientific basis for subsequent graded control. When conducting safety risk assessments, construction companies should no longer use a single assessment model but adopt a combination of qualitative and quantitative methods to ensure accurate and reliable results[5]. Qualitative assessment can be carried out using the expert scoring method. The company can involve professionals from fields like engineering technology, safety management, and emergency rescue to conduct a preliminary grading of identified risks based on core indicators such as risk occurrence frequency, impact scope, and severity of harm. Risks are generally classified into three levels: low, medium, and high risk, allowing for quick screening of risk types that require special attention. Quantitative assessment should utilize professional mathematical models like the risk matrix method or fault tree analysis, combined with historical accident data from the project location and real-time monitoring data from the construction site, to quantitatively calculate the probability of risk occurrence and potential losses, further refining the risk level and making the assessment results more accurate and persuasive. Furthermore, based on the grade results from the risk assessment, the company should implement targeted graded control: low risks are responsible by construction teams for daily dynamic monitoring, regularly reporting risk changes to the project department; medium risks are led by the safety management department of the project department, jointly with the technical department to develop special control plans, conduct weekly on-site inspections, and timely adjust control measures; high risks require direct intervention and supervision from corporate headquarters, organizing expert demonstrations to optimize control measures, arranging dedicated personnel for daily inspections to ensure risks remain controllable.At the same time, the company should incorporate risk control responsibilities into the performance appraisal system for various positions. Personnel who fail to implement control measures as required, leading to risk escalation, should be publicly criticized and have performance points deducted, ensuring control work is implemented at every level through responsibility binding, avoiding mere formality.

3.3 Introduce Advanced Technical Means to Achieve Real-Time Risk Monitoring

The deep penetration of information technology in the construction field has allowed advanced technologies such as the Internet of Things (IoT), BIM, and big data to break through the limitations of traditional safety risk management, providing more efficient and precise solutions for safety risk control in construction engineering. Construction companies should actively adapt to technological changes, integrate these technologies into the entire construction process, and use real-time monitoring and intelligent early warning to enhance the timeliness and scientific nature of safety risk management. For real-time risk monitoring, construction companies can rely on IoT technology to build intelligent monitoring networks. Deploy various sensors in key areas of the construction site: settlement and displacement sensors on deep foundation pit slopes to monitor stability changes in real-time; moment limiters and tilt sensors on lifting machinery to monitor equipment operating parameters; current and voltage monitors on temporary power lines to promptly detect circuit abnormalities[6]. These sensors transmit the collected risk data to a central management platform in real-time via wireless networks. Managers can view data dynamics anytime using mobile APPs or computer terminals. Once data exceeds the preset safety threshold, the platform automatically triggers alerts via SMS, pop-ups, etc., to remind relevant personnel, ensuring timely corrective measures are taken. For risk visualization and predictive management, BIM technology and big data technology can play key roles. Companies can use BIM technology to build 3D models of the project, accurately correlating the previously identified risk register with model components, and using different colors to mark risk levels—red for high-risk areas like work-at-height platforms, yellow for medium-risk areas like temporary power distribution boxes—making it easier for managers to intuitively understand risk distribution and formulate targeted control plans[7]. At the same time, companies can use big data technology to integrate historical accident data from the project location and real-time monitoring data from the construction site, analyzing risk evolution patterns through algorithms to predict risk development trends.

3.4 Improve Emergency Mechanism Construction and Enhance Accident Response Capability

Although scientific safety risk control can significantly reduce the probability of accidents, the complexity of the construction environment means accidents cannot be completely eliminated. Therefore, building a sound emergency mechanism becomes key to responding to sudden accidents and minimizing casualties and property damage. Construction companies need to focus on three core dimensions: emergency plan development, emergency team building, and emergency supplies reserve, to systematically strengthen emergency management capabilities[8]. In emergency plan development, companies need to establish a three-level plan system based on project risk characteristics. The comprehensive emergency plan defines the organizational structure, overall response process, and division of responsibilities among departments, providing an overall framework for emergency response. Special emergency plans are separately compiled for high-frequency, high-risk links like deep foundation pit collapses or falls from height, detailing rescue steps, technical solutions, and resource allocation methods to ensure handling of high-risk accidents follows established procedures. On-site handling procedures focus on specific positions and scenarios, such as scaffolding collapses or electric shocks, clarifying the emergency operating procedures for frontline personnel to ensure quick initiation of initial response when accidents occur. Emergency team building needs to balance internal formation and external linkage. Select key construction personnel, technicians, and personnel with basic medical knowledge to form an internal emergency rescue team. Conduct regular practical drills: organize fire drills quarterly to enhance basic emergency capabilities, and conduct specialized rescue drills for collapses, falls, etc., semi-annually to test plan feasibility and strengthen team coordination. At the same time, establish regular linkage mechanisms with local fire rescue departments and hospitals, clarifying liaison procedures during emergency responses to ensure quick access to external professional rescue support after an accident occurs. Emergency supplies reserve should be configured according to needs and dynamically maintained. Establish a dedicated emergency supplies warehouse on the construction site, categorizing and storing fire-fighting equipment, rescue devices, medical supplies, and communication equipment. For special projects like super high-rise buildings, set up emergency supply points on different construction floors, storing portable supplies like emergency lighting and escape ropes.

4. Conclusion

Safety risk management in construction engineering projects is inherently a systematic project that must run through the entire process from project planning and construction to completion. Currently, the construction environment is becoming increasingly complex, and safety risks are characterized by diversity and dynamism. The traditional management mode of post-accident rectification can no longer keep up with demand. It must transition to a full-process risk management mode involving prevention beforehand, control during the event, and handling afterwards. Construction companies can proceed from four aspects—risk identification, assessment and control, technology application, and emergency mechanisms—to effectively carry out safety risk management, continuously optimize the safety risk management system, and provide strong support for the construction industry to achieve the safety production goal of zero accidents and zero casualties.

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