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The Analysis Method Research of Steel Tubular Scaffold with Couplers Collapse Accident

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Abstract: Steel tubular scaffold with couplers is the most widely used scaffold system in construction site of China. But because of its low safety performance and lacking of supervision, these problems lead to massive collapse in the process of long-term using and became potential risks which are difficult to eliminate. The factors bring about collapse accident of steel tubular scaffold with couplers come from many aspects, including production, design, using and regulation. These factors present a diverse and interconnected situation. With the improvement of structure calculation theory and strengthening of policy guidance, an increasing number of scientific evaluation methods have been applied in collapse accident analysis of steel tubular scaffold with couplers. In order to meet complex engineering safety problems and the requirements of dynamic quantitative analysis with multiple factors, the comprehensive analysis which has many advantages will become the mainstream of collapse accident analysis of steel tubular scaffold with couplers in the future.

Keywords: Steel Tubular Scaffold with Couplers, Collapse Accident, Analysis Method

1. Introduction

Steel tubular scaffold with couplers dominated the main construction market for a long time with its simple construction technology and low cost. But compared with other types of scaffold, Steel tubular scaffold with couplers exist the shortcomings of low security and large material consumption. According to the security incidents statistics of construction projects in Chengdu, it has happened massive collapse accident of Steel tubular scaffold with couplers in recent decades and caused enormous losses to the safety of people's life and property.

In a water tower construction site of “Chengdu Fengfeng duck industry” in industrial concentration district of Chong Zhou, Si Chuan, the scaffold and gantry collapsed because a formwork support collapsed under construction on November 11, 2006. This accident caused five construction workers were killed and one person suffered minor injuries. In a construction site near the Beixin Avenue of Chengdu, the scaffold collapsed suddenly in the process of disassembly on May 7, 2011. Three workers were injured out of ten. In Chengdu, the scaffold of a bridge under construction collapsed on December 14. This accident caused one person was killed and four were injured. In Chenghua District, Chengdu, the exterior facade of library was decorated on May 31, 2012. The scaffold collapsed in the course of dismantling, leading to many constructors and pedestrians were injured.

All kinds of scaffold collapse accidents has begun pushing the engineers realized that it is necessary to analyze the causes of collapse accident carefully and take effective technical or management measures to control the risk factors of accidents from the source indeed. As a result, increasingly safety evaluation methods on system are applied to the analysis of steel tubular scaffold with couplers collapse accident gradually.

2. Current Situation of Steel tubular scaffold with Couplers

The traditional steel tubular scaffold with couplers has been widely used in the construction project in China. It may be still in a dominant position for a long time [1]. With the rapid development of domestic construction industry in recent decade years, it put forward higher requirements to the quality and safety of steel tubular scaffold with couplers as far as high-rise buildings and large public buildings continued to spring up. As the increasing expansion of the current engineering, the steel tubular scaffold with couplers was facing many prominent problems, such as backward production technology, unimplemented security measure. Therefore, due to reduce scaffold collapse accident, it is an effective approach to accomplish rational design and scientific management of steel tubular scaffold with couplers.

In engineering practice, people found that the improper design assumption of the scaffold has become one of main causes of collapse. Because the steel tubular scaffold connects with couplers, it brings about most stress components at the state of eccentricity. It is completely different from the traditional situation which is regarded

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as axial tension or compression member. On the other hand, people also gradually realized that the connection state between the members is not originally assumed rigid connection.

In 2004, Ao Hongfei et al. [2] provided the second-order finite element method of double row scaffold with couplers ultimate bearing capacity. They found that the semi-rigid and geometrical nonlinear of couplers should be taken into consideration in analysis and calculation of scaffold bearing capacity. It helps to reduce errors in the calculation.

In addition to the innovation of design and calculation, the Chinese government strengthened the policy guidance. It will promote the quality and safety of the scaffold to a higher level. In 2009, with the purpose of normalizing the security management of construction site and being targeted to reduce accidents, "The Safety Management Method of High Risk Branch Sub-Item Project" was issued by Ministry of Housing and Urban-Rural Development of China (Hereinafter referred to as "MOHURD"). The scaffold project was in range of the high risk of branch sub-item project. In 2011, "Technical Code for Safety of Steel Tubular Scaffold with Couplers in Construction" JGJ130-2011 was promulgated by MOHURD. This standard further emphasized construction safety requirement of steel tubular scaffold with couplers from structural design, construction management and acceptance checking, etc.

Comparing with the domestic frequent scaffold collapse accident, Japan or other advanced countries of the scaffold safety problem occurred very rarely. Therefore, some researchers have proposed that it is essential for us to absorb the advanced experience from abroad. In 2011, after studying the development experience of foreign scaffold, Yu Qingyuan et al. [3] found that it is effective to reduce scaffold engineering accidents from production, design, using and supervision, etc. We not only should accelerate the promotion of new type scaffold, but also improve the system of the supervision function and safety training. Only in this way could the development of scaffold project gradually towards the direction of standardization, specialization and integration.

However, to eliminate the steel tubular scaffold with couplers collapse accidents radically, it is necessary to comprehensive analysis injury factors which result in accidents and quantitative analysis the consequences and incidence probability of these factors. Therefore, the researchers began to apply many security system evaluation methods to analysis steel tubular scaffold with couplers collapse accident in construction site. It is efficient for people to further improve the understanding of accident risk factors. The application of these scientific analysis methods could play an early warning role specifically and promote safety managers to take preventive measures ahead of time.

3. Analysis Method of Scaffold Collapse Accident

3.1. Job risk analysis method (LEC)

Job risk analysis method was put forward by Kenneth J. Graham and Gilbert F. Kinney of the United States [4]. They used the product of three factors which related to the operational risk to evaluate the size of risk, including the possibility of accident, the frequency of the exposed in hazardous environment and the possible consequences of accident. In order to simplify the analysis process, the different levels of three factors were respectively corresponded to the different score. If the calculation result is greater, that means the risk is higher. This intuitive semi-quantitative calculation method was easy to master, but it was difficult to further quantify specific risk factors. Therefore, the application of LEC had certain limitation.

In 2011, Chen Lingcai et al. [5] evaluated the operational risk of scaffold by LEC. The result indicated that the quality of steel tubular and couplers, misusage and foundation problems of scaffold became the major risk source of scaffold collapse. They argued that the size of accident possibility completely depended on artificial judgment. It would lead to blindness of hazard management. The value should be corrected in practice.

3.2. Fault tree analysis (FTA)

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Fault Tree Analysis (FTA) was proposed by Telephone Laboratories of American Telephone & Telegraph Company in 1962. It has become an important analysis method in safety system engineering. FTA was firstly applied to scaffold safety accidents by Feng Bin et al. [6] in 2009. In their study, they argued that scaffold collapse was gravely influenced by design factors. Design factor were the most effective one to prevent the accident. But because of data limitations, they failed to quantitative analysis the system unreliability which was influenced by the probability of bottom events.

In 2010, based on the cause investigation of various steel tubular scaffold collapse accidents at home and abroad, Zheng Yifeng [7] of Central South University found out low-level events which brought about scaffold collapse. Through the analysis and reorganization of survey data, he reduced such events to two factors which including "collapse tendency" and "management defect". After drawing the fault tree of scaffold collapse accident, he

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simplified the fault tree calculation of minimum cut sets by using Boolean algebra and got the minimum path sets through dual transformation. He calculated the frequency of each basic event by using analysis on the structure importance degree analysis. He finally determined that the "management defect" was the main cause of scaffold collapse in many risk factors, such as scaffold materials, design and building.

In 2012, Wei Xinhe [8] of Xi'an University of Architecture and Technology proposed the general procedure of scaffold construction safety analysis by using FTA in his research. It was necessary to get each influence factor and risk value in the analysis process and set up the guarantee system about scaffold construction safety. The high risk projects must be controlled seriously to prevent collapse accidents.

In 2014, after analysis the steel tubular scaffold with couplers accidents by using FTA, Yang Qingxiong [9] of Chang'an University argued that the safety performance steel tubular scaffold was impacted enormously by cumulative effect of steel tubular defects. These defects included corrosion of steel tubular, abrasion of tubular wall and initial bending, etc.

3.3. Grey correlative analysis method

As early as 2006, Li Xiaowei et al. [10] evaluated the importance of various risk factors of scaffold with couplers by using the Grey Correlative Analysis Method. The risk factors of scaffold collapse were complex. Due to the small sample size of many analysis methods, the evaluation results were easy to be limited by individual cases and caused misjudgment. Grey Correlative Analysis Method could determine the strong-to-weak sequence of different factors by using the correlation because of its less calculation and low data requirement and was applicable to multivariate statistical analysis of scaffold accident. By Grey Correlative Calculation, they found that the oversize interval of steel tubular was the biggest factor and followed by safety management and quality issues of steel tubular.

In 2010, Zheng Yifeng [7] also analyzes the main factors which led to the scaffold collapse by using Grey Correlative Analysis Method from three aspects, including safety supervision, material issues and erection. Through the quantitative calculation and comparison of the correlation between various factors, he argued that these factors including unorganized site acceptance, couplers damage and unreasonable erection of frame unit were the main causes of scaffold collapse.

3.4. Comprehensive analysis method

In 2008, in order to overcome the defects of Fuzzy Comprehensive Evaluation (FCE) in index system and multiplicity of weight, Cai Qingyu [4] of Liaoning Technical University organic integrated with Fault Tree Analysis (FTA) and Job Risk Analysis (LEC), and constituted "FTA-LEC-FCE" method. First of all, risk factors of scaffold collapse should be based on the existing accident data In application of this method. And then the evaluation index system of fuzzy comprehensive evaluation method ought to be established. Job Risk Analysis Method was used to determine the weight of each index. Finally, the FTA-LEC-FCE evaluation model could be completed. FTA-LEC-FCE method reflected the advantage of three safety evaluation methods in the analysis of steel tubular scaffold with couplers collapse accident and had good application value.

In 2013, Luo Yuan [11] of Chang'an University mentioned the Fuzzy Analytic Hierarchy Process (FAHP) in his research. The method was the combination of Analytic Hierarchy Process (AHP) and Fuzzy Mathematics and remedied the defect of quantitative results which the AHP lack of.

4. Conclusion

In order to reduce the steel tubular scaffold with couplers collapse accidents effectively, engineers and technicians sought the causes of the accident, strengthened the supervision and preventive measures. The scaffold safety evaluation system would be improved from the scaffold design, construction and material purchase, etc. At present, in the research of the analysis method of steel tubular scaffold with couplers collapse accident, the following conclusions can be drawn:

(1) The predominant qualitative traditional safety evaluation methods such as Safety Check List (SCL), Preliminary Hazard Analysis (PHA), etc. would no longer be able to accommodate the current analysis requirements of dynamic multifactor factors. They would be replaced by new evaluation methods such as FTA or Grey Correlative Analysis Method. These kinds of methods could determine the various factors, their probability of occurrence and internal connection of accident scientifically. They were able to adapt to the complex engineering problems. The safety analysis results of system would be more accurate and reliable.

(2) The FTA-LEC-FCE method was combined with Fuzzy Comprehensive Evaluation (FCE), Fault Tree Analysis (FTA) and Job Risk Analysis (LEC) and was a comprehensive analysis method which took advantage of these three methods. With its complete analysis system and strong adaptive capacity, it would be the mainstream of scaffold collapse accident analysis methods in the future. On the other hand, with the continuous development of modern computer technology, the application of computer algorithms such as Back-Propagation Neural Network Method would further improve the scaffold system safety analysis technology.

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