# Computer-aided Risk Management Research on Construction Techniques

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*Abstract*—**With the rapid development of economic and technology in China, structural forms are becoming more and more complicated, which requires more rigorous construction technology and construction management. However, the risk management in our country is still in its infancy, and managers are short of awareness of risks and lack of ability to manage risks. Study on risk management methods mode of conventional construction process shows that only relying on the qualitative analysis by perfecting manage system and engineering experience cannot satisfy the construction requirement of the complicated structures. Thus, integrating the ideal, characteristics, procedure and goal of risk management meanwhile combining the achievements of computer simulation technology in building structures, this paper presents a new construction technology risk management model, takes overall lifting of steel gallery engineering project of Shaoxing World Financial Center as an example and validates its applicability of the management mode to engineering projects construction.**

***Keywords-risk management; construction technology; computer simulation technology***

## I. INTRODUCTION

Building complicated structures is an extremely complicated system. There are lots of uncertain factors having a great impact on it, especially on construction. On the one hand, it is hard to identify all the uncertain factors for the faultiness and backwardness of information. On the other hand, the technical problems occurred in complicated structure construction are seldom encountered in the previous projects. Mechanical issues in construction have become a key problem due to the complexity of structural forms. It is obviously blind for construction to simply rely on engineering experience. The degree number of construction accidents and death toll has being high nowadays, second to the transportation and mining industry. As the construction safety is an important part of public security, the public pay more attention on it. Overall, the safety management and accident prevention of construction engineering in China mostly belong to “experience control” and “process control”, which focus on experience and deal with the accident afterwards, and have not yet formed a complete accident prevention system [1]. So, it is very urgent and necessary to study mechanical issues in complicated structure construction, and to provide exact quantitative indexes for establishing construction plan of key working procedure. Meanwhile, it is useful to change the project management from “experiential and extensive style” to “calculative and elaborate style”.

## II. STATE OF RESEARCH ON RISK MANAGEMENT OF BUILDING ENGINEERING CONSTRUCTION

Risk management originated from America in 1930s, and it was associated with insurance business in the early time. With the vigorous development of the world economy, risk identification, risk assessment and management were endowed with rich contents in various professions (in all walks of life). Project risk management had gradually become the focus for construction analysis. Analysis of construction risk management gradually became a hot spot after the 1970s.

It is not until the 1980s when China began to study risk management in scientific circle and business one. In the 1990s, the development of domestic risk analysis became steady, and risk theories were carried out in the relevant fields. With the deepening of reform and opening-up policy and the transforming of investment system, the project management and evaluation system were gradually brought in line with international standards. It created more opportunities for risk analysis theory and application, and successful application had been gained in the domestic large civil engineering projects. At present, the use of risk management methods for evaluating investment project is pervasive, while technical risk avoidance issues caused during the construction have not been paid enough attention. In fact, there are many technical risks in construction, especially for the complicated structures with a novel style and irregular structural form. In addition, the entire structural system is a time-varying system during the construction process, which increases the possibility of risk. Once there are problems with complicated structures during the construction process, it is not only hard to maintain and repair, but it is easy to cause heavy casualties. As large complicated structures are often local landmarks, it is impossible to measure loss in society and culture. Therefore, management research on technical risks caused by complex mechanical issues of construction phases for engineering project must be carried out. Project managers should raise the awareness of risk management, and have a good grip on risk identification, risk assessment and technical analysis, which assures that risk is identified first, and then disposal methods are determined to prevent and dissolve issues. So the projects can go on safely and smoothly.

## III. THE PROCEDURE OF RISK MANAGEMENT OF BUILDING ENGINEERING CONSTRUCTION

The procedure of risk management of building engineering construction consists of “preconstruction stage risk”, “risk during the construction” and “post-construction risk”. Before construction, engineering construction scheme should be programmed, including construction circumstance, resource requirement and technical plan. During the construction, managers must formulate specific implementation rules, and enforce construction disciplines strictly. Meanwhile, they should monitor construction process and ask for feedback on it, and solve problems in time. After construction, they also need to inspect the various performance indicators of structure, to record the changes in the structure after construction, and keep completion data on file. Fig.1 shows the main procedure of risk management of building engineering construction.

Various risks during the erection process are linked together, composing a risk chain. Losing the control of any link will cause the risk to occur. The key risk control should be placed on “preconstruction”, which is so-called <7 parts preparative and parts construction>. Nearly 70% risks may occur before construction. A strict and reasonable construction scheme can greatly reduce the risk of project construction.

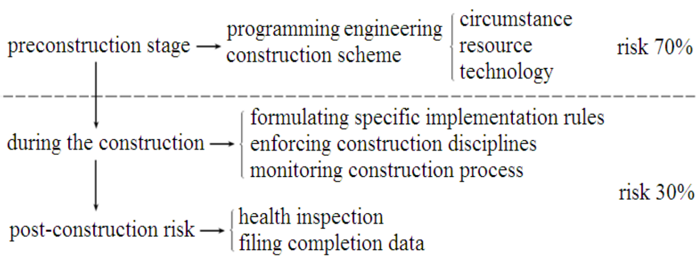



Figure.1 The main procedure of risk management of building engineering construction

## IV. THE CHARACTERISTICS OF RISK MANAGEMENT OF BUILDING ENGINEERING CONSTRUCTION

When compiling engineering construction scheme, the risk control of environment and resource can be archived by system management, organization management and economic management methods, but that cannot satisfy the requirement of construction technology risk control, which is shown as follows:

*1)* Due to novel building style and special structural system of complicated structure, usually no similar engineering projects can be learned from. Expert investigation method and data method etc. qualitative methods can only identify those problems that are macroscopic and common, but they cannot make a reasonable judgment that whether the risk will happen or what’s the consequence the risk may cause. Therefore it is blind to draw up a technical scheme just according to qualitative analysis.

*2)* The accuracy of using probability statistics method to estimate the probability and loss of risk events depends on enough sample spaces and reliable historical data. Yet complicated structures triggered by the construction technology risk factors, uniqueness of project and lack of sufficient statistical data consequently affect the accuracy of evaluation, and limit the use of probability statistical method.

*3)* Sometimes, experimental model test is used to simulate erection process to achieve the purpose of risk management for conventional structure. However, for complicated structure construction, due to many uncertainties, if each model test will be done for each program, it may cost a lot of time, manpower and material resources. Although the technology can achieve the goal of risk control, it increases the risk and investment risk period.

Therefore, how to provide adequate analysis data based on theoretical basis for weaving construction scheme has become the main problem of risk management.

## V. MANAGEMENT MODEL FOR TECHNOLOGY RISK MANAGEMENT BASED ON COMPUTER-AIDED CONSTRUCTION

With the rapid development of computer technology, computer hardware and software have been improved. It becomes true that computer software can be applied in engineering simulation analysis. Recently, the use of computer simulation technology on complicated structure construction process in construction industry in China is becoming increasingly more popular and has achieved remarkable results. The most typical case is National Grand Theatre. To ensure the safety of the steel shell during unloading, the sequence of removing the temporary supports are studied by the method of analogy simulation. With a large amount of calculation, the displacements of each unloading step are obtained. The technical guideline for unloading which takes the jack travel as a control variable is put forward and proved in the construction practice [2].

Regarding the existing defects and characteristics of risk management in China, it is not easy to break through the limitations of traditional risk management. With the aid of computer simulation, this chapter aims to propose a construction process-oriented and dynamic risk-management mode using technology risk management as a research platform during the construction phase for engineering project. The new construction risk-management mode should meet the following requirements:

*1) Comprehensiveness of information reflection:* The mode must be able to gather all kinds of risk information simultaneously which are dispersed in projects. That is, using computer simulation technology can identify risk from different angles and multi-level.

*2) Flexibility in use:* The mode can be applied to identify different kinds of project risk, such as taking overall consideration of structure or detailed analysis in partial component, without being restricted to a particular form.

*3) Having certain universality:* Computer simulation technology should be applicable to different project risk identification. It can stimulate and analyze a variety of structural forms and construction conditions.

*4) Reflecting the dynamic characteristic of project implementation:* Computer simulation technology must be able to carry out dynamic risk identification for project risk anytime according to specific project implementation, gather risk information, and rectify the results, and provide complete and reliable info for management decision-making.

*5) Classify first, identify second:* In the process of construction risk identification of complicated structures, the sequence of the classification and identification related to accuracy and comprehensiveness of the recognition results. The method of "classify first, identify second" lets analysts analyze the risk thoroughly first, and then classify all the issues according to their aspects, such as steel engineering, foundation engineering, superstructure etc., so that analysts can identify each risk based on individual expertise and experience related to the identification project. This method not only can give full play to analysts' professional expertise and improve the accuracy of identification, but also can reduce work load, save time, and improve efficiency. Meanwhile, it will avoid omissions, and identify the project risk factors more comprehensively.

The management model of complicated structure construction technology based on computer simulation can be expressed as follows: After the project begins, analysts track and collect relevant project activities and risk information first, refer to similar engineering experience, and list the possibility of risk by means of expert investigation. Then, whether the risk can be controlled by traditional risk management method or not will be judged. If it can, end the study, and continue to search for the next risk. If can't, it shows that traditional risk management method can't satisfy the requirement of construction risk control, so this risk factor is taken as construction risk controlling factors, and it will be quantitative analyzed by introducing computer simulation technology. Through simulating, analysts will get numerical results, and then ensure the countermeasures. The last, the project managers and technical experts do the qualitative analysis, judging its rationality, so that they determine whether the results will be calculated as the implementation scheme. The model combines the qualitative and quantitative analysis, realizes the dynamic analysis, and provides the quantitative indices of risk disposal for construction object oriented, so will avoid risk ahead [3]. The main approach is shown in Fig.2.

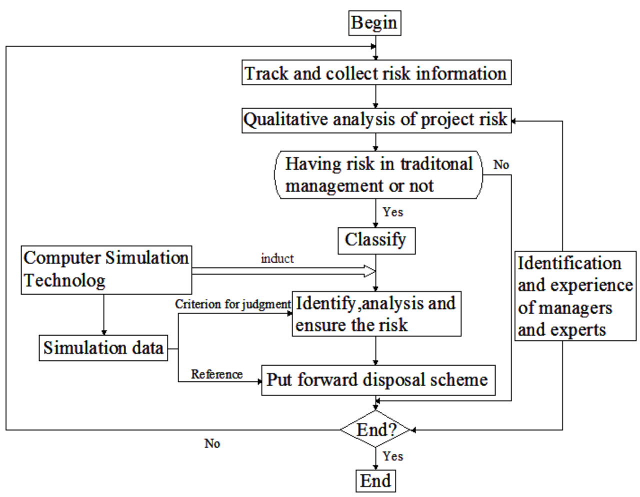



Figure.2 Management model concluding computer simulation technology

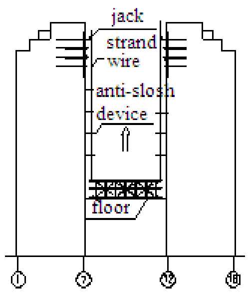
## VI. INSTANCE

### A. Project profile

Shaoxing World Trade Center "A" official building is located in Keqiao of Shaoxing, Zhejiang province. It covers an area of about 3145m². The main structures are two 27-story reinforced concrete towers, which are surrounded by a 7-story podium structure. The two towers are connected by a 2-story steel gallery in 22th~24th floors (in Fig.3). The steel gallery adopts space truss structure system, and is supported on stiffened columns. It consists of four trusses which are connected with steel girders [4].

The construction scheme called "assemble first, overall lift second" was adopted. Assembling was finished on the 7-story podium. Eight LSD40 type steel wire hydraulic lifting equipments were used for ascension. "Steel strand bearing, computer synchronous control, and hydraulic jack cluster" called overall lifting technique was adopted during lifting process. The steel gallery which weights 215t was lifted from the 7th floor of the podium to 76.9 m (lifting distance is 54m). Eight hydraulic jacks were divided into two groups and were separately set on the both sides of the steel girders of the towers of 87.7 m height. Control system controlled hydraulic pump station to drive jacks with the oil cylinder to move in circles and formed a closed circulation. At each cycle, the steel gallery would be lifted to a certain height, so that it could be docked at 22th floor. Fig.4 shows the beginning of ascension, while Fig.5 shows the ready condition.

Figure.3 Shaoxing World Trade Center



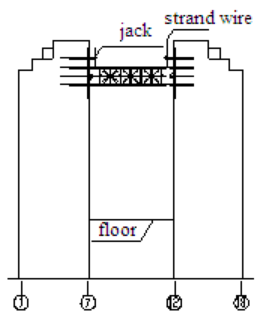




Figure.4 The beginning of ascension Fig.5 The ready condition

### B. The risk identification of steel gallery ascension process

After determining the integral lifting scheme, the experts discussed relevant engineering materials and suggested the following three points as risk factors:

*1)* As hoisting points were on the top chord of trusses, the structure was like a cantilever and was unable to bear the lifting force needed.

*2)* When steel ropes were lifting the steel gallery, it was equivalent to a pendulum system and was prone to shaking, resulting in structure instability damage.

*3)* Because of non-synchronization of the 8 hoisting points during overall lifting, additional internal force was inevitably caused which led to excessive deformation of the structure and even caused structural damage.

Three measures for each risk factor were presented:

*1)* In order to avoid the damage of hoisting points, a rod was set in the point to connect the truss chord. As there were eight hoisting points on the steel gallery, eight rods had to be set on. Through calculation, two 20a channels were adopted (in Fig.6).

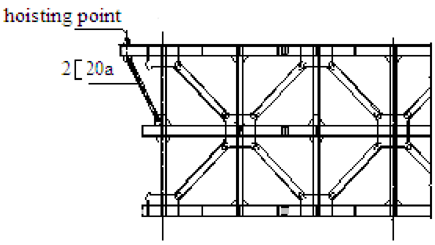



Figure.6 Hoisting points on the truss

*2)* Aiming at strengthening the structural stability of the entire gallery and avoiding the dislocation of space truss, scissors-type cable wind ropes were installed on the upper and lower layers, with a flower basket bolts twisted tight. Anti-wobble devices were also needed. Only when the wind was lower than 5-level, could the steel gallery be lifted to ensure the safety of the overall lifting.

*3)* The hoisting point cannot be maintained absolute synchronization during overall lifting. In order to avoid too much additional stress within the structure, the elevation of hoisting point should be adjusted in time.

Through the qualitative analysis and structural measures, the local damage of hoisting points and sloshing could be avoided during overall lifting. But it was blind to analyze construction risks qualitatively without quantitative data, so that constructors could not know clear adjustment standards. Therefore, research on the structural response due to non-synchronization of the hoisting point during overall lifting should be carried out.

### *C. Computer simulation analysis on the integral lifting of the steel gallery*

Because of non-synchronization of the 8 hoisting points during overall lifting, additional internal force was inevitably caused which leads to excessive deformation of the structure and even causes structural damage. Therefore, it was necessary to carry out numerical simulation analysis on structure responses caused by unsynchronized lifting, and to obtain the stress value in a variety of structural conditions. According to those mentioned above, managers would identify and assess the lifting risks, and put forward the corresponding disposal scheme.

Internal force change during lifting process was simulated and analyzed by MIDAS. Under normal use, eight embedded stiffened columns supported the gallery, so that eight hoisting points were set on the corresponding position during overall lifting. Under the static state, the reaction forces of 8 hoisting points were shown in figure 7.

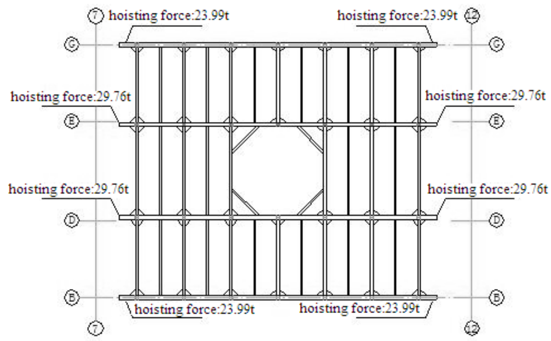



Figure.7 The weight and location of hoisting points

At this moment, hoisting points were at the same level, and the maximum stress of gallery members was 58.44MPa, which was far less than that of the steel design strength. It indicated that it was safe and reliable to use 8 steel strands for ascension.

When in the actual working condition, the hydraulic control system could not guarantee the complete synchronization of hoisting points. With the accumulation of displacement difference, internal force of structural members was increasing and resulted in deficiency of structural strength and overall stability during lifting, which led to construction safety problems. So it was necessary to carry out mechanical calculation analysis on all possible displacement differences. The alert level of differential displacement should be obtained to adjust elevation difference. In this case there were eight kinds of typical working conditions when internal force might reach the

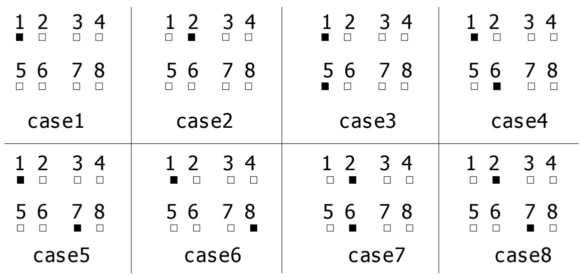



Figure.8 Eight kinds of typical working conditions

maximum value. (■was the maximum displacement of one point, while others were in the same level)

Calculating all conditions, the maximum stresses were obtained (in Tab.1).

| Displacement(mm) | Case1 | Case2 | Case3 | Case4 | Case5 | Case6 | Case7 | Case8 |
|---|---|---|---|---|---|---|---|---|
| 10 | 63.91 | 81.15 | 59.54 | 79.51 | 81.37 | 65.66 | 60.40 | 73.12 |
| 20 | 81.43 | 101.58 | 62.27 | 98.28 | 102.00 | 82.18 | 71.63 | 85.53 |
| 30 | 97.57 | 122.01 | 62.40 | 117.05 | 122.63 | 98.70 | 84.80 | 97.94 |
| 40 | 113.70 | 142.44 | 63.82 | 135.82 | 143.26 | 115.22 | 94.09 | 110.34 |
| 50 | 129.83 | 162.87 | 65.24 | 154.59 | 163.89 | 131.74 | 105.32 | 122.75 |

TABLE I. THE MAXIMUM STRESS (MPa)

It was can be seen under different working conditions that internal force of the structure was different from each other. In comparison with 8 working conditions, case5 was the most unfavorable condition for the maximum stress. Considering a certain safety margin, the construction control stress of components was 0.7 times of design strength of steel, namely $215 \times 0.7 = 150$MPa. Once the stress was close to control stress, lifting must be ceased. After the height of points was adjusted to the same level, ascension continued. When the displacement became 40mm, the maximum stress value had reached 143.26MPa, which was so close to the control stress that 40mm was reckoned as the vigilance limit.

## VII. CONCLUSION

With the improvement of design technology, Building style becomes more innovative, structural form becomes more complicated and brings about a lot of mechanical problems on construction, resulting in many risk factors. Still using conventional risk management mode already cannot satisfy the safety requirement of complicated structure construction. In recent years, computer-aided technology is a newly introduced technology. By means of computer simulation of the entire construction process, managers can adopt dynamic analysis and control to avoid possible risks. In view of this, this paper develops a computer-based simulation of construction risk management model, and provides quantitative analysis of data for risk managers by simulation technology in order to reduce the probability of risk occurrence. The installation case quoted in the last part of the paper achieves a very good effect in project construction, thus validating the applicability of the model on technical risk management during construction process for actual engineering project.

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