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Prevention and Safety Research of Bridge Life Cycle Risk Accidents

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***Abstract* -** In this paper, the realization process of the project is a process with great uncertainty, because this process is a complex, one-time, innovative, and involves many relationships and variables. We do research and classification the current situation of bridge risk accidents at home and abroad, which are mainly caused by natural factors, including natural disasters such as earthquake, flood, debris flow, typhoon and other natural disasters; and human factors, Including design factors, construction factors, operation management factors, overload factors, collision factors (ship collision and vehicle collision) and other factors for the damage of the bridge; aiming at the typical case analysis of collapse risk of multiple bridges. There are summarizes the experience and lessons of bridge risk accidents, puts forward safety countermeasures and methods to prevent risks, emphasizes the importance of bridge life cycle design, construction and maintenance management to prevent risks, and puts forward useful safety measures and suggestions.

***Keywords*:** Diseases of old bridges, Accident prevention, Cause analysis, Natural risk, Human risk, Safety countermeasures.

1. Introduction

It is expected that any civil engineering project to avoid the occurrence of risks, but in reality, this is impossible .These features of the project cause a variety of risks in the project implementation process. If these risks cannot be well managed, all kinds of losses will be caused. Therefore, project risks must be fully identified, measured and controlled in project management, and project risk management must be carried out actively.The bridge connects the ocean and the valley, and the road leads to all directions. The construction and smooth flow of the bridge have promoted. The completion and smoothness of bridges promote the development of human society. The prosperity and development of cultural and economic life. But once the bridge collapses accident will bring huge loss and disaster. Therefore, both the government and the people great importance is attached to bridge safety. Ministry of Transport of the People's Republic of China[1], according to the statistics, by the end of 2019, there will be 878300 highway bridges and 60634600 meters in China; according to "technical specification for highway bridge maintenance"[2], there are 100000 dangerous bridges attract attention.

Although it has strengthened the renovation of dangerous bridges in Ministry of Transport of the People's Republic of China since 2001. It is not enough to meet the requirements of the Ministry of Communications. The capacity of the bridge to bear the load level is low, and now the national economy is developing rapidly. During the exhibition, overloaded vehicles were banned repeatedly, and new dangerous bridges were added every year. In the railway bridge, there are due to alkali aggregate reaction, the porous reinforced concrete beam cracked and the reinforcement was severely corroded.

It is also an arduous task to reconstruct the dilapidated bridges abroad. For example, in the United States[3] ,according to the NBI, there are about 588930 bridges as of 2003. There are 158859 defective bridges, accounting for 27% of the total number of bridges. The average design life reference period of bridges is 75 years, while the actual service life of bridges is flat. The average life span is 44 years, and the interstate bridge is 39 years.

The International Bridge Association (IABSE) organized the "Structure for the Future--The Search of Quality" in 1999; “Risk and Reliability” in 2001. At the international symposium, the risk of collapse of existing bridges is systematically analyzed. The experience and lessons are summarized. Experts and scholars advocate bridge life cycle new concept and mechanism of design, construction and maintenance management have important theoretical significance Meaning and practical value.

It is in the period of large-scale bridge construction during the period of rapid economic development in China, especially the climax of bay bridge construction. At the same time, there are many problems[4]. For example, a large number of concrete bridges have serious cracks, engineering accidents in the construction process, and serious quality and safety problems of bridges that have not been in operation for a long time, which need urgent repair, reinforcement and even reconstruction. In the life cycle of bridges, the causes of the diseases are analyzed and classified, which can be roughly divided into the following categories.

2. Risk Assessment Overview

2.1. The connotation, flow and content of risk estimation

Connotation: Project risk estimation is the estimation of the size of the possibility of the occurrence of risk events in each stage of the project, the possible consequences, the possible time and the size of the scope of influence.

Content:

Estimation of the probability of occurrence of risk events;

Estimation of the severity of the consequences of risk events;

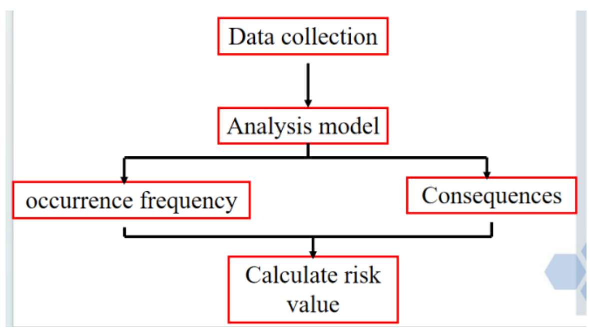

Fig. 1: The process of engineering risk estimation

Figure 1 Refer to the tale below for a sample.Method for estimating probability of occurrence of risk events
Analyze the probability distribution of risk factors or risk events using available data.

The theoretical probability distribution is used to determine the probability of risk factors or risk events.

Subjective probability is used to analyze the probability of occurrence of risk events.

Synthetic inference.

2.2. Engineering project risk classification

The risk classification of engineering projects is shown in Table 1.

Table 1: Engineering project risk classification

Classification criteria	The specific risk
Source of risk	Internal risk refers to the risk within the project team. Such as resignations, unclear responsibilities, delays, cost overruns, cash flow difficulties, etc External risk refers to the risk outside the project team. Such as market risk, policy risk, legal risk, inflation, exchange rate fluctuations, etc
Nature of risk	Natural risks, such as earthquake, flood, fire, etc Social risks, such as unrest, terrorism, etc
Area of risk	Technical risk refers to the uncertainty of the effect, prospect and life of the technology Production risk refers to the uncertainty of whether a product can be produced Market risk refers to the mismatch between products and market demand, such as insufficient effective market demand and shrinking demand Financing risk refers to the risk caused by insufficient fund supply, untimeliness or excessive financing cost Management risk refers to the risk caused by disordered management and lack of procedures
State of risk	Static risk is the risk under normal circumstances such as politics, economy and society Dynamic risk is the risk directly caused by political, economic, social and other changes
Range of influence	Local risks, risks that have little impact, such as delays in activities on non-critical paths. Overall risk, risks that have a large impact, such as delays in activities on the critical path
Probability of occurrence	Systemic risk refers to the risk with stable frequency and strong regularity that can be generally controlled Accidental risk refers to the risk caused by the change of internal and external accidental factors
Degree of loss	Serious risk refers to a relatively serious loss or a high probability of occurrence. Once such risk occurs, it is often difficult to make up for and control it, so it should be given priority consideration. General risk refers to the risk loss degree is light and the probability of occurrence is small, if the occurrence, can take remedial measures or can be prevented in advance
Consequences of occurrence	A pure risk, such as a fire, in which losses are incurred but no gains are made. Speculative risk, such as buying a stock, that produces a loss when it occurs and a gain when it does not

3. Various factors that affect safety

In actual civil engineering, various events and disasters affect the construction, operation, maintenance, and use of the project. Civil engineering project risk: Refers to any event that may have a negative impact on the scope, time, cost, quality and performance of the project, or even make the project objectives impossible to achieve.

3.1. Natural disasters

Unforeseen strong natural disasters: such as large earthquakes, strong hurricanes, floods, etc.

3.2. New materials

Unreasonable expectation of life cycle of new materials [6]: due to lack of engineering application practice inspection, serious natural and stress corrosion damage occurs, improper maintenance or maintenance funds are not invested, resulting in loss of maintenance.

3.3. Design issues

There are mistakes or defects in the design[5]: due to the limited understanding of natural laws in different historical periods, the constraints of the development of productivity level, the imperfection and update of bridge design theory and design specifications are slow or seriously lagging behind.

3.4. Construction method

Poor construction measures or improper process procedures: also including cutting corners, improper and backward manufacturing technology and hidden dangers of construction quality.

3.5. Influence of overloading

Due to excessive truck load, the bridge is crushed and collapsed, which is also a lot. For example, on October 10, 2019, a heavy truck carrying 300 tons of steel was overloaded in Wuxi, China. The overload was more than 5 times of the designed vehicle load, resulting in the collapse of highway bridges.

4. Analysis of bridge accidents

Investigation and analysis of bridge accidents at home and abroad.

4.1.Statistics of bridge accidents

In order to study on the influence of various adverse factors on bridge accidents, a total of 916 bridge accident data at home and abroad were collected by consulting a large number of literature and books, including 376 cases of domestic bridges and 540 cases of foreign bridges.

It can be seen from Figure 1, that design, construction, collision, water damage and overload are the main causes of accidents, and the causes of bridge accidents are often the joint action of many adverse factors[7].

The causes of bridge accidents are basically the same at home and abroad, and the proportion of construction, collision, overload and water damage is the largest. The proportion of bridge accidents caused by construction, overload and water damage in China is higher than that in foreign countries, indicating that the pressure of bridge accident treatment in China is greater.

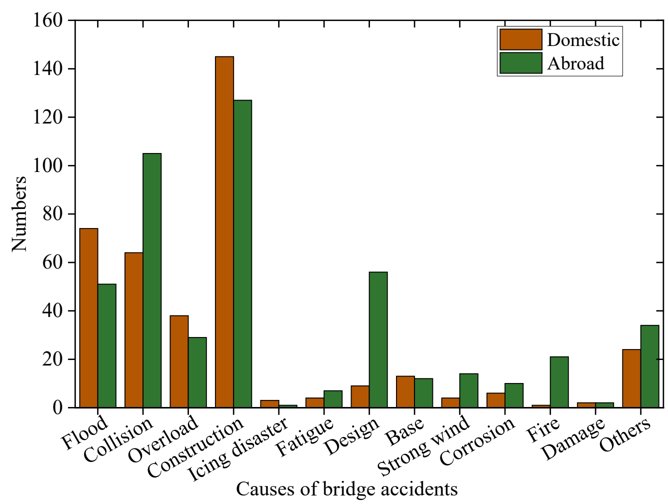

Fig. 1: bridge accidents.

4.2.Statistics of bridge types and accidents

The statistical analysis of different types of bridges (girder bridge, arch bridge, cable-stayed bridge) at home and abroad is shown in Figure 2.

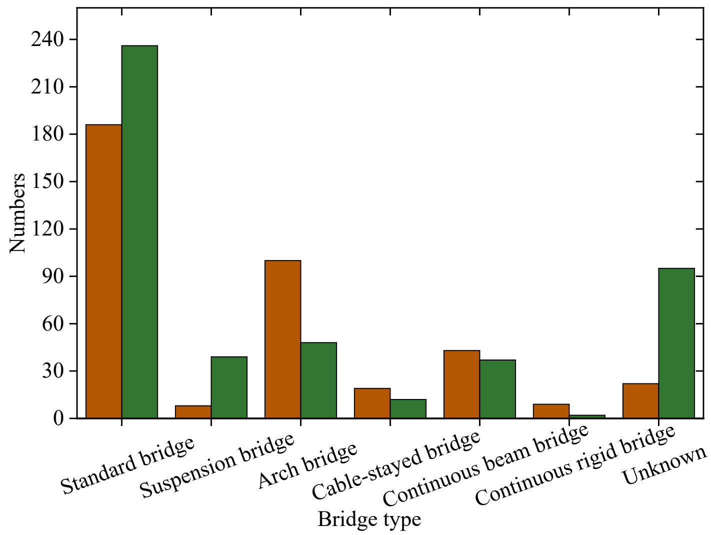

Fig.2: Bridge types and accidents.

The number of accidents of conventional bridges (smaller span) at home and abroad is the most, more than 50%. The number of accidents of arch bridges in China is significantly higher than that in foreign countries, while the number of accidents of suspension bridges in foreign countries is much higher than that in China. The main reason for the difference in the number of suspension bridge accidents is that the development of suspension bridges in foreign countries is earlier than that in China. In the initial stage of development, due to the relatively insufficient design experience, long operation time and more bridge accident risks, there are many accidents in foreign suspension bridges.

4.3.Statistics of Actual average life of some bridges

As can be seen from Figure 3, Statistics of Actual average life of some bridges.

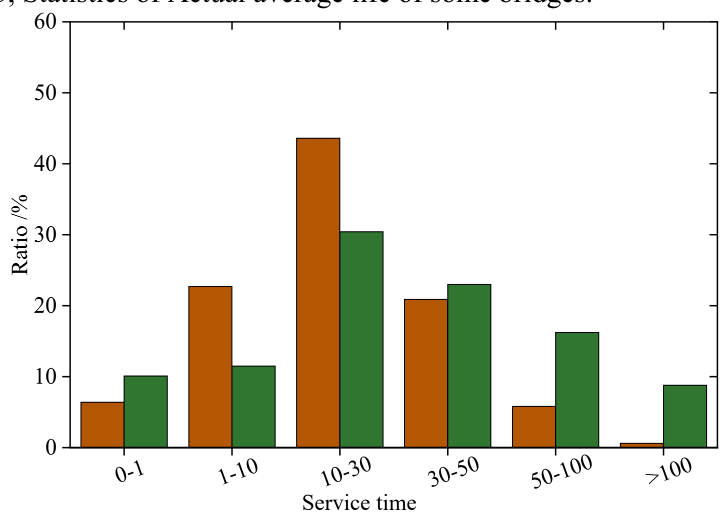

Fig.3: Actual average life of some bridges

From Figure 3, it can be seen that about 5.8% of bridges in China have been in service for more than 50 years when damaged, and only 0.6% have been in service for more than 100 years, which is much lower than foreign bridges. At the same time, the average service life of these bridges is only 23.8 years, far less than the average service life of foreign accident bridges (40 years), and less than 1/4 of the design life (calculated based on 100 years).

4.4 .Statistics of the disease situation of American bridge

By collecting the disease situation of American bridges at different times, the technical condition of American bridges before and after the implementation of LTBP can be analyzed, as shown in Figure 4.

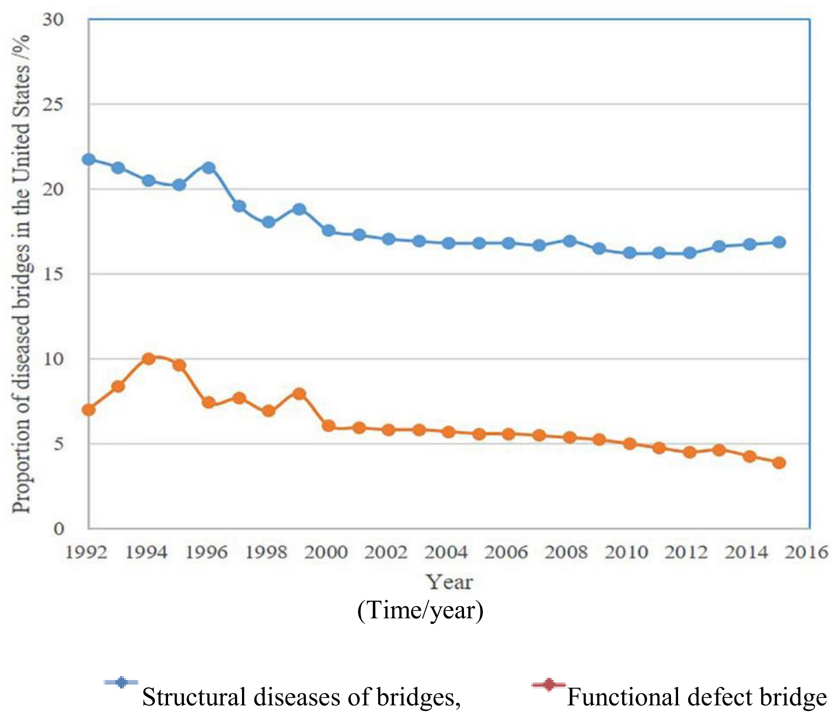

Fig. 4: The proportion of bridge structural defects managed by the US NHS database

From Figure 4, it can be seen that the condition of bridges in the United States was not optimistic in the 1990s. On average, 8% of bridges had structural defects, 20% had functional defects, and over 1/4 of bridges had varying degrees of damage. In recent years, the proportion of structural defects in bridges in the United States has gradually decreased, especially after the implementation of LTBP. The structural defects of bridges included in the National Highway System (NHS) database management have been controlled at 3% to 4%. This indicates that as long as the safety of bridges is given sufficient attention and practical solutions are proposed, the safety of bridges can be guaranteed.

5. Methods of preventing bridge accidents

Prevention of bridge disease accidents and Countermeasures to ensure bridge safety and durability as follows.

5.1.Preventing the effects of natural disasters

Using scientific analysis method to prevent bridge diseases caused by strong natural disasters.

（1）Prevent the influence of flood disaster

Disaster prevention caused by flood. The flood will scour the bridge foundation in a certain area and cause the destruction of several bridges. However, the calculation of the scour on the riverbed is difficult to be very accurate. Therefore, before the design, the hydrogeological data should be mastered as much as possible, and the hydraulic model experiment should be carried out when necessary, and the dynamic action of riverbed should be calculated and analyzed.

（2）Prevention the influence of earthquake disaster

Disaster prevention caused by earthquake. At present, the earthquake prediction is still in the experimental stage, and the seismic design of bridges in multi earthquake areas is a prominent problem. The appropriate fortification standards and technological measures should be formulated in consideration of seismic safety and economic factors. To prevent bridge damage accidents caused by earthquake.

5.2.Improve Bridge Specifications and standards

Risk prevention bridge disease accidents from perfecting bridge design specifications and other design aspects. The revision cycle of foreign bridge specifications is about 7 years, while that of China is about 15 years[8]. The specification lags behind the production practice seriously, which leads to the situation that there is no standard to follow in design or construction. The current specifications and standards should be strictly followed, and the operation status and construction process of each working condition should be checked carefully.

Especially for the design of super long span bridge generally, it is necessary to study new structure, new material and new design theory, which is suitable for the construction and maintenance of super long span bridges.

5.3.Improving construction technology

It is urgent to improve the construction management and new technologies and methods to prevent the occurrence of bridge disasters and accidents in the construction stage. The main reason is that the design of arch frame, support and other temporary engineering facilities is unreasonable or the technology is improper. The design of construction stage and temporary facilities should be strict, and the test and intelligent monitoring control in the construction stage should be strengthened. It is also necessary to formulate detailed, safe and feasible construction technology measures and strengthen scientific management.

5.4.Strict management of overloading vehicles on the bridge

Risk prevention of bridge disease accidents from overload control. Recently, the Ministry of communications and other Ministries and commissions have achieved initial results in dealing with overloading. However, it is necessary to improve the awareness of the whole people about the bridge collapse caused by overloading or accidental accidents, so as to prevent and eliminate the damage to the bridge caused by overloading and overloading of vehicles. The industrial technical standard of "special vehicle for large transport" is being consulted and can be implemented in the future, so as to ensure the safety of the bridge through the reinforcement before overload.

5.5.Strengthening the maintenance and repair management of bridges

Most of the existing bridges in China have been in service for more than 30 years, so it is urgent to carry out maintenance and even reinforcement. Due to the shortage of funds for maintenance, untimely maintenance and overload service, some bridges were damaged and collapsed quickly. Therefore, it is necessary to pay attention to the regular inspection and maintenance of old bridges, strengthen the health inspection for long and long bridges[9], and timely reconstruct and reinforce the diseased bridges in service with diseases.

5.6.The Security Plan for Bridges in the United States

In 2008, the Office of Infrastructure Research and Development under the Federal Highway Administration, along with transportation departments and other federal agencies in various states of the United States, launched the Long Term Performance Study Program for Bridges (LTBP). We plan to establish a detailed bridge health database within 20 years and conduct research on the basic theory and application technology of bridge structural performance, in order to improve the safety, longevity, and reliability of US highway transportation assets. In December 2015, Obama signed the "Fix America's Ground Transportation Act," which will provide $305 billion in financing for transportation infrastructure construction in the United States from fiscal years 2016 to 2020. The bill also increases support for LTBP.

This program is mainly used to fund research on the mechanism of bridge performance degradation, promote the development of bridge degradation and prediction models, promote the development of non-destructive testing and evaluation technologies, quantify the efficiency of bridge maintenance, repair, and reinforcement, optimize bridge maintenance operations, nurture the next generation of bridge maintenance management systems, and provide a basis for the government to formulate relevant policies.

6. Conclusion

Conclusions should state concisely the most important propositions of the paper as well as the author's views of the practical implications of the results.To sum up, the author believes that the safety and durability of bridge life cycle is of great importance, and the main countermeasures and methods are summarized as follows:

(1) Establish innovative design concept, timely revise design standards and specifications, increase the content of science and technology, and design excellent bridges.

(2) Promote the progress of construction technology, strengthen the project management and scientific monitoring of the whole process of bridge construction, reasonably arrange the construction period, strictly supervise and supervise the quality, strictly control the quality from the construction technology, and put an end to the occurrence of bridge construction accidents.

(3) Strengthen the bridge safety operation management, from the treatment of overload to operation safety, the whole process of traffic safety monitoring, in order to eliminate the serious damage of the bridge.

(4) It is suggested that the health monitoring of bridges should be carried out, and the maintenance funds should be invested. From the maintenance of damaged bridges to reinforcement and reinforcement, attention should be paid to the safety and durability of bridges in the life cycle. Only by careful design, careful construction, strengthening safety monitoring and safety management, can we ensure the long-term development of bridge engineering, quality first, benefit the people, ensure the smooth traffic lifeline, and realize the great rejuvenation of the Chinese nation.

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