Analysis of Highway Bridge Structural Vulnerability Based on PSHA

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Abstract: Damage or collapse of highway bridges can cause serious casualties and significant economic losses. Traffic layout is the context of various post-disaster reconstruction efforts, while bridges play an important role. Based on this, the analysis of highway bridge structural vulnerability based on PSHA is proposed. The damage of ground motion intensity to seismic function of highway bridge structures, the vibration of the distance in the PSHA to the power of highway bridge structure, and the damage of the stability of the highway bridge structure by earthquake spatial distribution can come to the conclusion about the vulnerability of the highway bridge.

Keywords: PSHA; Highway bridge; Structure; Vulnerability

1. Introduction

Bridges are important parts of the layout of various transportation networks. The proportion of bridges by trains, buses, and ships in all provinces, cities, and places in China is even more than 94%, such as Beijing-Tianjin Intercity Railway, Qingrong Intercity Railway and the other series of railway systems[1]. If the bridges in the road traffic networks are damaged by the influence of the external environment (such as the severity of the earthquake), there is a great possibility that some or even the entire traffic network will be broken, and the reliability of the network communication will be rapidly reduced. Although there are few casualties caused by bridge vibration or breakage, the damage of key links in the road traffic layout network will lead to the interruption of important traffic lifelines, and indirectly cause more serious casualties and economic losses. On the other hand, large bridges that are severely damaged are often difficult to get a complete repair in a short period of time, and thus will have a serious impact on the casualties and production life in the affected areas and the subsequent reconstruction work. Therefore, it is very important to ensure that the traffic lifeline continues to maintain traffic flow after damage in a certain aspect[2]. Therefore, how to effectively avoid dangerous areas when selecting bridges; how to ensure that the bridge construction beam structure has sufficient seismic resistance; how to screen out daily maintenance and key earthquake-resistant objects; how to make timely and correct anti-seismic rescue measures after earthquake occurs; how to select the best path to encounter the lowest risk of earthquake, and other problems are urgently need us to solve. Studying the reliability of inter-city highway transportation network connectivity has an important effect for guaranteeing the smoothness of roads after large-scale geological disasters or accidents, and is convenient for on-site personnel rescue and disaster relief. The use of scientific and effective traffic planning layout design is of great significance for the greatest impact of disaster or accidents reduction on the road network[3]. Bridge robustness is one of the most important factors in the earthquake loss system of road transport network systems. Bridges are often placed in key parts of the road transport network system, and the repairability of the bridge is very low, so it becomes a key point in the road transport network. Therefore, in general, the bridge is related to the normal operation of the entire road traffic network operating system, which plays a decisive role in the earthquake damage of the road traffic network.

2. Damage of Ground Motion Intensity to Seismic Function of Highway Bridge Structures

The hazard level of earthquakes mainly describes the potential dangers of earthquakes to society and people's production and life, as well as a series of natural phenomena along with geological disasters, such as frequent ground vibrations, fault fractures or soil damage. All in all, the earthquake effect that may be encountered in a certain period of time in a certain situation, its severity can be reflected by the earthquake vibration amplitude or the earthquake influence parameter[4]. The PSHA method specifically organizes all the data information that occurs within a certain range. Considering the frequency of the earthquake activity, the space of occurrence, and the randomness of the earthquake amplitude, a more flexible theoretical system is formed. A variety of earthquake can occur from the source, which is the magnitude. For estimating the earthquake information that occurs at a certain point in time, the distance of the source and the range distribution of the source are also necessary. For a known occurrence of earthquake, it is generally assumed that the earthquake frequency occurring at each point of the fault is under the same conditions. The projected locations are evenly distributed in space, so mathematical distances are used to determine the distance distribution from the source to the location of the accident. "Distance" sounds like a specific definition of vocabulary on the surface, but in fact there are different definitions by PSHA theoretical analysis[5]. Before the dynamic analysis, some parameters of the model need to be adjusted. On the premise of the previous investigation, the number of locations where the model occurs and the vibration frequency of the earthquake are modified. These two parameter settings also need to be repeatedly modified. It is necessary to ensure that the maximum displacement distance of the formation fracture affected by the source dynamics can keep pace with analysis results of the fiber model dynamics. And it is also necessary to perform multi-time and multi-entry earthquake wave frequency analysis and then repeat the adjustment according to the analysis result to avoid accidentality.

3. The Vibration of the Distance in the PSHA to the Power of Highway Bridge Structure

The selection of the appropriate organizational structure is the central content of the seismic design of the bridge structure. At the micro level, the organizational structure goal is a quantized value used to specifically measure the consequence and loss caused by the earthquake. The quantized value must be easy for the project decider to grasp and understand, for example, the number of casualties, the specific cost of repairs, and the specific time to repair, and so on[6]. However, because of the influence of various unclear factors, the specific quantized values of these performance targets cannot be accurately estimated. Therefore, it is necessary to take reliable measures to calculate the frequency of use to achieve or exceed the expected performance targets, and the possible consequences of a disaster are presented in the form of wave frequencies, making it more recognizable for road engineering stakeholders, including the public. For bridge actual engineering, the organizational structure target is closely related to the definition of the maximum damage degree in the earthquake fragility function. Therefore, it is also extremely important to determine the maximum damage of the component structure of the bridge, as shown in Table 1.

Table 1. Bridge Damage Indicators

Damage State	Damage Index
no	More than 0 and less than 1.00
Slight	More than 1.00 and less than 1.50
Medium	More than 1.50 and less than 3.71
Severe	More than 3.71 and less than 7.82

In the past research, the specific criteria for judging the damage of bridge engineering mainly include the principle of high damage, the principle of deformation damage, the principle of energy damage, the principle of double damage and the principle of basic functions damage. On the other hand, the principle of basic functions damage may directly or directly affect the seismic design concept of the project, emphasizing the application performance and damage degree of the construction to divide the security fortification.

4. Damage of the Stability of Highway Bridge Structure by Earthquake Spatial Distribution

In the construction of the bridge, the main function of the abutment is to support the main beam and restrict the large-scale horizontal displacement of the main beam under strong vibration. At the same time, the load-bearing wall and the side wall of the abutment have the effect of hiding the soil. Under the strong vibration of the earthquake in the real environment, the bearing capacity of the abutment becomes very complicated. On the one hand, the effect of the earthquake wave frequency will be effectively transmitted to the inside of the abutment by the abutment foundation and the background force, which will generate a pressure under the active pressure measurement inside the abutment. On the other hand, the impact between the support and main beam and the load-bearing wall will cause severe deformation of the abutment, resulting in the soil pressure under the passive abutment, as shown in Figure 1.

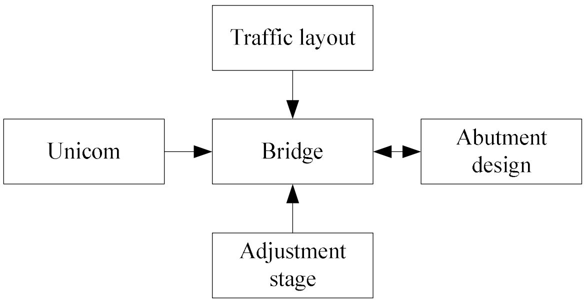

Figure 1. Abutment association

Nowadays, laws and regulations in China do not give specific details for the construction and design of the abutment. In this paper, for the abutment erection conditions, only the earthquake vibration between the support and the collision will be considered in a short time. The force and displacement distance will be based on advanced research results from abroad. Although in the MAZUS-MH-MR802118 issued by the US government in 2011, the four damage conditions of the abutment were specifically described, for example, a small crack in the abutment indicates that the abutment is slightly damaged; a relatively large displacement of the abutment (displacement is less than 7cm) means medium damage, and the vertical fracture of the abutment in the horizontal direction indicates serious damage to the abutment. However, research on how to quantify these damage indicators is rare. In fact, the relevant concept of PSHA is often regarded as a specific variable relationship, which makes the visual effect more intuitive and vivid. There is a certain necessity here to explain the annual vibration rate and the status of the recovery period. The annual vibration rate refers to the occurrence probability of the occurrence of the internal seismic source beyond the surface intensity within a specified period of time, which is obtained according to several years of statistics. Recovery period refers to the number of times that a certain vertical earthquake occurs within a specified time. Both are mathematically probabilistic definitions, and not mean that they will reappear within the specified time. According to the definition of annual vibration rate and recovery period, a formula can be found, and can transform the above-mentioned geological disaster into the organic relationship between PSHA and recovery period.

5. Conclusion

In this paper, the vulnerability of highway bridge structure based on PSHA is analyzed. Based on the relevant understanding mechanism structure of PSHA, the damage of bridge structure is adjusted according to the design data of highway bridge and the analysis of damage. It is hoped that the research in this paper can provide a theoretical basis for the vulnerability analysis of highway bridge structures based on PSHA.

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