Earthquake Damage Prediction Assessment for Xichang Urban Bridge Engineering

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SUMMARY:
Xichang is a city of southwest Sichuan. It is a important city in southwest China. There are several active faults near Xichang city. Earthquake with magnitude 7.5 has occurred in Xichang in history and the earthquake hazard is very serious. The maximum of earthquake intensity in some regions has reached Ⅹ degree. Xichang is one of the Ⅸ intensity degree earthquake resistance cities in China. In 2009, Xichang government started to make the earthquake disaster prevention and mitigation plan for urban regions. The plan aims to improve the capabilities of earthquake disaster reduction of Xichang. In the previous earthquakes, the bridge engineering are always seriously damaged. This directly impacts the earthquake disaster relief operations, such as rescue and reconstruction. Therefore the investigation and assessment of bridge engineering is necessary and very important for earthquake disaster prevention and mitigation plan for urban regions. Based on a brief introduction of the commonly used method for bridge damage prediction and investigation data of earthquake disaster prevention and mitigation plan of Xichang city, the paper uses empirical methods to make earthquake damage prediction assessment for the urban bridge engineering. The results show that most bridges of Xichang urban regions have poor seismic performance. They can not meet the requirement for Ⅸ intensity degree earthquake resistance. All of the bridges need seismic strengthening or reconstruction as soon as possible. Some advices on earthquake disaster mitigation of Xichang bridge engineering are also provided in the paper.

Keywords: Earthquake damage prediction assessment Bridge engineering Empirical method

1. GENERAL INSTRUCTIONS

The economic losses caused by the Wenchuan earthquake, which occurred on May 12, 2008, are enormous. Roads and infrastructure in Wenchuan County near the epicenter were heavily damaged, especially the bridges of National Highway 213 and the Dujiangyan—Wenchuan expressway. Most bridges of National Highway 213 are girder bridges, either simply supported or continuous. Laminated-rubber bearings are usually placed directly under the main girder of these bridges. The investigation of the girder bridges' performance on National Highway 2l3 after the Wenchuan earthquake shows that typical damage includes: span collapse, bearing displacement, shear key failure, destruction of the expansion joint, pounding of adjacent girders, and cracking of abutments. These damage phenomenon are similar to those observed in Chi—Chi earthquake in Taiwan. These types of earthquake damage of bridges on National Highway 213 and the Dujiangyan—Wenchuan expressway are described and discussed. The corresponding seismic design recommendations are proposed. (Li, Peng and Xu, 2008)

After the great earthquake, the government pay more attentions on disaster prevention and mitigation planning. From the end of 2008, most of the country-level cities in China have invested much money than they did before for unban earthquake disaster mitigation plan. Lifeline engineering is a very important part of cities and the plan. This article introduces the earthquake disaster prevention and mitigation plan of bridge engineering, which belong to lifeline engineering in Xichang. The results have a reference value.

2. OVERVIEW OF XICHANG BRIDGE ENGINEERING)

In the main distinct of Xichang, there are three major rivers. They are Dong River, Xi River and Hai River which all cross the area. There is also a river, Anning River, which runs through the valley. Many small tributaries flow from the both sides of the mountain into the Anning River. According to the field investigation, there are 29 bridges which have varying sizes in the working area. Eight bridges cross the Hai River, four cross the Dong River and four cross the Xi River. Most of the other bridges around Xichang are in the mountain areas. They cross some rivers such as Guanba River, Ezhang River, Datang River,Reshui River and so on. We should focus on the 16 bridges in the urban area in this article.

In the urban area, only a few bridges are built in recent years, most of the bridges are built for many years. Some bridges, which are built in 1960’s, even don’t have the blueprints. People built them only with their experience. Therefore, some of the bridges have a few of earthquake resistant measures and some have no engineering measures for earthquake resistant. In the 1990’s, the government of Xichang make some renovation and transformation for bridges. They widened the bridges, reinforced the piers and set anti-slip measures. These improve the seismic performance of the bridges. Xichang is 9 degree earthquake zone. We shall consider the impacts of the lifeline engineering when the intensity reaches ten degree.

Currently none of the bridges in Xichang can meet seismic requirement. The basic data and status of the bridges are showed in table 1.

Table.1 The basic data and status of the bridges

No.	bridge	Bridge type	Year	Span	Abutment	Bridge pier	Site
Hai River							
1	Guanhai bridge	Masonry arch bridge	2006	37×1	Stone mortar	Stone mortar	IIISand and gravel
2	Sanchakoudong road Hai River bridge	Precast concrete girder-type bridge	1976 (1987reconstruction)	8×3	U-Gravity	Physical gravity	IIISand and gravel
3	Mingzhuhuayuan Hai River bridge	Concrete slab beam bridge	2003	11×2			IIISand and gravel
4	Yaoshan Hai River bridge	Reinforced concrete slab beam bridge	1990	7×3	Stone mortar	Stone mortar	IIISand and gravel
5	Donghekou Hai River bridge	Reinforced concrete slab beam bridge	2000	7.5×2,8×1	Independent front wall	Physical gravity	IIISand and gravel
6	Jiancaishichang Hai River bridge	Masonry arch bridge	1977	21×2	=	Stone mortar	IIISand and gravel
7	Changfu Road Hai River bridge	T plate beam bridge	1991	20×1,29.5×1	U-Gravity	Double cylindrical concrete	II -III Sand and gravel
8	Shuinichang Hai River bridge	T plate beam bridge	1960’s	16×3	Stone mortar	Double cylindrical concrete	IIISand and gravel
Dong River							

9	Shengli bridge	Solid abdominal masonry arch bridge	1975	21×2,22.5×2	U-Gravity	Stone mortar	II Sand and gravel
10	Nanmen bridge	T plate beam bridge	1966 (1983reconstruction)	16.5×6	U-Gravity	Physical gravity	II Sand and gravel
11	Yihuan Road bridge	Precast concrete girder-type bridge	2009	28×2,38×1	U-Gravity	Physical gravity	II Sand and gravel
12	Dong River bridge	Prefabricated prestressed concrete hollow slab	1993	20×6,13×2	Stone mortar	6 solid cylindrical column pier	IIISand and gravel
Xi River							
13	Xi River bridge	Prefabricated prestressed concrete hollow slab	1993	20×3	Stone mortar	6 solid cylindrical column pier	II Sand and gravel
13	Changban bridge	T plate beam bridge	1966 （1983reconstruction）	22×2	U-Gravity	Physical gravity	II Clay
15	Wuyi bridge	Precast concrete girder-type bridge	1975 (2007reconstruction)	13.8×3	U-Gravity	Dual rectangular columns	II Sand and gravel
16	Ningyuan bridge	T plate beam bridge	2010rebuilt	15.6×3	U-Gravity	Physical gravity	II

3. EMPIRICAL METHODS OF BRIDGES EARTHQUAKE DAMAGE

Currently the main methods of bridges earthquake damage are specification checking method, pushover method, seismic response time history analysis method and empirical statistical method. There is no long-span bridge in Xichang. Considering the practice of unban earthquake disaster mitigation plan, we should choose an efficient and convenient method to do the earthquake damage prediction assessment. Therefore, we choose the empirical method as the main assessment method

Empirical methods we often use including Saburo Okubo Qing, Japan Society of Civil Engineers method, Zhu Meizhen method and Buckle method. Saburo Okubo Qing collected and analysis 30 highway bridges data which are seriously damaged by earthquake in 1982. He found 10 factors as the most important ones to make the earthquake damage prediction assessment, such as seismic intensity, site conditions, liquefaction, the upper structure types, bearing types, pier height, number of holes, bearing width, foundation form and materials of piers. He defined different values for each factors and multiplied the value of a bridge. The result was defined as the bridge’s vulnerability factor. If the vulnerability factor is greater than 30, the bridge is dangerous and its beams may fall off in earthquake.

In 1986, Japan scientists give out a new vulnerability analysis method of highway bridge seismic evaluation. The method is based on Saburo Okubo Qing method. They collected 124 earthquake damage bridge data and choose 15 factors such as design specifications, the upper structure type, the upper structure (curved and straight beam bridge), the materials of upper structure, bridge’s axis slope, resistance measures for falling beam, foundation type, pile height, site conditions, field liquefaction, stratum heterogeneity , soil contaminants, foundation’s materials and ground motion intensity. Then they used statistical method to get empirical formulations. The method includes cable-stayed bridge and suspension bridge as the upper structure. But it doesn’t consider the impact of seismic intensity. The peak ground motion implicitly assumed to be above the 0.25g.

In 1990, Zhu Meizhen developed a empirical method based on more than 100 bridges' data which are damaged in Tangshan, Haicheng and Tonghai earthquake. She choose 9 factors as the vulnerability factors, such as seismic intensity, site classification, failure of the foundation, upper structure type, bearing form of piers, the height of piers, material of piers, foundation form and length of bridge. She proposed a non-linear empirical method of highway bridge earthquake damage prediction assessment.

Buckle and his team researched the earthquake damage data of 114 bridges. All the damages are caused by 11 earthquakes in America from 1964 to 1991, such as Alaska earthquake and Costa Rica earthquake. They choose 12 factors as the vulnerability factors, such as peak ground motion, design specifications, the upper structure type, the upper structural shape, the hinge at mid-span, pier type, foundation type, material of pier, regularity, site condition, extent of liquefaction and bearing length. They use multi-parameter regression method to establish a empirical formulation of earthquake damage and impact factors. They found from their study that the peak ground motion, extent of liquefaction, design specifications and bearing support length are the most important factors affecting the bridge. The method also includes cable-stayed bridge and suspension bridge into the upper structure.

Zhu Meizhen method is often use for earthquake damage prediction assessment in China. But this method is based on relatively old data and considers only nine factors. Some important factors are not considered such as construction era and design specifications. This may lead mistakes for prediction. The results calculated by Zhu Meizhen method are show in table 2.

Table.2 The result calculated by Zhu method

bridge	intensity		
	7 degree	8 degree	9 degree
Guanhai bridge	medium	serious	serious
Sanchakoudong road Hai River bridge	medium	serious	destruction
Mingzhuhuayuan Hai River bridge	medium	serious	destruction
Yaoshan Hai River bridge	serious	destruction	destruction
Donghekou Hai River bridge	serious	destruction	destruction
Jiancaishichang Hai River bridge	medium	serious	serious
Changfu Road Hai River bridge	medium	serious	serious
Shuinichang Hai River bridge	serious	destruction	destruction
Shengli bridge	Largely intact	slight	slight
Nanmen bridge	Largely intact	slight	slight
Yihuan Road bridge	Largely intact	Largely intact	Largely intact
Dong River bridge	slight	medium	medium

Xi River bridge	Largely intact	slight	slight
Changban bridge	Largely intact	slight	slight
Wuyi bridge	Largely intact	slight	slight
Ningyuan bridge	Largely intact	slight	slight

Dalian university of technology propose a new prediction assessment method in 2007. They research 243 highway bridges earthquake damage data in China and compare them with the investigation data of similar bridges in Qingdao. They choose 13 factors as vulnerability factor, such as intensity, the site soil classification, foundation failure, construction age, resistant measure of earthquake, bridge main span length, upper structure, the form of piers, pier height, abutment height, foundation type, bearing form and bridge type. This method is the developments of Zhu Meizhen method. It is based on relatively new data and considers more factors. So it is more comprehensive than Zhu's method. The results calculated by Dalian university of technology method are showed in table 3.

Table.3 The result calculated by Ocean university method

bridge	intensity			
	7degree	8degree	9degree	10degree
Guanhai bridge	medium	serious	collapse	collapse
Sanchakoudong road Hai River bridge	slight	medium	serious	serious
Mingzhuhuayuan Hai River bridge	medium	serious	collapse	collapse
Yaoshan Hai River bridge	medium	serious	collapse	collapse
Donghekou Hai River bridge	slight	slight	medium	serious
Jiancaishichang Hai River bridge	medium	serious	collapse	collapse
Changfu Road Hai River bridge	slight	slight	medium	serious
Shuinichang Hai River bridge	serious	serious	collapse	collapse
Shengli bridge	medium	medium	serious	collapse
Nanmen bridge	Largely intact	slight	medium	serious
Yihuan Road bridge	Largely intact	Largely intact	Largely intact	slight
Dong River bridge	Largely intact	Largely intact	slight	medium
Xi River bridge	Largely intact	Largely intact	slight	medium
Changban bridge	Largely intact	slight	medium	medium
Wuyi bridge	Largely intact	slight	slight	medium

Ningyuan bridge	Largely intact	Largely intact	Largely intact	slight

Compare the two prediction results, we can find that the results calculated by Zhu's method are less serious than the other one. Zhu's method doesn't consider the situation of 10 degree earthquake, but Dalian university of technology's method considers the situation. Based on the investigation data, Dalian university of technology's method is more suitable. Therefore we choose Dalian university of technology's method as the main earthquake damage assessment prediction method for Xichang city.

4. SUGGESTION FOR EARTHQUAKE DISASTER MITIGATION OF BRIDGES IN XICHANG

1) Xichang is 9 degree earthquake zone. The task of earthquake disaster mitigation is relatively more urgent than most of the other cities in China. In the urban area, the seismic performance of bridges are generally poor and can't meet the requirements of 9 degree seismic resistant. All of the bridges should be examined as soon as possible. Based on the results, the bridges should be strengthen or rebuilt.

2) Considering the local economic condition and needs of emergency response, all the 16 bridges in urban area should be strengthen or rebuilt priority. We should ensure the main pathways of emergency relief have good conditions and the bridges on main road, such as Hangtian road and Chengnan road, have good seismic performance.

3) The depth of most rivers in Xichang are shallow when it is not the wet period. Most of the river bed are full of alluvium. We can choose several narrow place of river bed as the emergency crossing. If all the bridges are collapse in great earthquake, we can still use these emergency crossing to ensure the implementation of rescue.

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