EQUIVALENT ENERGY-BASED SEISMIC DESIGN OF HIGH SPEED RAIL BRIDGE

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The safety and comfort of train running on the bridge is the fundamental problem considered in the design of high speed rail bridge, so firstly the pier, girder and track structure should be stiff enough to satisfy the train running requirement. And the bridge bearing is the key member connecting the girder and pier of high speed rail bridge. In the current design code of high speed rail bridge in China, the performance goals corresponding to different earthquake intensities are usually not well defined, and by the design code the whole bridge structure retain the elastic state under small earthquake, and the ductility factor of pier must be less than 4.8. And the bearing and girder are considered to be designed being undamaged under large earthquake, in order to prevent the falling of girder. As it's obviously seen that the elastic design of small earthquake and the numerical verification of large earthquake are the main means to ensure the seismic design goal, and by the simple and rough design strategy it's hard to realize the performance design under different earthquake intensities. Considering the rapid development and distinct advantage of performance-based seismic design in last 20 years, and utilizing the adaptive design of bearing of high speed rail bridge, the performance-based seismic design can be realized and the modification of bearing will not influence the stiffness of the whole bridge system. In this paper, the bearing is selected and well designed to ensure the multiple performance level's design goal of high speed rail bridge, that is 'bearing sliding under small earthquake, pier yielding under moderate earthquake, and ductility factor less than 4.8 and bearing displacement controlled to prevent the falling of girder under large earthquake'. To realize the design goal, an equivalent energy-based seismic design method is proposed in this paper, in which the input energy of earthquake is considered to transformed into elastic energy and plastic energy, and the bearing is the vital part to control the transmit and transform process. The theory and formulas is established to efficiently and accurately accomplish the seismic design of high speed rail bridge. The most prominent advantage of the equivalent energy-based seismic design method is no need of iteration in the design process.

In reality, the spherical steel bearing and pot rubber bearing frequently used in the high speed rail bridge are prone to be damaged in the severe earthquake. So in this paper the friction pendulum isolator is adopted to realize the bearing sliding in the small earthquake, in order to release the inertial force from the girder, by which the bearing can be ensured to be operational in earthquake. And the stiffness for running train can be guaranteed by adding stiff connection, which is designed to be sheared off while earthquake occurs. Figure 1 describes the main components of the typical high speed rail bridge in China with a train running on. In the Figure 1, the girder, bearing, and track structure are shown. In the Figure 2 and Figure 3, the force-displacement relationships of bearing and pier are given respectively. By the equivalent energy-based method proposed in this paper, the performance design goal, that is 'bearing sliding under small earthquake, pier yielding under moderate earthquake, and ductility factor less than 4.8 and bearing displacement controlled to prevent the falling of girder under large earthquake', is realized by adapting the bearing. Figure 4 schematically explains the concept of the energy-based design.

Based on the proposed equivalent energy-based design method, the high speed rail bridge perform different and specific performance under different earthquake intensities. The time history responses of bridge corresponding to multiple earthquake records are adopted for numerical verification, by which the accuracy and effectiveness of proposed energy-based design method is studied. As shown in Figure 5-7, the comparison of design and real time history response value (t-h value or t-h mean value)of bearing displacement, pier displacement and pier shear force are given. It can be seen that the values nearly equal to each other in statics. The proposed equivalent energy-based method can be used to effectively realize the performance-based seismic design of high speed rail bridge. The research results can provide a support of seismic design of bearing of high speed rail bridge.

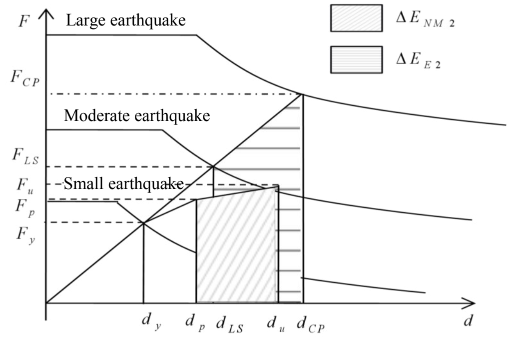
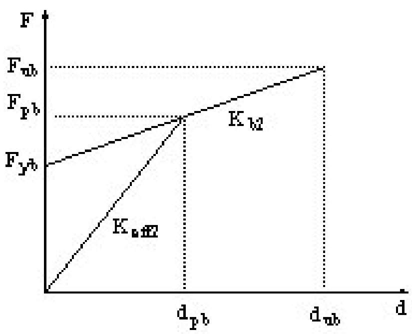


Figure 1 High speed rail bridge and running train

Figure 2 Equivalent energy-based design method



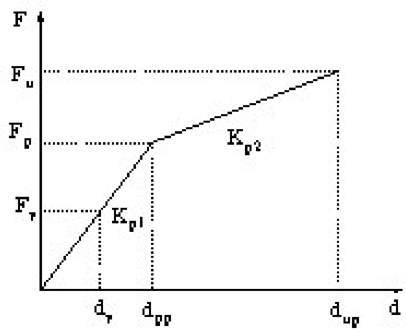


Figure 3 Force-displacement of friction pendulum bearing

Figure 4 Force-displacement of bridge pier

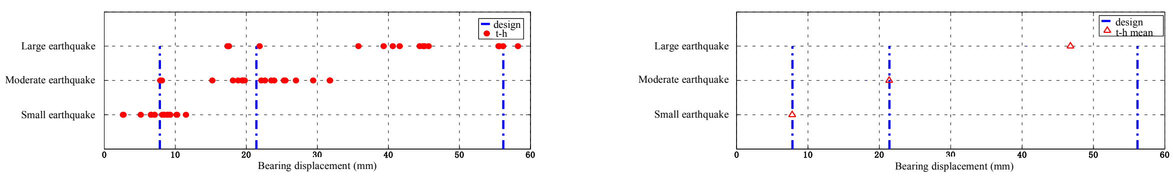


Figure 5 Comparison of design displacement and real time history displacement of bearing

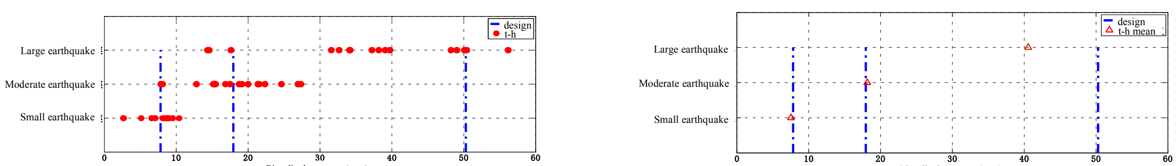


Figure 6 Figure 5 Comparison of design displacement and real time history displacement of bridge pier

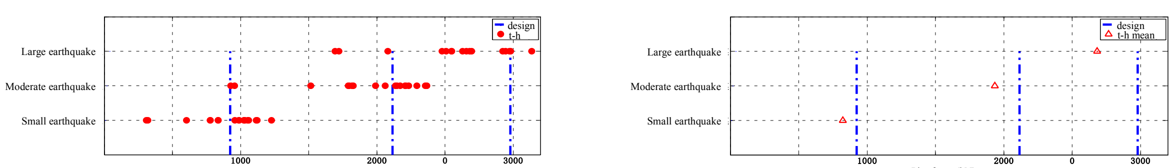


Figure 7 Comparison of design force and real time history force of bridge pier7

DYNAMIC ANALYSIS AND REINFORCEMENT DESIGN OF CHANG QING BRIDGE

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Concrete-filled steel tube arch bridges have many advantages, such as high stiffness, great bearing capacity and convenient construction. There are over 200 concrete-filled steel tube arch bridges had been built in China during 1990-2005. Though the development speed of this kind of bridge is very fast, some structure and construction defects are gradually apparent in service. The low dynamic rigidity of bridge deck is one main problem of them.

Taking Changqing Bridge in Shenyang as the background, this paper analyse the dynamic characteristics of old bridge and based on the velocity-time history and acceleration time history, the comfort evaluation of this bredge is conducted. The results show that the bridge is uncomfortable. This paper also proposed reinforcement scheme that is adding two longitudinal beams to original bridge deck. The comfortable degree of reinforced bridge is better that original bridge, which is comfortable.

This paper gives a dynamic analysis and comfort evaluation case of a concrete-filled steel tube arch bridge and proposes the corresponding reinforcement scheme of this bridge. The results show that the reinforcement scheme is effect to relieve the vibration of the bridge deck. This research contributes to the comfort evaluation and reinforcement of Concrete-filled steel tube arch bridges.

Seismic Design Method for Bridge Bents with Structural Fuses

To improve the seismic performance of bridge in transverse direction, the bridge bents with double columns by using buckling-restrained braces(BRBs) was proposed based-on the concept of structural fuse. The seismic design parameters of bridge bents with BRBs were systematically analyzed. The relationship between length of the BRBs core and shear span ratio, the ratio of intercolumniation and diameter or side length of the pier section is derived from the point of seismic capability for the new structural system, and the length range of core section of BRBs was also determined. The inelastic response spectra for a single-degree-of-freedom(SDOF) system including structural fuse was developed from the perspective of seismic demand, these are in a format amenable for use in design of similar structures with a wide range of response characteristics. Then the displacement-based design method of bridge bents with BRBs was developed based on the seismic capability and demand. Finally, the feasibility of the proposed method was validated by using an example on the seismic design for a bridge bent.