Seismic Behavior Analysis of Steel Tower of Self-anchored Suspension Bridge

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Abstract: Self-anchored suspension bridge is composed of tower and its foundation, stiffened beam, main cable, sling, side pier and its foundation, auxiliary pier and its foundation. The performance and importance of the components of the bridge are different. The main tower of self-anchored suspension bridge is a very important component. Once the injury and damage occur under earthquake, it is not only difficult to inspect and repair, let alone replace. This paper calculates the seismic performance of self-anchored suspension bridge steel tower based on the application of Wuhan Gutian Bridge steel tower.

Keywords: Self-anchored suspension bridge; Steel tower; Seismic performance; Analysis

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1. Introduction

The vulnerability of each component of bridge structure under earthquake is different. The main damage of the bridge structure caused by the earthquake are mainly：(1) the damage of the superstructure caused by the failure of the supporting connection; (2) failure of support connections: bridge bearings, expansion joints and shear keys have always been considered to be a relatively weak link in the seismic performance of bridge structure system; (3) tower, abutment, pier failure, serious damage phenomena include collapse of pier abutment, fracture and serious tilt; (4) bridge foundation failure.

Self-anchored suspension bridge is composed of tower and its foundation, stiffened beam, main cable, sling, side pier and its foundation. Under seismic action, the seismic wave is transmitted from foundation to superstructure, and the seismic wave that reaches the upper structure is reflected again and then returns to the foundation of tower pier. The reflection of seismic waves forms the seismic inertia force, and the seismic inertia force of the bridge deck system is fed back to the tower (pier) and its foundation in two directions.

2. Project Overview

The span of Wuhan Gutian Bridge is arranged as (48+57+110+110+110+57+48) m, of which 2 * (48+57+16.5) m is composed of pre-stressed concrete box girder structure, and the rest are composed of steel concrete composite beams in the form of side main girder. As shown in figure 1.[1]

The main tower is a frame structure, which consists of four parts: the lower column, the middle tower column, the upper tower column and the tower top beam. The middle tower column and the tower top cross beam are steel structures, and the rest are concrete structures .The height of the Hanyang side and Hankou side tower bottom (top height of the cap) is 13.50m and 18.50m respectively, and the tower height is 69.624m and 64.624m respectively. The horizontal distance of the tower column bridge is 40m.As shown in figure 2.

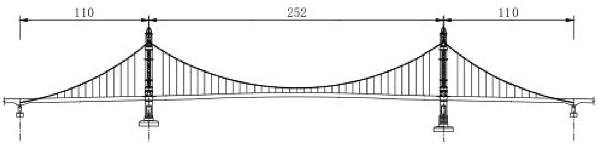

Figure 1. Elevation of Main Bridge (unit: m)

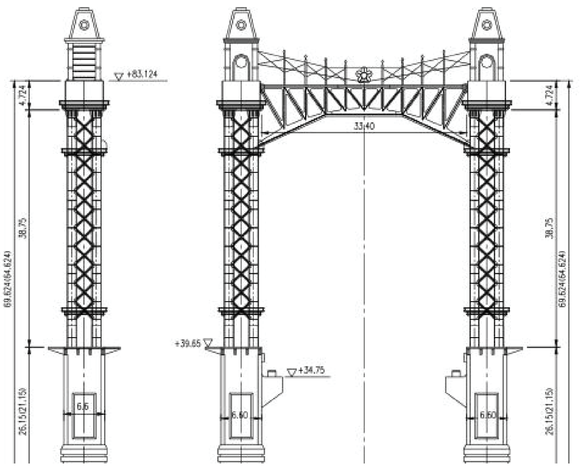

Figure 2. Schematic Diagram of Main Tower Structure (unit: mm)

3. Seismic Performance Targets

The main seismic performance targets of the bridge are summarized as follows:

(1)The main tower, main beam, foundation and other important structural members have no damage under E1 earthquake, and the structure works in the elastic range. Although repairable damage can occur locally under the action of the E2 earthquake, it is required that after the earthquake occurs, the traffic of the vehicle is basically not affected.

(2)Side piers, the components of bridge structure which are easy to repair are not damaged under E1 earthquake, and the structure works in elastic range. Under the action of E2 earthquake, the structure does not collapse and can be repaired after the earthquake, which can be used for emergency rescue vehicles to pass through.

The seismic checking calculation of the main bridge structure according to the aseismic calculation method of Detailed Rules for Seismic Design of Highway Bridges, according to the reinforcement of section, using fiber element, considering the most unfavorable axial force combination under dead load and earthquake action to the main tower and side pier, The control section of the most unfavorable single pile of auxiliary pier and pile group foundation is analyzed by P-M-f analysis, and the bending resistance of each control section is obtained, and the seismic performance is checked and calculated.[3]

4. Seismic Checking Calculation of Steel Tower

The space finite element model is used for the main bridge, the main beam is simulated by the plate beam element, the deck slab is simulated by the plate element, the longitudinal and transverse beam is simulated by the beam element, the cable and suspension are simulated by the cable element, and the sag effect of the cable is modified by Ernst formula. The influence of cable force on the geometric stiffness of the structure is also considered.[4] The towers and piers are simulated by beam element, and the mass is added to the deck of the bridge.[5]

Figure 3. Bridge State Calculation Schema

The strength checking calculation method of steel main tower is allowable stress method.

The main steel tower adopts Q345qD, which conforms to the standard of "Bridge structural Steel" (GBP/T714-2008). The main mechanical properties of the tower can be found in the following steel mechanical property index. [6]

Under the action of E1 earthquake, the increase coefficient of allowable stress value after the combination of seismic load and dead load is considered as 1.5, namely[σ]=1.5*195=292.5Mpa.

Under the action of E2 earthquake, the allowable stress values after the combination of seismic load and dead load adopt yield stress，namely[σs]=315.0Mpa.The results of the physical examination are shown in Table 1:[7]

Table 1. Strength Checking of Main Steel Tower

effect combination	bar	position	The stress (constant load plus or minus longitudinal seismic action) (MPa)	The stress (constant load plus/plus horizontal seismic action) (MPa)	Allowable stress (MPa)	Whether to meet
Constant load plus or minus E1 earthquake action	The towerpos	The bottom of the column	128	150	292.5	satisfaction
Constant load plus or minus E2 earthquake action		The bottom of the column	190	215	315.0	satisfaction

As can be seen from the table, the column of steel tower meets the requirements of seismic design.

5. Conclusion

The spatial dynamic calculation model is established to calculate the dynamic characteristics of the structure based on the example of steel tower of Wuhan Gutian Bridge. The seismic response analysis of the main bridge structure is carried out by using the response spectrum method and nonlinear time-history analysis method. The seismic response of the steel tower of Gutian Bridge under two fortification levels E1 (50 years transcendence probability 10) and E2 (50 years beyond the probability of 2%) has been studied. The checking calculation structure shows that the steel tower of self-anchored suspension bridge meets the seismic performance goal and the safety performance is better.[8]

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