Seismic Pounding Response of Girder Bridges Considering Lateral Stiffness of Ground Motion

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Keywords: lateral pier stiffness; earthquake; pounding; transition pier

Abstract. In order to study the effect of pounding at expansion joints of beam bridge on the seismic responses of bridge structure during earthquake, the research is based on multi-particle of single degree of freedom system, and the pounding effects of adjacent girders on seismic responses with 3 different of farming waves are studied by using nonlinear vibration equations of motion. The results indicated that the influence of ratio of peak moment on lateral rigidity may attenuate or increase with the reduce of lateral pier stiffness, which depends on a great extent on the effective peak acceleration (EPA) and duration. With the decreasing lateral pier stiffness, the maximum collision force between beams first increased and then decreased. The main parameters influencing of collision number is effective peak acceleration(EPA) when lateral pier stiffness is big, otherwise, duration is the main parameters .The influence of the effective peak acceleration(EPA) is attenuated gradually with the reduce of the lateral pier stiffness, while the influence of duration increased.

1 Introduction

The bridge usually produces the vibration of longitudinal and transverse during the earthquake along the axis direction. Because of the symmetrical design, the effect of coupling deformation term in lognitudinal and in transverse direction is ignored. The collision can be considered as the displacement caused by flexural vibration which exceeds the gap in expansion joints, eventually causing the diseases such as girder decreasing tendency. The diseases shows a highfrequency for small and medium-span bridges in WenChuan earthquakes, which has a serially delayed in traffic and rescue process. Therefore, the seismic response of beam bridge on pounding has became a serious problem to be solved. At present, there has extensive research both domestic and foreign scholars in the collision, Dwairi and Kowalskey [1] indicates that the relative stiffness of the beam pier has an important influence on the continuous girder bridge of regularity. Yi Zheng[2] studied the impact of relative stiffness, rigidity distribution between girders and piers size regularity, but it takes just few samples and qualitative analysis. Yang Yumin[3] analyzed the earthquake response of the structure and its fractal characteristics consider the main span across the side ratio, but only by changing the lateral bending stiffness of the beam to adjust the horizontal flexural rigidity ratio, which ignore the effect of Lateral Pier stiffness. Chen Liang[4] took a 4-span continuous girder bridge as example to study the effect of lateral stiffness ratio pier, then established the divide indicators of continuous beam bridge, but it is not deep enough for transitional forms pier beam bridge expansion joints.

2 Theoretical Model

Two continuous beam bridges are selected, and the spatial variation of ground motion for longitudinal is ignore. The model takes the beam element to simulate the main beam, the pier is simulated by elastoplastic beam element, and the delay system for rubber bearings, expansion joints for the contact elements. Schemes of bridge models shown in Figure 1.

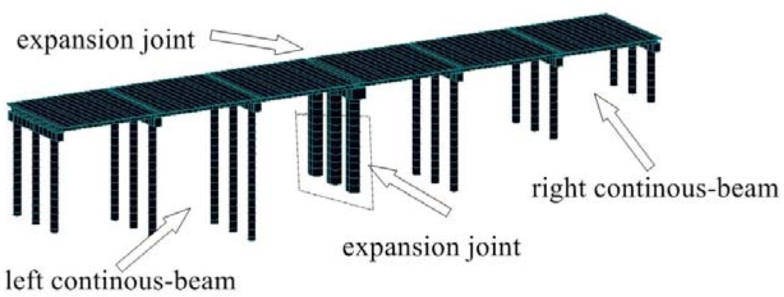


Fig.1 Schemes of bridge models

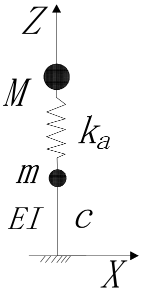


Fig.2 Analytical model

To facilitate the influence of the lateral stiffness on transition pier, the paper set up the structural dynamic simplified model including the isolation damping bearings and pier body composition,which is shown Figure 2. The vibration of the main beam is simplified as a single degree of freedom nonlinear system which take the vibration of ground displacement as excitation. Considering the impact of quality, the model assumed that the quality of the bridge piers and the transition to a centralized of M、m,anti-push rigidity is k_b, shear of the isolation bearing deformation $X_a(t)$, with the displacement steady relative to the bridge is q_a. and the restoring force is [5]

$$T(t)=k_a(t)x_a(t)+c_a\dot{x}_a(t)+f_a(t)z_a(t) \quad (1)$$

In which, K_a is plastic stiffness of isolation bearing ;c_a is damping coefficient;f_a is yield force; z_a is hysteresis displacement

the system of vibration equation：

$$\begin{cases} M(\dot{x}_a+\dot{q}_a)+[k_a(t)x_a(t)+c_a\dot{x}_a(t)+f_a(t)z_a(t)]+M\ddot{x}_a=0 \\ m\dot{q}_a+k_bq_a-[k_a(t)x_a(t)+c_a\dot{x}_a(t)+f_a(t)z_a(t)]+m\ddot{x}_a=0 \end{cases} \quad (2)$$

Take the period ratio T_1/T_2 is 0.7. In order to simulate the process of collision between two joint ,it takes damping ratio of concret 5% [6-8],and take the Rayleigh damping to analysis linear and nonlinear process, which shown in Figure 3.

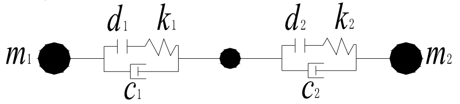


Fig.3 Pounding model of continuous bridge

Impaction stiffness is equal to the longitudinal stiffness of the shorter main beam,and the coefficient of restitution is 1.0[9-10], the relationship of nonlinear contact elements force － displacement is

$$f=\begin{cases} \lambda(d+x_s) & d+x_s<0 \\ 0 & d+x_s\geq 0 \end{cases} \quad (3)$$

In which, d is the gap between Joints,x_s is the relative displacement , λ is contact stiffness。

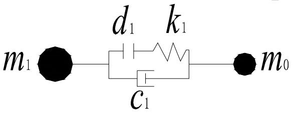


Fig.4 Schematic diagrams of contact element

3 Pounding Response of Seismic

This paper takes three earthquake waves, which are acceleration response spectra similar to the goal, and their peak acceleration were 0.366g, 0.526 g, 0.417 g.Fig.5 and Fig.6 shows the longitudinal acceleration time-history curve.

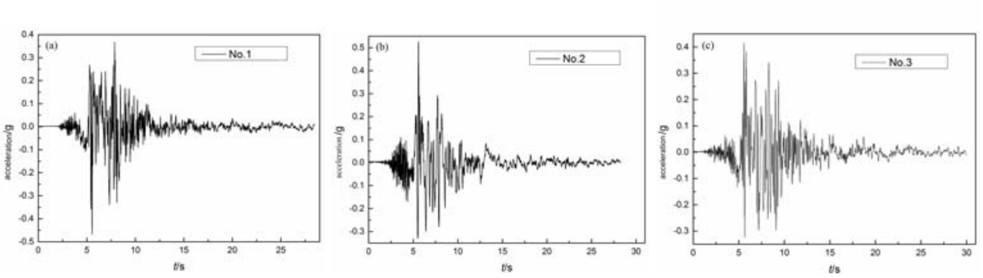
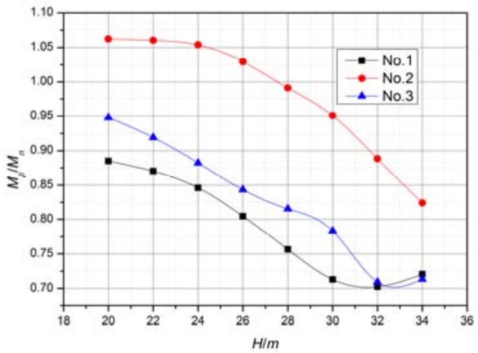


Fig.5 Longitudinal acceleration time-history curve

3.1 Result analysis

The changing of transition pier lateral stiffness depends on the height. Pier height *H* is took 20m, 22m, 24m, 26m, 28m, 30m, 32m and 34m. Ratio of peak moment of lateral pier stiffness *Mp* / *Mn* (where p represents consideration collision effect, n shows without considering the time of collision) and peak value of pounding force are shown in Fig. 6 and Fig. 7.



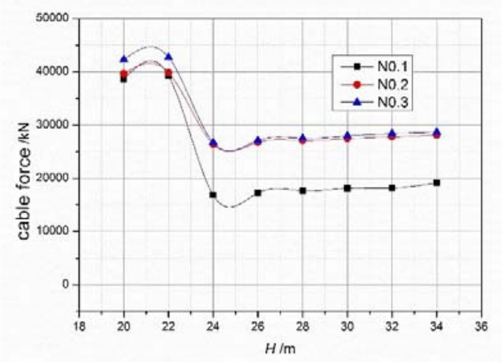
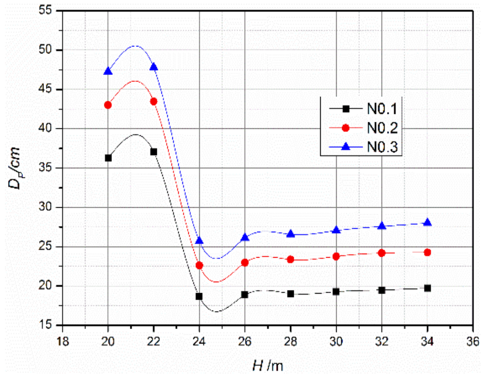


Fig.6 Ratio of peak moment of lateral pier stiffness

Fig.7 Peak value of pounding force

Figure 6 shows that the moment of collision effects have a significant impact on the pier at the end. With the decrease of transverse stiffness, the effect of peak moment for collision ratio *Mp* / *Mn* decreased proportionally ,which is close to linear. The seismic wave No.2 shows that when *H* < 28m, the moment of transitional Pier has a larger effect than the value without considering the pounding effect, means that *Mp* / *Mn*> 1. when *H*>28m, *Mp*/*Mn*<1. Therefore, ratio of peak moment of lateral pier stiffness is largely depends on the seismic waves peak and duration related. As can be seen from Fig. 7, with the increase of height *H*, it may increase the maximum impact force, or reduced. Therefore, the design of transition pier should meeting the requirements of impact on the beam anti-crash performance.



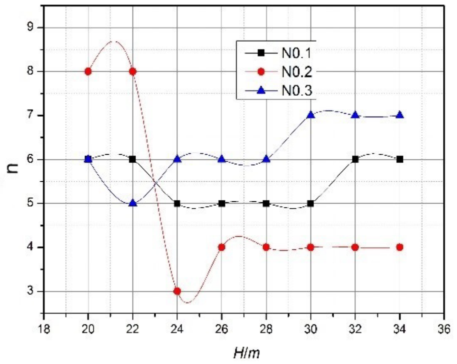


Fig.8 Peak displacement between left and right girder

Fig.9 Numbers of collision

Figure 8 shows the peak displacement of girder between left girder and right girder.The smaller lateral pier stiffness is, the smaller the influence of the beam relative displacement is. With the decrease of the transition pier transverse stiffness of joints,the effect of relative displacement is urgently reduced. Although the relative displacement will be a slight increase, but soon it will stabilize to the minimum place. Figure 9 shows that the peak acceleration of seismic waves and the duration is associated with the frequency of collisions. To No.2,for the short duration, it have higher frequency than relatively small lateral stiffness. No.3 is close to No.2 in effective peak acceleration ,but the value of No.3 is larger because of the longer duration.

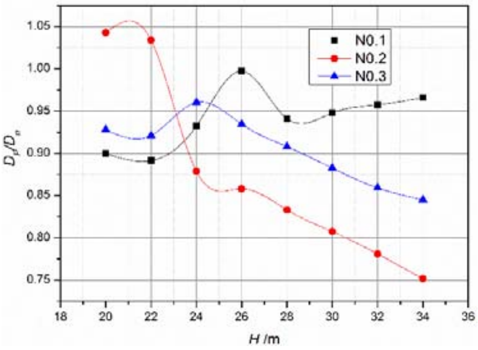


Fig.10 Peak displacement amplification between left girder and right girder

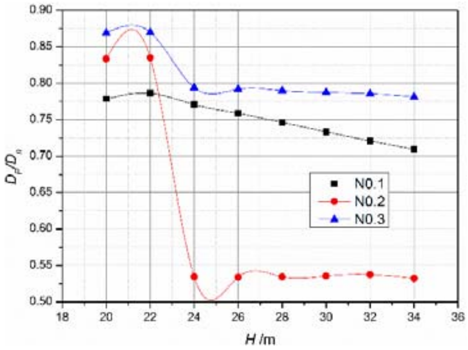


Fig.11 Relative displacement amplification of the transitional pier

As is shown in Figure 10, with the decrease of lateral stiffness, relative displacement amplification between left girder and right girder D_P / D_n is decrease. And in most cases, the relatively displacement considering collision is less than the displacement without congsidering collision. Therefore, peak displacement amplification of the transitional pier may reduced or increase. Figure 11 shows the relative displacement amplification between left girder and right girder. With the increasing of pier height, the maximal ratio of relative displacement showed a decreasing tendency

4 Summary

1) With the reducing of the transverse stiffness , the ratio of peak moment of lateral pier stiffness on collision may increase, or reduced, which is largely depends on the peak acceleration and duration of seismic waves;

2) the more *H* is, it may increase the maximum impact force, or reduced. Therefore, the design of transition pier should meeting the requirements of impact on the beam anti-crash performance.

3) With the decrease of transverse stiffness, the relative displacement amplification is reduced under earthquake action, but the impact of acceleration is increased. Therefore, it is feasible to improve the problem of collision response by adjusting the transverse stiffness in engineering practice.

Acknowledgements

This work was financially supported by the National Natural Science Foundation (51408040, 51408042), Program of Yunnan Provincial Transport Department of Science and Technology (2013(A)02)).

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