学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Seismic performance of curved highway bridges with steel bearings under serious earthquakes
(鋼製支承を有する曲線格子高架橋の地震応答性状に関する研究)

As urban areas have become more congested and highway interchanges have become more complex, horizontally curved composite steel I girder bridges have become an essential component in highway infrastructure. These types of bridges are key to providing smooth transitions from one highway to the next, allowing for a seamless flow of traffic. Unfortunately, bridges with curved configurations may sustain severe damage owing to rotation of the superstructure or displacement towards the outside of the curve due to the complex vibrations that occur during serious earthquakes. So how to improve the seismic behavior of curved viaduct becomes important during strong earthquakes. Stopper installed at both sides of roller bearing in tangential direction, cable restrainer equipped between adjacent superstructures, viscous damper installed at expansion joint and shock absorber device set between roller bearing and stopper are all evaluated respectively in this thesis.

Traditional steel bearings are very common, but they are easy to be broken in earthquakes. Recently roller bearings equipped with stopper are installed on top of piers. Because stopper can be easily installed and the price is not expensive, so it has wide application prospect in future. Therefore, the effect of stopper together with cable restrainer on mitigating curved viaduct damage during serious earthquake is carried out. The relationship between different stopper values and the different types of damages is obtained. The calculated results clearly demonstrate that roller bearing with stopper could provide an effective means for overcoming the potential problems associated with deck unseating. In addition, as stopper value decreases, the possibility of deck unseating damage decreases. According to evaluation of pier inclination damage, the results could be divided into three parts. In first part, as stopper value is less than cable restrainer's slack value of 4 cm, residual pier inclination decreases with stopper value increasing. In second part, as stopper value is larger than cable restrainer's slack value but less than expansion joint gap of 10 cm, residual pier inclination increases with stopper value increasing. In third part, as stopper value is larger than expansion joint gap of 10 cm, residual pier inclination presents fluctuating curve.

Recently, cable restrainer installed at curved viaduct can significantly reduce the possibility of deck unseating damage. In this thesis, the effect of stiffness and slack value of cable restrainer on curved viaduct damage is presented. Curved viaducts without cable restrainers are more vulnerable to deck unseating damage. In addition, the possibility of deck unseating is reduced by increasing the stiffness of cable restrainers. According to evaluation of pier inclination damage, viaducts with cable restrainers present less residual pier inclination than those without cable restrainers. Moreover, as stiffness of cable restrainer increases, residual pier inclination decreases. So cable restrainers with large stiffness are appropriate to be used to reduce pier damage. The possibility of deck unseating is reduced by decreasing the slack value of cable restrainers. As slack value of cable restrainer decreases, residual pier inclination decreases. So viaduct with slack value, 2 cm and 3 cm, presents no pier inclination damage. Hence cable restrainers with less slack value are appropriate to be used to reduce pier damage.

In addition, application of viscous dampers to viaducts has gained significant attention in recent years. Due to its large resistance force and energy dissipation capacity, viscous dampers have wide application prospect. The most advantage of viscous dampers is that it shows no resistance forces under slow relative movements of segments results from thermal changes, creep and shrinkage effects. It is only activated when earthquake happens. Therefore, this thesis analyzes the overall performance of highway viaducts with different kinds of viscous dampers and different stopper values. The relationships between different kinds of viscous dampers, different stopper values, and curved viaduct damage have been found respectively. Stopper can effectively reduce deck unseating possibility. However, deck unseating possibility could also be significantly reduced in case of D2000 because of its large resistance force and stiffness. Maximum closing relative displacement could be significantly reduced in case of viscous dampers. In addition, maximum closing relative displacement obviously decreases as damper's resistance force and stiffness increases. Viaducts with smaller stopper value present less residual pier inclination. As stopper value increases, residual pier inclination increases. Comparing with other piers, P1, fixed bearings on top of it, exhibits smallest residual pier inclination. Viaducts with viscous dampers present less residual pier inclination than those without viscous dampers. Finally, residual pier inclination, maximum pier inclination, residual curvature and maximum curvature at piers bases present similar change trend for all cases. The calculation results demonstrated that stopper value plays a more important role in piers damage than viscous damper.

In recent years, the effects of shock absorber devices installed between adjacent viaduct segments on reducing pounding forces, have been studied by many researchers. But the effectiveness of shock absorber devices installed between roller bearing and stopper on reducing pounding damage, is lack. In this thesis, calculation results clearly show that the curved viaduct with shock absorber devices between roller bearing and stopper present less damage. In addition, the effect of stiffness and thickness of shock absorber devices on mitigating curved viaduct damage is evaluated respectively. Besides, strain hardening, strain softening and elastic shock absorber devices are also analyzed in this thesis. Curved viaducts without shock absorber devices are more likely subject to deck unseating damage. As stiffness and thickness of shock absorber devices increases, the pounding forces between roller bearing and stopper gradually decrease. Pounding forces between roller bearing and stopper play more important influence on bearing damage and piers bases' damages than fixed bearing forces. As stiffness and thickness of shock absorber device increases, residual pier inclination decreases. Strain softening SAD is more effective in reducing residual pier inclination and pounding forces between roller bearing and stopper. Curved viaduct with strain softening shock absorber devices exhibits less viaduct damage.