Research on Subgrade and Pavement Construction Technology of Highway Bridge Transition Section

Hongyan Yin, Li Tang, Dongxia Liu

Chongqing Vocational College of Transportation, Chongqing 402247, China

Keywords: Bridge-Subgrade Transition Section, Usual Structure Form, Disease, Fem Model

Abstract: In the last two decades, with rapid development of infrastructure construction in China, a large number of roads have been constructed. The bridge-subgrade transition section is the position where bridge and subgrade are connected. The structure includes a sudden change of the flexible foundation and the rigid foundation. The disease could be more severe than the ordinary road sections, which could lead to hidden dangers in traffic safety. Therefore, this paper analyzes the influence stress change of pavement structure due to structural change in bridge-subgrade transition section, which has reference significance for the future design and construction.

1. Introduction

With the rapid development of expressways and high-speed railways, higher requirements have been placed on the ride comfort, comfort and safety of road-bridge transitions, especially the rapid development of China's high-speed railways in recent years has made road-bridge transitions and vehicles The state of stress has been valued. In the field of highways and railways, many scholars have studied the mechanical state of road-bridge transitions.

2. Common Structural Forms and Diseases of Road-Bridge Transition

In order to analyze the impact of the structural change of the road bridge transition section on the stress, the transition section between the concrete bridge and the roadbed that is prone to non-differential settlement problems and the transition section between the steel box girder bridge and the approach bridge are summarized in this chapter. Related structural forms commonly used at home and abroad have selected the structural forms of road and bridge transition sections of two typical structures as the object of subsequent finite element analysis.

2.1 Common Structural Forms of the Transition Section of the Cement Concrete Bridge

At present, domestic design codes do not uniformly specify the structural form of the highway bridge transition section where the concrete bridge is connected to the roadbed, only the allowable post-construction settlement of the roadbed at the road bridge junction is specified, as shown in Table 1.

Table 1: Highway Grade and Engineering Construction Position

Highway grade	Project location		
	Abutment and Embankment	Culvert, box culvert, passage	General section
Expressway, first class highway	⩽0.10	⩽0.20	⩽0.30
D	⩽0.20	⩽0.30	⩽0.50

* Note: The post-construction settlement control standards for secondary non-arterial roads and below secondary roads can be appropriately relaxed compared with secondary roads after demonstration.

In actual engineering, most designers design road and bridge transition sections based on previous experience on the basis of meeting the requirements of the code.The common structural forms are as follows.

At present, a reinforced concrete slab is cast in place on the subgrade fill in the transition section,

DOI: 10.25236/acete.2019.083

and one end of the slab is supported on a rigid abutment. The bending stiffness of the reinforced concrete slab is used to increase the stiffness and eliminate the transition section structure. The method of the wrong platform, that is, the method of setting the bridgehead slab, has been most widely used in highways, and has achieved good results. However, the bridgehead slab cannot eradicate differential settlement, and requires subsequent continuous maintenance work to slow down Destruction of road bridge transition sections. Zhang Hong et al summarized the current design methods of bridgehead slabs in China, and divided the types of slabs into three types: equal thickness, variable thickness and step type. Positioned and low-positioned. The thickness of the plank is between 20cm-40cm and the length is about 6m-12m according to the bridge type.

In addition, Qu Zhanhui et al. Proposed a flexible slab based on the analysis of the mechanism of the flexible slab treatment measures in the transition section of the road and bridge, and with reference to the test data of large scale settlement platform tests and the results of finite element simulation and topology optimization. Design method. The flexible slab uses the geogrid as the carrier, which can limit the lateral deformation of the subgrade filler, thereby turning the subgrade into a “floor” as a whole. The layout of the geogrid is shown in Figure1. The treatment effect It is related to the overall modulus of the complex composed of the geocell and the backfill.Generally speaking, the larger the modulus, the better the disposal effect.

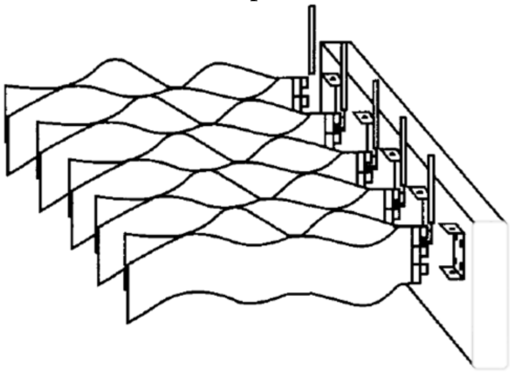

Fig.1 Arrangement of Flexible Laminated Geotechnical Cells

For railway road-bridge transition sections, the high-speed railway design specification specifies the structural forms that can be adopted for high-speed railway road-bridge transition section. It adopts the longitudinal inverted trapezoidal transition form along the line, and the transition section The material of the inverted trapezoidal part is made of graded crushed stone mixed with 3% cement, and the surface of the bed is made of graded crushed stone mixed with 5% cement.The length l of the transition section is determined by Equation 1.

$L = a + (Hh) \times n$ Equation 1

Where:

H--height behind the platform (m)

h-the thickness of the surface of the bed (m);

a-the length of the bottom of the inverted trapezoid along the line, generally 3m ~ 5m;

n ---- constant, generally 2 ~ 5.

There are several structural forms of road-bridge transition sections commonly used in high-speed railway passenger dedicated lines in China. Among them, the road-bridge transition section of the Qinhuangdao-Shenzhen Passenger Dedicated Line adopts two methods of filling the roadbed with coarse graded filler and filling the roadbed with reinforced soil. Looking at the operation situation in the past, the effect is better; the road-bridge transition section of the Wuhan-Guangzhou High Speed Railway and Zhengxi High Speed Railway adopts the form of graded crushed stone and cement.

2.2 Main Diseases in Road-Bridge Transition

The common diseases of the concrete bridge transition section are summarized, mainly including the following forms.

(1)Pavement cracks. There are several reasons for this. One is that the driving load is too large, which causes the asphalt layer to have excessive tensile stress and insufficient tensile strength to cause cracks. The second is that when the plank is broken, the cracks will reflect upwards. This causes reflective cracks in the asphalt pavement; third, excessive tensile stress caused by the difference in base stiffness causes cracks. The direct cause of road surface cracking is that the tensile stress on the asphalt layer is higher than its tensile strength.

(2)The breakage of the bridge slab at the bridge head is mainly due to the vehicle's excessive load and soil foundation settlement or soil erosion caused by the bottom of the slab to be emptied, the slab is not enough to withstand the effects of gravity and driving loads, and the cement concrete The tensile strength of the slab is relatively poor, so the bottom of the slab is first broken and cracks occur, which causes the slab to be broken off as a whole. Generally, the location of the slab break is a certain distance from the bridge abutment. The direct cause of the slab fracture is the The tensile stress on the slab is greater than the tensile strength of the concrete.

(3)Road surface depression. The main cause of road surface depression is the uneven settlement of the soil foundation in the road-bridge transition section or the excessive pressure strain on the top surface of the roadbed in some locations under the action of driving loads, resulting in large local settlement and its occurrence. The location is a certain distance from the bridge platform.

(4)There is a longitudinal gradient difference between the original slab and the original slope of the road. The main reasons for this are the large post-construction settlement of the soil foundation in the transition section, or the excessive compressive strain on the top surface of the subgrade, which results in the longitudinal gradient of the slab. Changed.

3. Rutting. It is Usually Caused by Insufficient Ability of Asphalt Mixture to Resist Permanent Deformation At High Temperature, and It is Generally Related to Excessive Driving Load.

3.1 Structural Optimization of Road and Bridge Transition Sections

According to the calculation result of the most unfavorable load position, the maximum value of the maximum principal stress of the SMA-13 layer appeared at 8m from the lower bridge end, and the maximum value of the maximum principal stress of the epoxy asphalt layer appeared at 10m from the lower bridge end. Under the action of dynamic load, a large tensile stress is generated along the longitudinal direction of the road, and the tensile stress of the SMA-13 layer is greater than that of the epoxy asphalt layer.When the tensile stress exceeds its tensile strength, the pavement layer will crack. In addition, the extreme shear stress along the road across the two asphalt pavements appears at a distance of 10 m from the lower bridge end, and the extreme shear stress along the road longitudinal direction occurs at the lower bridge end. The shear stress at the location is generally greater than the mid-span location between the diaphragms, and the epoxy asphalt layer is subject to greater shear stress. Larger shear stress extremes at these locations may cause lateral slippage of the pavement Diseases such as migration, swelling, crowding, and flaking.

On the other hand, the ground pressure of the rear wheel is enlarged due to the change in the force state caused by the structural change when the front wheel of the vehicle is lowering the bridge. In this range, the extreme value of the mechanical response of the pavement structure in this range has increased to varying degrees, especially the shear stress index of the asphalt layer along the road, which is greatly affected, and the maximum value can increase up to 40%. According to the position of the most unfavorable load in the range of influence, the larger tensile stress at the lm from the lower bridge end will cause cracks in the SMA-13 layer, and the crack and epoxy paving of the epoxy asphalt layer will appear at 3m from the lower bridge end. Diseases such as layer slip, swelling, encapsulation, and spalling. According to the above analysis, the locations of the disease that are prone to occur in the transition section of the steel bridge, the corresponding disease forms and their causes are shown in Table2.

Table 2 : Disease-Prone Locations, Corresponding Disease Forms, and Causes of Steel Bridge Transition

Distance to the end of the steel bridge	Disease form	the reason
0	Pavement slides, bulges, crowds, and peels along the road	The pavement's longitudinal shear stress along the road is too large and the shear resistance is insufficient.
1m	Wear layer crack	Structural changes lead to an increase in the extreme values of the mechanical response.
3m	Epoxy cracks, pavement slip, swelling, encapsulation, and spalling	Structural changes lead to an increase in the extreme values of the mechanical response.
8m	Wear layer crack	The sma-13 layer has insufficient tensile properties.
10m	Epoxy asphalt layer cracks, abrasion layer reflection cracks, Pavement slips, bulges, crowds, and flakes along the road	The epoxy asphalt layer has insufficient tensile performance, the epoxy asphalt layer cracks are reflected upward, and the pavement layer has excessive shear stress along the road, and the shear performance is insufficient.

It can be seen that the extreme values of the response of the above several mechanical indicators during the passing of the vehicle are too large and may exceed their own strength, causing these diseases. In order to reduce the extreme value of the structural response when the vehicle passes, reduce According to the results of parameter sensitivity analysis in this chapter, the following optimization measures are proposed:

(1) Overweight vehicles are prohibited from passing through the transitional structure. When the vehicle axle load increases linearly, the structural response also increases linearly. Therefore, the actual axle weight of the vehicle should be strictly controlled, and overweight vehicles should not be allowed to pass through the transitional structure.

(2) Decrease the elastic modulus of the epoxy asphalt layer. When the elastic modulus of the epoxy asphalt layer is increased, all indexes are gradually increased except that the maximum principal stress of the SMA-13 layer and the shear stress along the road gradually decrease. Large, and these two indicators are not sensitive to the elastic modulus of the epoxy asphalt layer, and the change is small.Therefore, in order to reduce the extreme value of other indicators, the elastic modulus of the epoxy asphalt should be guaranteed to be less than 3000 MPa.

(3) Select the appropriate distance between the diaphragms of the steel bridge. When the distance between the diaphragms changes, the maximum change in the maximum principal stress of the two asphalt layers is the largest, and when the 4m distance is used as the standard, the distance increases or decreases. The small ones will cause the maximum value of the maximum principal stress of the asphalt layer to increase. Therefore, attention should be paid to the design of the steel bridge, not only the overall force of the steel bridge, but also the force of the pavement. From this perspective, See, the distance between the diaphragms is generally 3.5m-4.5m.

On the other hand, in addition to reducing the extreme value of the structural response, the strength of the material can also be increased and controlled from the construction aspect, including the following measures:

(1) For the paving layer within 15m from the lower end of the steel bridge, SBS modified asphalt should be used, and the gradation of the asphalt should be used to improve the tensile performance of the asphalt mixture. It should be noted that, The response of the asphalt pavement structure under dynamic load is much larger than that under static load, so the dynamic splitting strength should be considered to evaluate the tensile performance of the pavement.

(2) A bonding layer is specially added to play a role of shear resistance.In addition, the aggregate of the asphalt mixture should be selected to have angular and abrasion-resistant crushed stones to prevent slippage, swelling and encapsulation due to insufficient shear strength. And peeling and other diseases.

(3) Aiming at the disease caused by the structural response extreme increase near the lower

bridge end caused by the structural change, within 3.5m from the end of the steel bridge, steel fibers can be added to the asphalt mixture to improve its fatigue resistance and Tensile performance, reduce the occurrence of cracks; spread a certain amount of crushed stones on the adhesive layer, increase friction, improve the overall shear performance of the structural layer; In addition, you can add welded structural steel bars or steel mesh on the steel bridge deck, Prevent slippage between layers.

In addition, the extreme difference in the maximum principal stress of the asphalt layer between the position above the diaphragm and the position between the diaphragms indicates that the stress state of the steel box girder pavement is more complex, and the stress state at different positions Great

Based on the above conclusions, this article concludes the recommended optimization scheme for the transition section of the steel bridge from the aspects of structure, materials, and management, as shown in the table3.

4. Conclusion

Finally, for the transition section of the steel bridge, the most unfavorable load position of the maximum principal stress of asphalt layers are respectively at 8m and lOm away from the bridge's end. The most unfavorable load position of the shear stress of the asphalt layers along horizontal and vertical of the road are respectively at 8m away from the bridge's end and at the bridge's end. Each index is sensitive to the axle load of the vehicle, but not sensitive to the vehicle speed. The extreme value of the maximum principal stress and the shear stress along vertical of the road of the epoxy asphalt layer are more sensitive to the elastic modulus of the epoxy asphalt concrete.

References

[1] Hani H. Nassif, Talat Abu-Amra, Nakin Suksawang, et al.(2009).Field investigation and performance of bridge approach slabs.Structure and Infrastructure Engineering.Health,vol.5, no.2,pp.105-121.

[2] Yasser Khodair, Hani Nassif. Finite element analysis of bridge approach slabs considering soil-structure interaction. Bridge Structures.Health,vol.1,no.3,pp.245-256.

[3] Sujata Roy, Ganesh Thiagarajan.(2007).Nonlinear finite-element analysis of reinforced concrete bridge approach slab. Journal of Bridge Engineering.Health,vol.12, no.6,pp.801-806.

[4] R. Insa, P. Salvador,J. (2012).Inarejos, et al. Analysis of the influence of under sleeper pads on the railway vehicle/track dynamic interaction in transition zones. Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit.Health,vol.226, no.4,pp.409-420.