DOI: 10.53469/jpce.2024.06(06).05

Study on the Influence of Buried Depth on the Deformation of Bridge Approach Slab

Xinyu Wang

School of Urban Construction, Yangtze University, Jingzhou, China

Abstract: ***The setting of the bridgehead slab can effectively alleviate the harm caused by the bridgehead bump, but the secondary bump may occur due to the fracture and void of the slab. Given the above problems, the influence of buried depth on the deformation of the bridge approach slab is studied through theoretical analysis and numerical simulation. The results show that compared with the conventional slab, the shear force of the slab is reduced and the service life is increased when the slab is deeply buried. The deep-buried slab can help to reduce the differential settlement of the road-bridge transition section and alleviate the phenomenon of vehicle bumping at the bridgehead. And the deeper the buried depth of the slab, the more gentle the settlement change of the transition section of the bridge.***

Keywords: Bridgehead jump, Bridgehead slab, Settlement, Numerical simulation**.**

1. Introduction

A bridgehead bump is a kind of dislocation phenomenon caused by uneven settlement at the junction of the bridge and subgrade. In road and bridge construction, the problem of bridgehead bumps is a common disease in road and bridge engineering. The setting of the bridgehead slab is a common measure to reduce the uneven settlement of the bridge connection section.

Domestic and foreign scholars have carried out a lot of research on the design of the bridge approach slab in the road-bridge connection section. Creep studies the deformation mechanism of the bridge approach slab based on the stress analysis method of the bridge approach slab, and puts forward the design suggestions of the bridge approach slab [1]. Xiang et al studied the dynamic response of the slab under different treatment methods and different depths by finite element simulation [2]. The results show that the durability of the slab at the bridgehead can be improved by using deep slab treatment. Tang et al. established a finite element model by simulating the horizontal and vertical constraints of the bridgehead slab with horizontal and vertical springs [3]. The results show that the simplified spring simulation method is more practical than the shell element simulation method. Dong Li proposed a new type of permeable abutment slab and studied the failure mechanism of the new type of porous abutment slab under vehicle cyclic load through an indoor model test [4]. Through theoretical analysis and finite element simulation, Xiao Kai studied the layout scheme of the bridgehead slab in the transition section of the road and bridge [5]. The results show that there is an optimal combination of slab length and thickness. Cai derived the deflection equation of the curved approach slab solved its analytical solution, and then compared the analytical solution and numerical solution with the measured values of the project [6]. The results show that the curved approach slab can effectively solve the problem of bridgehead jump.

Based on the previous research results, the numerical calculation models of different buried depths of the slab are established in this paper. The relationship curves between the buried depth and the shear force and settlement of the slab are obtained, and the influence of the slab's buried depth on the slab's deformation at the bridgehead is analyzed. To provide a valuable theoretical and experimental basis for the treatment of bridgehead jumping hazards.

2. Theoretical Study on Design Buried Depth of Bridge Approach Slab

The Winkler elastic foundation beam model can be applied to solve engineering problems such as bridgehead jump and secondary jump [7-8]. To determine the influence of buried depth on the deformation of the bridgehead slab, this paper uses Winkler elastic foundation beam theory to analyze. The bridge approach slab is simplified as an elastic foundation beam model with one end fixed and one end free. To facilitate the calculation, the friction force between the beam and the foundation is not considered, and the vehicle load on the upper part of the foundation beam is assumed to be a uniform load. Refer to the literature, the value of the uniform load is q = 10.5KN / m, and the length of the slab l is determined to be 6m, the thickness h is 0.3m, and the foundation stiffness K = mz, where m is the foundation stiffness ratio column coefficient; z is the distance between the foundation beam and the ground [9-10]. The calculation model is shown in Figure 1.

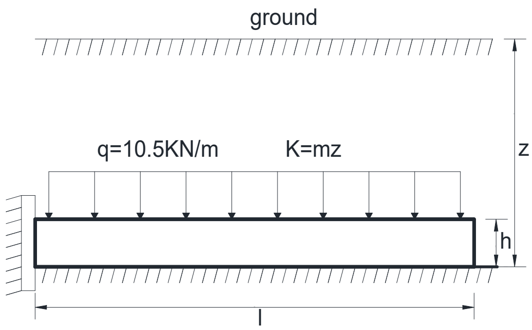

Figure 1: Mechanical model of the elastic foundation beam

The curve of the relationship between the bridgehead slab's buried depth and the slab's settlement value and shear force of the slab is shown in Figure 2 and Figure 3.

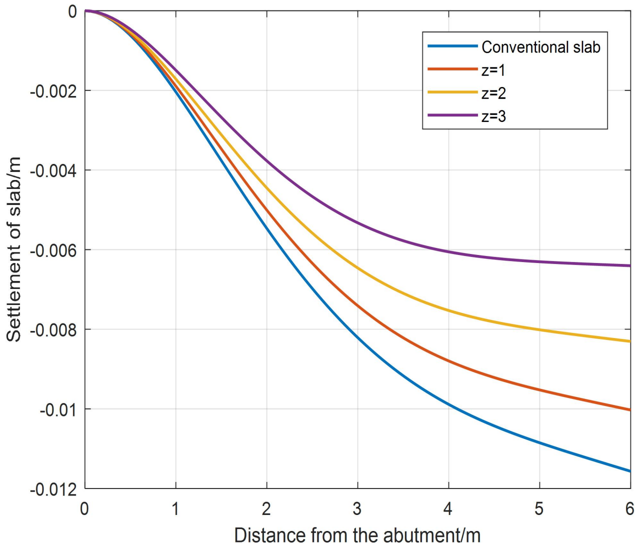

Figure 2: The variation law of settlement with different buried depths of slab

It can be seen from Figure 2 and Figure 3 that the settlement of the near end of the slab is large the change is significant under the uniform load, and the settlement of the slab tends to be stable after a certain distance. The deeper the buried depth of the slab, the more gentle the settlement change of the transition section of the road and bridge, that is, the deeply buried slab can help reduce the differential settlement of the transition section of the road and bridge and alleviate the phenomenon of vehicle jumping at the bridgehead. At the same time, with the increase of the buried depth of the slab, the shear force at the proximal end of the slab is significantly reduced, which does not easily cause the fracture of the bridgehead slab, which is conducive to the stability of the slab during the operation period of the expressway and reduces the occurrence of the bridgehead bump accident.

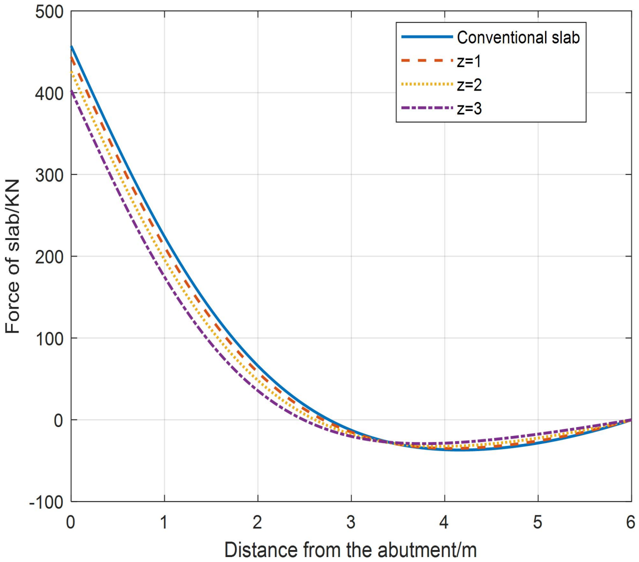

Figure 3: The variation law of force with a different buried depths of slab

3. Numerical Simulation

3.1 Modelling

The deformation of the back of the abutment is negligible compared with the settlement of the subgrade. When the numerical model is established, the back of the abutment can be simplified as a rectangular rigid body. The size of the numerical simulation model is as follows: the filling height of the subgrade is 7.5m, the length of the bridgehead slab is 6m, and the thickness is 0.3m.To eliminate the influence of the size effect and boundary effect, the length of the subgrade behind the abutment is 60m, and the length of the foundation before the abutment is 40m. The connection between the plate and the back of the platform is fixed. Both the abutment back and the slab are reinforced concrete structures with large stiffness, and the elastic constitutive model is adopted. The Mohr-Coulomb constitutive model is used for the subgrade and foundation soil. The uniform load is only applied within the length of the slab. The specific parameters of the numerical simulation calculation are as follows.

Table 1: Parameter value

	Young's Modulus/MPa	Poisson's Ratio	Friction Angle/(°)	Cohesion Yield Stress/KPa
Roadbed	60	0.35	19	40
foundation	40	0.35	18	25
concrete	21000	0.2	-	-

3.2 Rationality Analysis of Numerical Calculation Results

To verify the rationality of the calculation model, the settlement value of the slab calculated by the elastic foundation beam theory is compared with the settlement value of the slab calculated by the numerical simulation under the same working condition (the buried depth of the slab is 3m), as shown in Figure 4.

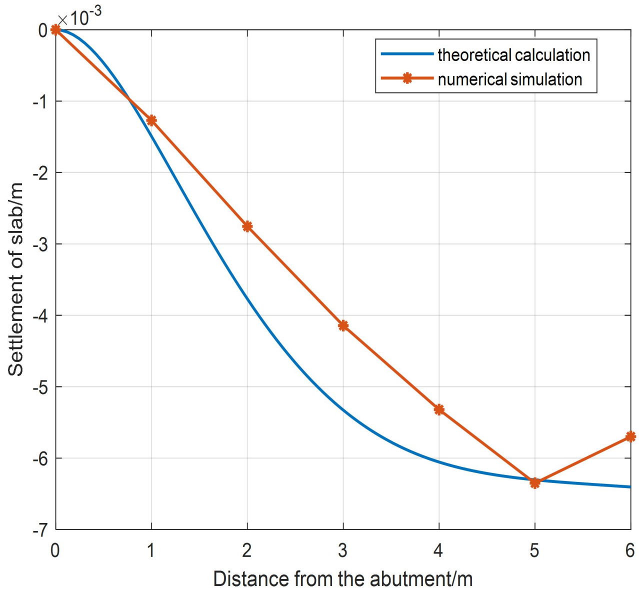

Figure 4: Comparison between theoretical and numerical simulated deflection of the approach slab

It can be seen from figure 4 that the settlement value of the slab calculated by the elastic foundation beam theory is the same as that of the numerical simulation calculation, and the difference is not large. The settlement value of the numerical calculation is slightly smaller than that of the theoretical calculation, which shows the rationality of the numerical calculation model.

3.3 Numerical Simulation Results Analysis

In the numerical simulation, four kinds of bridgehead slab schemes are set up, namely, no slab, conventional slab, and two kinds of deep-buried slab. Two kinds of deep buried slabs include scheme 1: the buried depth of the slab is 1m, and the contact element is set between the slab and the soil; scheme 2: The buried depth of the slab is 3m, and the rest is the same as scheme 1. The displacement of the transition section of the bridge under uniform load in different schemes is shown in Figure 5.

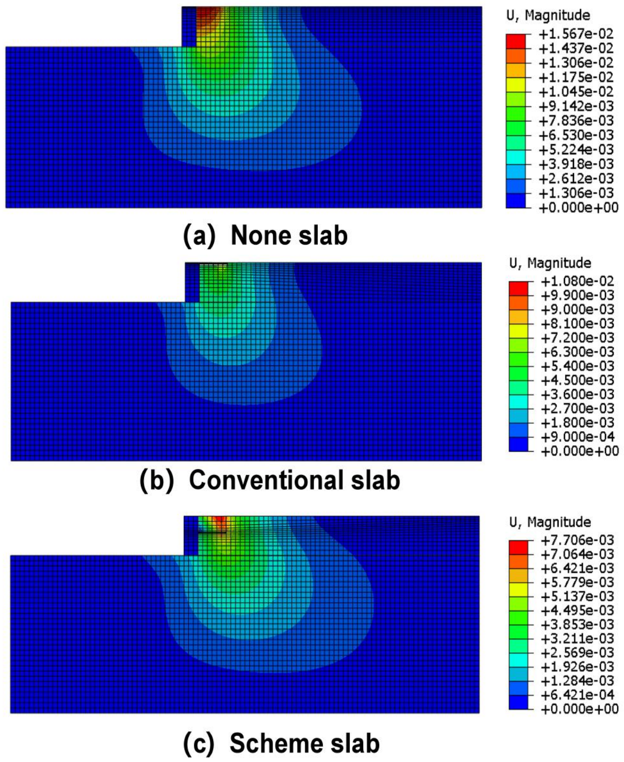

Figure 5: Displacement of road-bridge transition section under different schemes of the approach slab

It can be seen from Figure 5 that the filling soil at the back of the abutment decreases as a whole without slab under uniform load, and the differential settlement of the transition section of the road and bridge is obvious. After the conventional slab is set up, the settlement of the fill at the connection between the slab and the abutment is significantly reduced, and there is no differential settlement in the transition section of the road and bridge. When the deep-buried slab is set, there is no differential settlement in the transition section of the bridge, and the maximum settlement occurs at the end of the slab. The settlement of the surface soil in the transition section of the bridge is smaller than that in the conventional slab scheme, that is, the deep-buried slab can significantly reduce the differential settlement of the bridgehead.

The pavement settlement values in different slab schemes are shown in Figure 6. It can be seen from Figure 6 that when there is no slab in the transition section of the road and bridge, the settlement value of the road surface drops sharply, which leads to the jump disease at the bridgehead. After setting the slab at the end of the bridge, the settlement value of the road surface changes continuously, which gradually rises from 0 to the maximum value from the fixed end, and there is no dislocation of the road surface. When the conventional slab scheme is adopted, the maximum settlement of the road surface is 10.8 mm, when the deeply buried scheme 1 is adopted, the maximum settlement of the road surface is 8.9 mm, and when the deeply buried scheme 2 is adopted, the maximum settlement of the road surface is 5.7 mm, that is, the deeper the buried depth of the slab, the more gentle the settlement change of the road surface in the transition section of the road bridge.

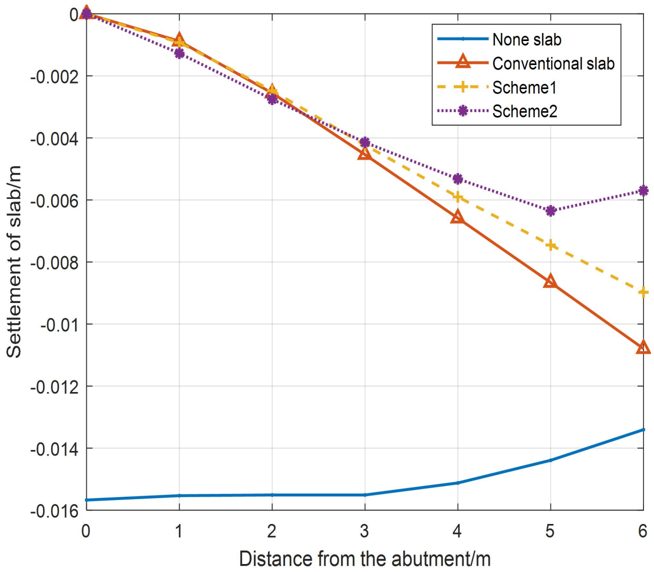

Figure 6: Vertical displacement of pavement under different schemes of the approach slab

The change of shear force in different slab schemes is shown in Figure 7. It can be seen from Figure 7 that the shear force at the connection between the slab and the abutment is the largest in all schemes. When the buried depth is shallow, the shear force at all parts of the slab is not much different from that of the conventional slab. When the buried depth is deep, the shear force at all parts of the slab is reduced. It can be seen that the deep burial of the slab can reduce the shear stress in the slab and effectively improve the service life of the slab.

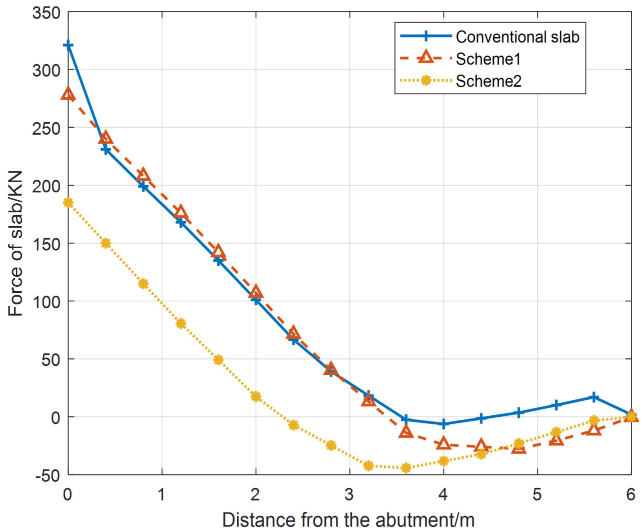

Figure 7: Shear of approach slab under different schemes of the approach slab

4. Conclusion

The influence of the buried depth of the slab on the settlement and shear force of the slab is studied by using the theory of elastic foundation beam. The numerical simulation method is used to analyze the differential settlement of the transition section of the bridge under different slab schemes. The main research results are as follows:

The deep-buried slab can help to reduce the differential settlement of the road-bridge transition section and alleviate the phenomenon of vehicle bumping at the bridgehead. And the deeper the buried depth of the slab, the more gentle the settlement change of the transition section of the bridge.

When the slab is deeply buried, the shear force is smaller than that of the conventional slab, which can effectively prolong the service life of the slab.

References

[1] Xu Bian, Wang Wei, Xu Hofu. Improved design of bridge approach slab [J]. Journal of China & Foreign Highway, 2005, 25(1):28-31.

[2] Xiang Yi Qiang, Sun Yun.Dynamic response of bridge approach treated with deep-seated concrete slab[J]. Zhejiang Daxue Xuebao (Gongxue Ban), 2010, 44(10): 1863-1869.

[3] Tang Y.F, Briseghella B, et al. Numerical analysis of the mechanical behaviors of girders in jointless bridge considering the grade flat approach slab[C]//Life-Cycle Civil Engineering: Innovation, Theory and Practice - Proceedings of the 7th International Symposium on Life-Cycle Civil Engineering, IALCCE 2020, 2020: 30-36.1486-1491.

[4] Dong Li, Zhang Yi, Li Shonghui. On Pseudo-static Test of Vehicle Load under New Through-bridge Abutment Strap Connection[J]. Science Technology and Engineering, 2020, 20(8):3284-3290.

[5] Xiao Kai, Sun Yong, et al. Layout Scheme of approach slab at bridgehead of expressway road-bridge transition section[J]. Science Technology and Engineering, 2023, 23(23): 10091-06.

[6] Cai Bingliang, Chen Deyi, et al. The Treatment Mechanism of Vehicle Bumping at Bridgehead Based on Arc Slab[J]. Journal of Civil Engineering and Management, 2023, 40(05):150-158.

[7] Yang Xuexiang. The feature of foundation pressure on Winkler foundation-beam with one fixed end and its application[J]. Engineering Mechanics, 2006, 23 (11):76-79.

[8] Yang Xuexiang. Imagination and analysis for solving the problem of bridge and roadbed by embedding elastic foundation beam with one end riveted into bridge[J]. Journal of Yangtze University (Natural Science Edition), 2005, (04):177-179.

[9] Peng Youjun. Study on the determination of foundation coefficient by using static cone penetration test results[J]. Geotechnical Investigation & Surveying, 2015, 43(9): 28-32.

[10] Zhu Ling, Ding Wenqi, Wang Qi, et al. Analysis of equivalent coefficient of subgrade reaction considering the variability of layered soils [J]. Chinese Journal of Rock Mechanics and Engineering, 2014, 33(S1): 3036-3041.