Field test and numerical analysis of a new expansion joint

WY Dou*
Anhui transportation holding group co., Ltd.hefei, 230000, china
*corresponding author’s email: xinjian@36haojie.com

Abstract. in order to realize the reasonable design of new type pile slab subgrade, this study, relying on the reconstruction and expansion project of Lintou Longxi Interchange Section of g5011 Wuhe expressway, constructs a pile slab subgrade model with 15 holes and each hole is 6m. Through the full-scale model, the displacement of the new type of vertical limited expansion joint of pile slab subgrade under the most unfavorable load is obtained. Based on the separated modeling method, the nonlinear analysis of full-scale specimen under test loading condition with load displacement curve in good agreement with the measured results is realized. Combined with the static performance test of full-scale members, it is verified that the expansion joint of the pile slab subgrade has good vertical displacement limiting ability, which can be applied to the engineering.

Keywords. pile slab subgrade; expansion joint; nonlinear analysis

1. Introduction

The pile plate subgrade used in this project is a new type of pile plate beam structure, which is a frame structure system composed of factory prefabricated plate beam and pipe pile. Compared with the traditional filled subgrade, it has the characteristics of large stiffness and small post construction settlement, which can be used to replace 3 ~ 8m filled subgrade widening. Compared with the traditional subgrade, the slope width is cancelled, and the land acquisition area is greatly saved; the prefabricated slab beam and pipe pile can be completed in the factory and assembled on site, and the construction speed is fast; in the reconstruction and expansion project, the culvert and other structures can be cancelled for the soilless subgrade, and the auxiliary facilities such as the ditch can also be continuously used, so as to speed up the construction progress and make full use of the existing structure to save the project manufacturing cost. The structure can change the traditional structure and construction mode of highway subgrade and pavement, improve the traditional expansion joint set on the concrete structure. The precast beam slab segment is connected by rigid and flexible combination, and elevated on the support pipe pile arranged according to certain spacing. The structure has the ability to completely eliminate its own longitudinal expansion deformation, and can be extended infinitely in theory. The flexible slab pavement is set on the continuous beam and slab formed by connection and can deform with it.

Zhan Yongxiang[1] used ANSYS to establish a three-dimensional finite element model to conduct numerical simulation analysis on the settlement and dynamic response of pile plate subgrade. The increase of elastic modulus of pile foundation is conducive to reducing the settlement of small road foundation, but it is not conducive to controlling the settlement deformation of subgrade when the elastic modulus value is too large. Under the action of earthquake load, the acceleration value of pile plate subgrade response is amplified, and the pile foundation and bearing capacity The stress at the interface of plates is the most unfavorable. Luo Zhaoxin[2] applied the specific allowable stress method and limit state method in the design of pile plate structure. According to the quantitative analysis and practical calculation, it is considered that the limit state method is better than the allowable stress method in theory. However, due to the dynamic response of train load, the allowable stress method should be adopted in the design to make the structure safer. At the same time, it is considered that the
limit state method can be used after solving the special problem of train load. Ma Bin[3] used finite element software to simulate and analyze the Mises stress distribution law of pile plate structure under vertical load. The Mises value of the pile top inside and outside the pile foundation on both sides of the longitudinal subgrade is larger, and the Mises value of the pile foundation in the middle is larger around the pile top and pile bottom, The Mises value of bearing plate reaches the maximum value near the top of side pile. Su Qian[4] studied and analyzed the structural design and structural optimization of pile slab structure Subgrade of Zhengzhou-Xi'an railway, and passed the verification of indoor model test. Hu Anhua[5] Based on model test, through long-term observation of typical section of pile slab structure Subgrade in comprehensive test section of Suining Chongqing railway, studied deformation law under dead weight and train dynamic load, and analyzed its settlement characteristics and structural stress characteristics.

2. Static load test of expansion joint

The full-scale test model of pile slab subgrade is constructed: the width of pile slab subgrade is 8.77m, and two piles are arranged horizontally. The standard span of the structure is set as 6m, and the layout of equal span is equal. It is recommended to use 15 holes in one unit with a length of 90m. The thickness of subgrade slab is 0.26M and the width is 8.77m; the width of rib beam is 1m and the height is 0.24M; the width of corbel rib is 0.417m. The subgrade slab is precast in longitudinal blocks, the precast slab is made of C40 concrete, and the HRB400 steel bar with a diameter of 22mm is used as the longitudinal and transverse reinforcement in the bridge deck, and PHC pipe pile is used to connect the bridge deck. See Figure 1 for detailed structural parameters of pile slab subgrade and expansion joint.
3. Nonlinear analysis

Nonlinear analysis model firstly establishes the geometric model according to the shape and cross-section size of the pile slab subgrade. According to the separation modeling method of reinforcement and concrete, based on ANSYS, the solid element is used for concrete, and the bar element is used for the reinforcement of slab surface and rib beam, and the coupling idea of the degree of freedom between the solid element and the bar element is obtained. The criterion is willam, which is commonly used in SOLID65 solid element. In warner five parameter model, the material physical and mechanical properties are taken as the experimental measured value, and the concrete elastic modulus is taken according to the current specifications. In order to simplify the model and improve the calculability, three span model is selected at the place with larger shear influence line value according to the internal force diagram. The pile is simulated by beam element and connected with the deck slab in multi-scale. The spring element is used to simulate the pile-soil interaction, and the vertical effect of steel mesh on the whole bridge is considered. The influence of displacement is small, so the reinforcement mesh and inclined reinforcement are only established in the area near the bracket expansion joint; the stress-strain relationship of the reinforcement is an ideal elastic-plastic model, the yield strength of the elastic section of the reinforcement is taken according to the actual measured value, the area near the bracket is evenly divided into grid elements, the rest of the bridge deck is divided into grid elements according to the conventional method, and the element division of reinforcement is similar to that of concrete Elements correspond. The contact element is considered in the expansion joint and between the upper and lower corbels, which only transmits the pressure but not the tensile force; the expansion joint only transmits the force through the embedded steel plate, the embedded reinforcement and the bracket, and defines the force transmission form; the bolt in the expansion joint is simplified as a cylinder with a diameter of 18 mm, and the shear studs and ribs of the expansion joint are simplified to consolidate the expansion joint with steel fiber reinforced concrete. The mesh division of concrete and reinforcement is shown in Figure 2.
According to the above finite element model, load displacement curves under simulated and experimental loading conditions and steel stress curves with load variation are obtained according to the loading mode of minimum shear force. Since the positions of measuring points 1 and 2, measuring points 4 and 5 at the expansion joint are close and the displacement is approximate, the displacements at three measuring points are selected for comparison, as shown in Figure 3. According to the comparison between the test and the simulation, the vertical displacement of the expansion joint fluctuates within ±0.1mm, and the minimum shear strain fluctuates within ±100, and the change trend is the same. The simulation and test data are in good agreement.
Figure 3. load vertical displacement and load strain curves

(a) Load vertical displacement curve at expansion joint

(b) Load strain curve at expansion joint

4. Conclusion

Based on the full-scale test of pile slab subgrade, the finite element calculation model is established and compared with the test results

(1) The test and simulation results show that with the continuous loading and unloading of the load, the upper surface of the expansion joint has a small displacement and fluctuates in a certain range, within - 0.1 mm ~ 0.1 mm, which plays a role in limiting the vertical displacement of the structure, which verifies that the expansion joint structure has good vertical limit capacity.

(2) The test and simulation results show that with the continuous loading and unloading of the load, there is only micro strain at the expansion joint, the absolute value is within 0 ~ 100, and the change trend is the same, the average error is within 15%, and there is basically no large deformation, which plays a role in limiting the vertical displacement of the structure. The finite element model can accurately simulate and analyze the limited displacement performance of the expansion joint of pile slab subgrade.

5. References

[1] Zhan YX 2012 Numerical simulation analysis on settlement and dynamic response of pile slab subgrade [J] Gansu science journal 87 pp 34-36
[2] Luo ZX 2015 Application of specific allowable stress method and limit state method in pile plate structure design [J]. *Highway traffic science and Technology (Application Technology)* **55** pp 54-55

[3] Ma B 2016 On Mises stress distribution of pile slab structure under vertical load [J] *Tunnel engineering* **47** pp 67-67

[4] Su Q 2014 Structural design and structural optimization of pile slab Subgrade in Zhengzhou-Xi’an railway [J] *Xinjiang building materials* **77** pp 85-88

[5] Hu AH 2018 Deformation law of pile slab subgrade under dead weight and train dynamic load [J] *Transportation world* **59** PP 163-164