Research on deformation coordination composite bridgehead plate structure and construction technique

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Abstract: Based on the stress characteristics of bridgehead plate structure and the difference deformation characteristics of bridgehead section, a kind of deformation coordination composite bridgehead plate structure was proposed in this paper. Meanwhile, the stress characteristics, construction process and quality control points of the structure are systematically analyzed. According to the application effect of site engineering, the structure proposed in the paper has good engineering benefit and promotion value.

1. Introduction
With the rapid development of our country's economy, the demand of driving comfortableness from drivers becomes more higher, so bridgehead bumping problem gradually becomes the focus for the domestic and international highway research institutions and the construction enterprise. Existing engineering practice shows that the factors causing the bridgehead bumping are complicated, such as the vertical compressive stiffness mutation of bridge and embankment sections, large differential settlement, differential deformation of the bridge abutment section, large self-compacting settlement of the bridge abutment of backfill material.

So far, scholars have carried out some research on the structure design and control measures of bridgehead plate. Yi Qin-jia etal[1] studied the symptoms of bridgehead bumping problem. A M et al[2] studied the action time of vehicle load on the joint node. Zhang Hong-wu etal[3] analyzed the influence factors about post bridge abutment settlement, and put forward corresponding design requirements and methods. Zhi Lei etal[4] studied the construction technology in the transition section of highway bridge by analyzing the structure of the transition section of highway and bridge. Liu Qiu Yue et al [5] put forward preventing measures to deal with the bridgehead bumping in practical project. Wu Xiu-fa[6] analyzed the design and construction points of the bridgehead plate. Xi Qiang-wei[7] analyzed the disease of bridge deck pavement and bridgehead bumping, and studied the corresponding prevention and control measures. Jia Ji-shou et al [8-9] analyzed the causes of bridgehead bumping, and put forward countermeasures.

The analysis shows that the existing research results have positive significance to solve the problem of bridgehead bumping, and some engineering construction techniques have achieved better engineering
results under appropriate working conditions. However, the problem of bridgehead bumping is still not effectively controlled, because the geological conditions are complicated in the special conditions, such as deep soft soil and high fill.

2. Engineering Situation
The road reconstruction and expansion project from Zhuozhou city to Shijiazhuang city costs 14.836 million Yuan, and the construction period is 240 days. The project is to build a bidirectional eight-lane bridge.

In order to improve the construction quality of the bridgehead plate structure, the bridgehead section of the double-width bridge was adopted to the deformation coordination composite bridgehead plate structure.

3. Technical Principle
In view of the factors causing bridgehead bumping problem and the subsidence deformation composition, a kind of deformation coordination composite bridgehead plate structure was proposed in this paper. The schematic diagram of the structure cross-section is shown in figure 1.

![Figure 1 schematic diagram of the structure cross-section](Note:1-embankment filling, 2-abutment backfill-material, 3- Late injection pipe, 4- shock pad, 5- anti-punching steel rebar, 6- lower connection plate, 7- packing area, 8- hock absorption, 9- abutment bracket, 10-aquiclude, 11- drainpipe, 12-upper filling, 13- bridge deck overlay structure, 14- Vertical connection bolts, 15- buffer layer, 16-Lower support, 17-upper support, 18-top mounting plate, 19-upper connecting plate, 20- horizontal deformation coordination board, 21- pavement structure.)

The process principle of the structure mainly includes the following aspects.

1) Reducing the effect of post-construction settlement on the structure.

According to differential settlement control requirements, we should cure the packing at the bottom of the lower connection plate to raise the bearing capacity of the backfill firstly. According to the need, the structure add bulk material to the gap between the top assembly board and the top or bottom connecting plates to adjust the top elevation of the top assembly plate. The restoration construction will not increase the pressure stress of the abutment backfill-material.

2) Controlling the differential deformation at the seam

Set horizontal deformation coordination plate at the seams between top assembly board and bridge deck overlay structure and pavement structure to change the line load at the joint to the surface load. In order to realize the smooth transition of the differential deformation before and after the joint, the structure put the horizontal deformation coordination plate to coordinate the uneven deformation in the joint area

3) Rapid treatment of post-construction diseases

The top assembly board and horizontal deformation coordination plate adopt prefabrication. We connect the horizontal deformation coordination plate, top assembly board, bridge deck overlay structure and the pavement structure connects by bolt, which can realize the quick installation and replacement in the construction.

4) Improve the seismic performance of the structure

We adopt flat lap joints among top assembly board, the upper connection plate and the lower connection plate, and set shock pad between the upper connection plate and the lower connection plate.
Meanwhile, add bulk material to the gap between the top assembly board and the top or bottom connecting plates, and set buffer layer on the surface of the lower and upper support to form the combined seismically-safe structure, which can reduce the influence of vehicle vibration load of road structure.

4. Construction Preparations

4.1 Material Preparations
Before construction, according to the requirement of designed engineering quantity and the site condition, we should determine the materials consumption of water, cement, fine sand, gravel or medium coarse sand, steel bar, tension reinforcement, injection pipe, section steel, shock pad, and so on. And the performance index of the material should be tested.

4.2 Equipment Preparations
The main construction equipment during the construction is shown in table 1.

| Sequence Number | name of the machine     | model                        | number |
|-----------------|-------------------------|------------------------------|--------|
| 1               | Excavator               | Qinguang220                  | 1      |
| 2               | Auto-dumper             | 40T (18m)                    | 4      |
| 3               | Road roller             | 20T                          | 1      |
| 4               | Collection hopper       | /                            | 4      |
| 5               | Fine concrete pump      | HBT20-8-30                   | 3      |
| 6               | Pumpcrete pipe          | diameter 85mm               | 300 m  |
| 7               | Total station           | GTS-332N                     | 2      |
| 8               | Level                   | DSZ2                         | 1      |
| 9               | Truck crane             | 165T                         | 2      |
| 10              | Grouting machine        | /                            | 2      |
| 11              | Bump-cutter machine     | /                            | 2      |

4.3 Work Preparations
1) The main construction equipment whose specifications and quantity should meet the construction requirements should be organized in time. The equipment and instruments for measuring devices should be recognized by the metrological supervision unit above the municipal level.

2) According to the requirements of site construction, engineering surveying and mapping should be carried out to find out the compaction degree of engineering geological soil, groundwater level, embankment and abutment backfill-material.

3) The detailed construction technology, construction parameters, quality control measures and emergency plan should be established, and technical disclosure should be carried out before construction to analyze and study the quality control difficulties during the construction process, and put forward the concrete construction technology plan.

4) According to the transverse width of the road and the design of the vehicle load, the plane size and thickness of top assembly board, upper connection plate and lower connection plate should be determined. And the prefabrication is made in the construction site or prefabrication field.

5) The sample obtained at the backfill site should be sent to the site laboratory to carry out the standard compaction test, which can get the optimum moisture content and maximum dry density of the filler.

6) The side wall connecting body is preset on the side wall of the abutment wall, and the side wall connecting body can be integrally poured with the whole deck, or adopted post-placement method.
5. Construction Process Analysis

5.1 Construction Technology Process
Figure 2 is the construction process of the compatibility and deformation of bridge head bridging slab structure

5.2 Construction Quality Control Points and Quality Assurance Measures

5.2.1 Backfill padding
(1) The moisture content of the filler is tested on site, and the dry and wet state of filler is strictly controlled according to the best moisture content and maximum dry density.

(2) All the machine tool should be suitable for the backfill operation space. If it is not suitable for the large roller compaction, it should be compacted with small hand.

(3) Bridge culvert structure platform back backfill should be timely stratified, and label the loose height control line on the bridge over the earth surface step by step. When using the roller to press, each layer of loose laying thickness is no more than 20cm, and when using small vibration to press, each layer of loose height should not exceed 15cm. The checking frequency is one point for each 50m², but when the area square is less than 50m², the checking point should be not less than two points, and every point must be qualified.

5.2.2 The lower connection plate installing

![Diagram of Backfill Padding Process]

Figure 2 Construction process of the compatibility and deformation of bridge head bridging slab structure

5.2.2 The lower connection plate installing

![Diagram of Lower Connection Plate Installation]
(1) The connection between steel mesh grille, abutment backfill-material and abutment should be strong. Adjacent steel mesh grille should be welded connection or ligation connection, and the steel mesh grille and the lower packing are set up with a u-shaped anchor tendon connection firm.

(2) The surface of side wall connection should be smooth, free of impurities and dry. There should be no gap between the joints of the flexible shock absorber.

(3) The lower connection plate hoisting should comply with the relevant provisions of special equipment safety technical specification.

(4) The anti-punching steel rebar should be anchored, and the depth and steel diameter should meet the design requirements.

5.2.3 The shock pad installing

(1) The mechanical properties, dimensions and durability of the shock pad should meet the design requirements. The strength of the adhesive should meet the design requirements.

(2) The location of shock pad should be rechecked before hoisting, and the lower connection plate should be firmly connected.

(3) The quality assurance measures for the filling of abutment backfill-material in the cross-section between the shock pad and the road embankment are the same as that described in 4.2.1.

5.2.4 The upper connection plate installing

(1) The hoisting of the upper connection plate should comply with the relevant provisions of the special equipment safety technical specification.

(2) When preloading on the lower connection plate and the upper connection plate, the loading should be firstly fast and then slow, and the maximum preloading period should not be less than 7 days.

(3) The anti-punching steel rebar should be anchored, and the depth and steel diameter should meet the design requirements.

5.2.5 The waterproof layer paving

(1) The upper surface of the upper connecting plate and the lower connecting plate should be cemented into the waterproof layer, and the rich width of 2-3cm should be reserved on the their side surface.

(2) The drain pipe is laid on the surface of the waterproof layer, and the gravel is filled with uniform grain size on the outside of the drain pipe. The slope surface of the drain pipe end is not less than 100mm.

(3) The height of the riser is not less than 200mm.

5.2.6 The upper support and lower support installing

(1) The section size and rigidity of upper support body and lower support should meet the designed requirements.

(2) The bottom of the upper support and the lower support should be embedded in the limiting slot upper of the supporting body, and it can't move around.

(3) The upper surface of the upper support and the lower support should be securely attached to the buffer layer.

(4) The upper support and the lower support hoisting should comply with the relevant provisions of the special equipment safety technical specification.

5.2.7 The upper gap filler

(1) The gradation and moisture content of the upper gap filler should meet the designed requirements.

(2) The Upper gap filler should be constructed with artificial and small construction machinery, with symmetrical filling and compaction on both sides of the upper support and the lower support.

(3) The upper surface of the upper gap filler is higher than the top elevation of the upper support, and the slope is controlled between 3-5 degrees according to the filling void ratio.

5.2.8 The top assembly board installing
(1) The buffer layer of the upper support and the lower support and the surface elevation of gap filler should meet the designed requirements.

(2) When hoisting the top mounting plate with hoisting equipment, the construction should comply with the relevant provisions of the safety technical specification of special equipment.

(3) The installing of top mounting plate should minimize disturbance to the lower structure.

(4) When the gap width between the top mounting plate and the outer pavement structure is more than 1cm, the gap should be grouted.

5.2.9 The horizontal deformation coordination plate installing

(1) The flexible material layer of the horizontal deformation coordination plate is closely connected to the top assembly plate and pavement structure groove road.

(2) The vertical connection plate of the horizontal deformation coordination plate should be inserted into the slot, and the gap should be filled with glue.

(3) The length, strength and tensile strength of the vertical joint bolt should meet the designed requirements, and the field drawing test should be carried out to test the tensile strength.

5.2.10 The packing solid layer construction

(1) The grouting pressure at the horizontal orifice of grouting is 0.3-0.5MPa. If the height of the hole changes, the grouting pressure should be adjusted accordingly.

(2) The water-cement ratio should be controlled strictly according to the designed requirements, and the grouting curing effect is evaluated by the void ratio and bearing capacity of the grouting.

(3) The slurry must be stirred evenly, and the mixing time shall not be less than 3min. During the use of slurry, the slurry should be gently stirred to avoid slurry precipitation.

6. Engineering Application Effect Analysis

The construction technique can greatly improve the construction efficiency and avoid the influence of site concrete pouring on construction period and quality. The construction technique can effectively reduce the construction load, save the cost of engineering equipment about 3%, and save labor cost about 10%. Through the analysis of the life-cycle cost, the construction technique can save about 8%-10% project cost, and the economic benefit is remarkable.

According to the application effect, the structure not only give full play to the bearing capacity of the different layer of bridging slab, but also can solve the problem of local stress concentration and vertical compressive stiffness mutation. Meanwhile, it also can improve the seismic performance of the bridge structure of strap. In addition, the structure has high field efficiency and small environmental pollution, which can effectively reduce the impact of construction on the environment.

7. Conclusions

Because of the effect of external environment and vehicle load, the bridgehead plate structure often encounters the problem of bridgehead bumping. Through the analysis about the influence factors of the bridgehead plate structure traits, a kind of deformation coordination composite bridgehead plate structure and construction technique is proposed in this paper. The conclusion is as the following.

(1) Through the analysis about the prevention and control, performance improvement and different deformation dynamic control of bridgehead plate, a kind of deformation coordination composite bridgehead plate structure is proposed.

(2) In combination with the practical construction, the construction process and quality control points of deformation coordination composite bridgehead plate structure are analyzed, and the rationality and the feasibility of the structure are demonstrated.

(3) Based on the actual need of bridgehead structure, the construction process and application effect of the structure are analyzed, and the engineering application value of the structure is clarified.
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