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Finite element analysis of consolidation zone of v-shaped pier beam

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ABSTRACT : *In this project, the method of photoelastic stress method combined with numerical analysis is used to establish the solid model of the consolidation zone of the v-shaped rigid-frame pier and beam, and to reveal the spatial stress distribution law in the construction and Operation Stages, on this basis, the structural optimization measures are put forward.*

Keywords *-stress; Bigid-frame; Operation Stages; structural*

I. INTRODUCTION

In recent years, along with our country urbanization construction scale unceasingly expands, has driven the municipal landscape bridge the research and the development. The v-shaped pier continuous rigid frame bridge has both the mechanical characteristics and the structural advantages of continuous rigid frame bridge and slant-legged rigid frame bridge, suitable for the construction and environmental coordination of human and natural landscape and other characteristics [1-3] . However, in the consolidation zone of the pier-beam, the beam body and the v-brace converge together, and the V-brace and the lower vertical pier converge together, so the structure is complicated. Moreover, the three-dimensional prestress design, the spatial effect is significant, determines the region of the complex way of force transfer and spatial stress state [4-5] . If the design is not reasonable, this area is easy to appear local high stress zone in the construction phase or operation phase, even cracks, resulting in serious structural defects, affecting the safety and durability of the bridge operation. Therefore, it is necessary to study the complex spatial stress in the consolidation zone of v-shaped piers and beams, summarize the law of stress distribution in this zone, and make clear the weak position of stress, it is of great theoretical significance and research value for the design and engineering application of such bridges.

II. FINITE ELEMENT MODEL

1 Cell type and grid division

We use the large-scale general-purpose calculation software ANSYS to build the structure model. The SOLID92 element is a spatial tetrahedron element with 10 nodes, each node has 3 degrees of freedom (UX, Uy, Uz) . This kind of element can reflect the actual structure of two-way v-shaped pier in this paper, and can consider the whole force effect of the structure, so the result is more accurate, the arc transition at the junction of the v-brace with the main beam and the vertical pier, as well as the broken line transition of the diaphragm in the main beam can be accurately simulated, which is beneficial to the stress analysis in the local stress concentration area. For the reinforced concrete material model, the integral model is adopted, and the reinforced concrete material is regarded as homogeneous continuum. The prestressing effect in the main beam has been considered in the loading condition, so the constitutive relation of the material is linear elastic. For the large volume structure of pier-beam consolidation area, three-dimensional solid element is adopted. The solid element can truly reflect the actual structure of the two-way v-shaped pier in this paper, and can consider the whole force effect of the structure, so the result is more accurate, the arc transition at the junction of the v-brace with the main beam and the vertical pier, as well as the broken line transition of the diaphragm in the main beam can be accurately simulated, which is beneficial to the stress analysis in the local area. There are 316258 elements and 491151 nodes in the finite element model of the consolidation zone of the v-shaped pier beam. The grid division of the model is shown in figure 1. The direction of the whole coordinate system is z axis in longitudinal bridge direction, x axis in transverse bridge direction, and y axis in vertical bridge direction.

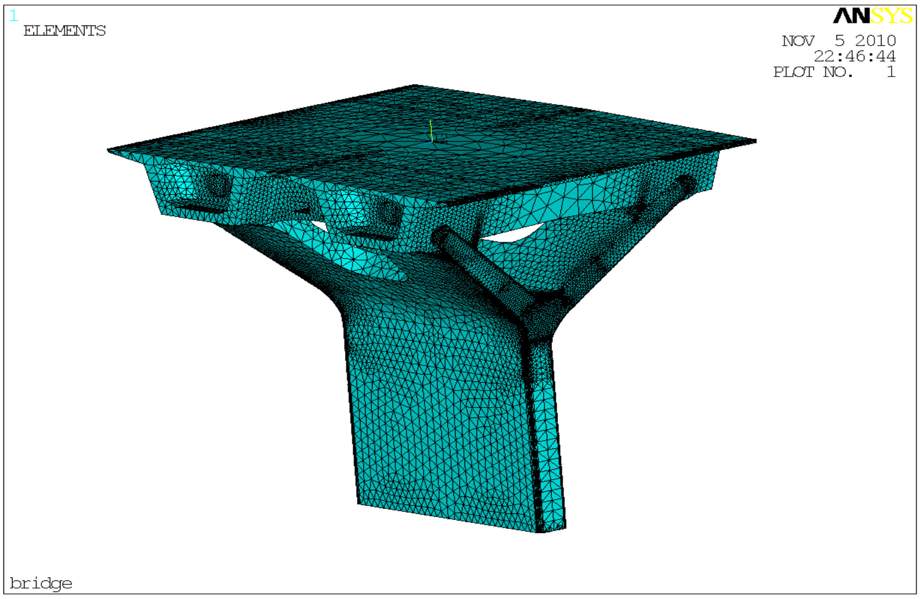


FIG 1 Finite element model

2Boundary conditions and load conditions

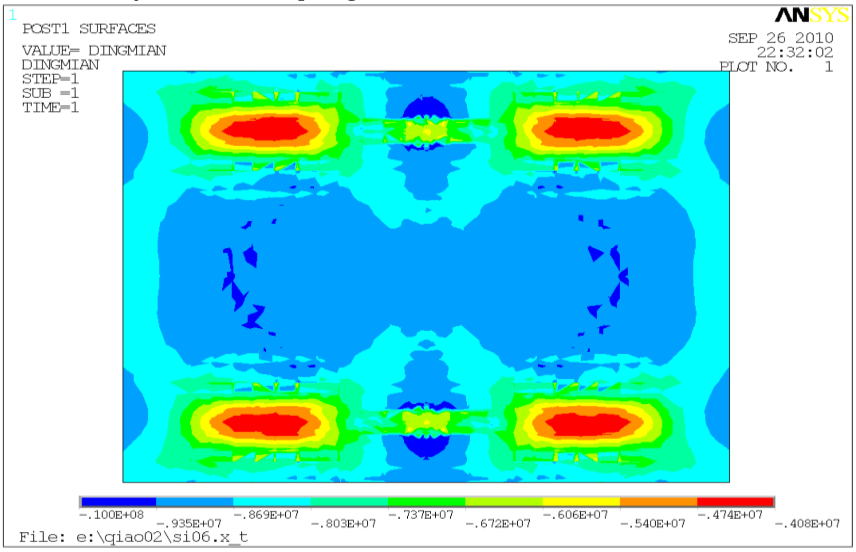
The bottom section of the vertical pier at the lower part of the structure in the consolidation zone of the v-shaped pier continuous rigid frame bridge is simulated as the fixed end, and all the degrees of freedom of the nodes on the section are restrained, without considering the influence of the Pile Foundation. The main beam and V-brace, v-brace and vertical pier are simulated as consolidation. The loading conditions were 1 and 2, which were corresponding to the photoelastic experiment. Condition 1 is the most disadvantageous load combination in the construction phase, and condition 2 is the most disadvantageous load combination in the normal use phase. In order to simulate the stress of the structure and avoid the local stress concentration of the loading section, the concentrated force on the section is converted into the surface load. The axial force and shear force are converted into uniform load on the left and right loading surfaces of the structure. The moment is converted to the linear load of the triangular distribution according to σ = Mei, and the moment at the center of the loaded cross-section is converted to the distributed load of zero.

III. RESULTS OF FINITE ELEMENT ANALYSIS

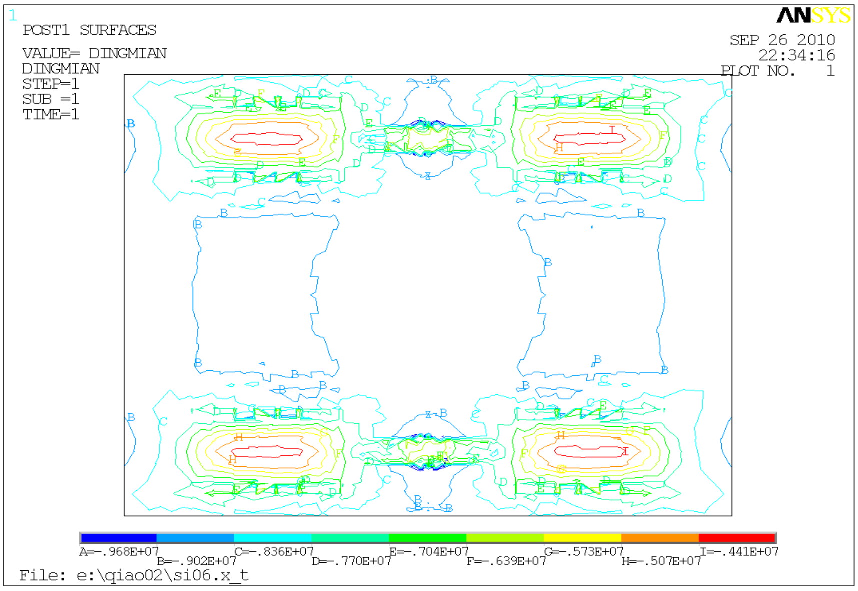
According to the previous analysis, the structure of the consolidation zone of the continuous rigid frame bridge with v-shaped piers is more complicated. The beam body is combined with the transverse v-shaped braces and the longitudinal v-shaped braces, and the four v-legs are combined with the lower vertical piers, it makes the way of bearing force and transmitting force of the structure in this area complex, and the space effect is obvious, and the local high stress area will appear. In order to understand the complex stress distribution in the consolidation zone of pier-beam, the roof, main beam, v-brace, vertical pier and the joint area of main beam and v-brace are selected from the results of finite element calculation, the stress analysis is carried out in the joint area of V-brace and vertical pier.

Figures 2(a) , (b) and 3（a) , (b) show the isochromatic and isochromatic lines of the longitudinal bridge σz stress of the roof of the structure under two load conditions, respectively. It is obvious that the normal stress of the longitudinal bridge on the roof surface is symmetrical along the transverse central line due to the symmetrical cantilever construction under condition 1. The normal stress σz is compressive stress in the range of-10.8 mpa-4.08 mpa, which is due to the placement of a large number of longitudinal prestressing tendons in the main beam, which counteracts the negative bending moment produced by the self-weight of the cantilever section. The longitudinal compressive stress on the roof surface is the smallest at the diaphragm of the main beam, which ranges from -5.40 mpa to -4.08 mpa. This is mainly due to the anchoring effect of the v-brace and the increase of the stress area of the cross-section caused by the diaphragm of the main beam. At the position of the diaphragm between the two box girders, the longitudinal stress concentration appears in the joint area of the diaphragm and the roof, which is up to -10.8 mpa. The longitudinal normal stress on the roof surface of the beam segment between the V-braces IS-9.35 mpa-8.03 mpa, which is distributed unevenly along the transverse direction. The longitudinal compressive stress at the junction of the top plate and the web of the two box girders is greater than the compressive stress on the surface of the external cantilever section of the top plate, the positive shear lag effect appears because the width of the top plate of the two box girders is 12m and the space between ribs is large.

However, the stress at the junction of the top plate and the web plate of the two box girders is not larger than that of the top plate of the inner cantilever section, which is due to the fact that the top plate of the inner cantilever section of the two main girders is poured as a whole and the shear lag effect is not obvious. At the root section of v-braces, the longitudinal compressive stress at the junction of the top plate and the web plate of two box girders is less than that of the cantilever section, resulting in negative shear lag effect. Under the action of working condition 2(the most unfavorable load combination in the normal use stage) , the longitudinal normal stress range of the roof surface is -12.3 mpa-1.51 mpa, the stress range of the loading surface is -7.51 mpa-1.51 mpa on the 1 and 3 sides, and the stress range of the roof surface is -1.51 mpa, this is because the effect of live load at the stage of use counteracts the effect of a part of prestressed steel bar. The stress range is -12.3 mpa ~ -5.11 mpa on the 2 and 4 sides of the loading surface. As in case 1, the longitudinal compressive stress on the roof surface is the minimum because of the diaphragm structure and the v-brace action at the diaphragm in the main beam. At the position of the diaphragm between the two box girders, the stress concentration appears in the joint area of the diaphragm and the top plate, forming the high pressure stress. The stress reaches -7.51 mpa on the 1 and 3 sides of the loading surface, and -12.3 mpa on the 2 and 4 sides of the loading surface, transitional measures should be set up in the project. The longitudinal normal stress on the roof surface of the beams between v-braces is -11.10 mpa--3.91 MPA. The distribution of the longitudinal normal stress along the transverse direction is relatively uniform, and the shear lag effect is not obvious. However, at the root section of the v-braces, the longitudinal compressive stress at the junction of the top plate and the web plate of the two box girders is less than the compressive stress at the top plate surface of the cantilever section, resulting in negative shear lag effect, this is mainly due to the diaphragm and v-braces of the embedded role.

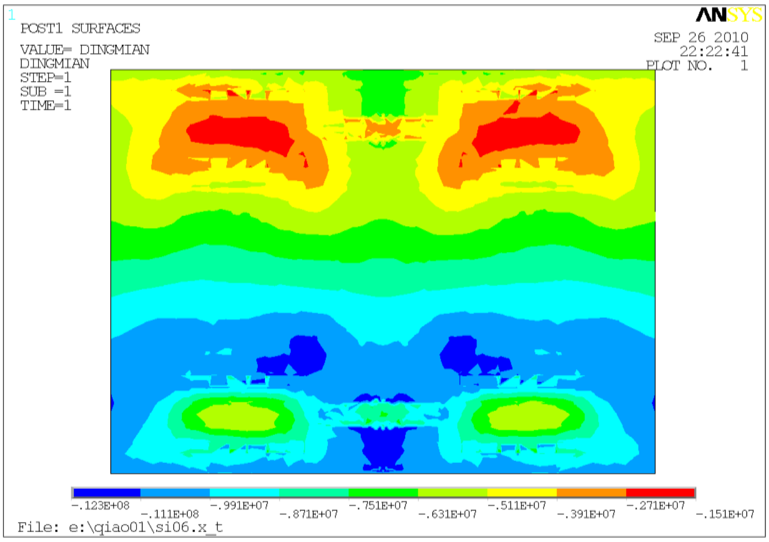


（a）isochromatic chart of the ceiling

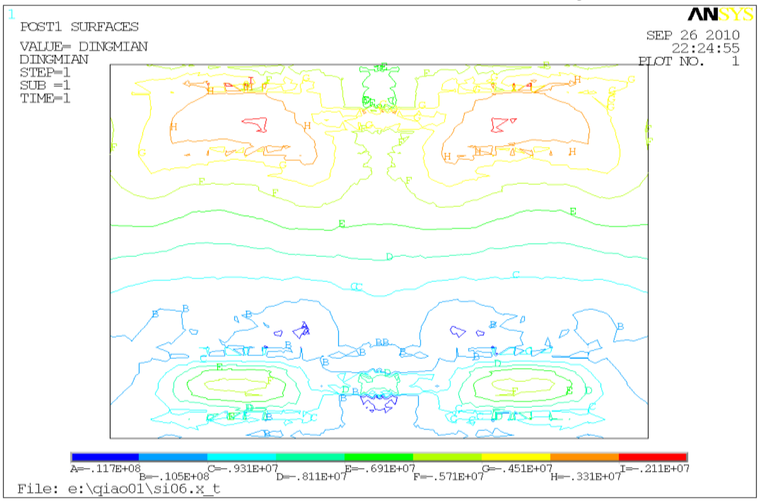


（b）Roof contour map

Fig. 2 isochromatic and isochromatic lines (in PA) of σz stress of longitudinal roof bridge under condition 1



（a）isochromatic chart of the ceiling



（b）Roof contour map

Fig. 3 isochromatic and isochromatic lines (in PA) of σz stress of longitudinal roof bridge under condition 2

IV. CONCLUSIONS

The stress rule of v-shaped pier in the operation stage is mainly due to the influence of shrinkage, creep and cooling of concrete in the later period of the main beam, which results in longitudinal horizontal displacement of the upper main beam, the displacement is limited by the v-shaped pier with high thrust stiffness, and the secondary tension force is produced in the main beam, which results in a large overturning moment to the lower structure. In order to optimize the mechanical characteristics of the v-shaped pier rigid frame bridge, it is suggested to increase the height of the vertical pier so that it can show the characteristics of flexible pier to adapt to the vertical horizontal displacement of the superstructure.

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REFERENCES

[1] J.A.Lozano-Galant，I. Paya-Zaforteza，D.Xu，J.Turmo． Analysis of Cable-stayed Bridges During Construction by Cantilever Methods[J]． Computer&Structures．2004，82(4)： 329-346．

[2] Becz，JanosKorong．Prestressed extradosed bridge[J]． Journal of the International Association for Bridge and Structureal Engineering．2006，(16)：28-30．

[3] Chelsa．Conceptual design for the sunniberg bridge Honigmann[J]．Journal of Bridge Engineering，2003．

[4] Xiang,Y.Q.，Feng, S.，Wang, J.F．Spatial Static Behavior Analysis of Long-Span P.C.Continuous Rigid-Frame Box Girder Brige with Single Cell[J]．Journal of Highway and Transportation Research and Developmen．2005，22(3)：58-61．

[5] Youliang Ding，Aiqun Li， Jun Sun，Yang Deng．Experimental and Analytical Studies on Static and Dynamic Characteristics of Steel Box Girder for Runyang Cable-stayed Bridge[J]．Advances in Structural Engineering．2009，32(4)：134-142．