International Journal of Intelligent Information and Management Science
ISSN: 2307-0692 Volume 4, Issue 2, April 2015

RESEARCH ONLATERALSTRESSOF THE DECK OF ASSEMBLED STEEL TRUSS-CONCRETE COMPOSITE CONTINUOUSLY RIDGED BRIDGE

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Abstract: Since the thickness of the deck of the assembled steel truss-concrete composite continuously ridged bridge is fairly thin, adopting finite element analysis software can not directly calculate the deck's lateral stress states. For decks with fairly large width-span ratio,using Structural Mechanics Solver and the finite element software MIDAS is a simplified method to analyse the deck's lateral stress distribution and get the distribution law of lateral stress, which is expected to have a guidance significance to engineering.

Keywords: Assembled Steel; Truss-concrete; Composite Continuously Ridged Bridge; Lateral Stress Distribution; Precast deck

1. Introduction

The main feature of assembled steel truss-concrete composite continuously ridged bridge is that its prefabricated steel truss and deck are assembled by welding the upper steel chord and the pre-embedded steel plate to transfer shear and work together. Currently the deck of steel truss - concrete composite beam bridge are poured on the completely installed steel truss beam and thus assembled steel truss-concrete composite continuously ridged bridge has few domestic and abroad projects.

When using the finite element software to calculate the longitudinal stress of prestressed concrete bridge, the structure is simplified into plane bars. Few finite element software can calculate its lateral stress and just consider the affect of lateral distribution[1].Not only the thickness of the deck of the assembled steel truss-concrete composite continuously ridged bridge with respect to the thickness of its span and width is small, but also lateral stress state of its bridge deck section is related to the design of the lateral stress and whether there will be many cracks in the negative moment zone during the operational phase, therefore we need carry on research on lateral stress of the deck of assembled steel truss-concrete composite continuously ridged bridge.

2. Background and Model Building

There is a assembled steel truss-concrete composite continuously ridged bridge whose span is41+70+41m ,total width 33m (divided into left and right bridge, width of a single bridge is 16.25m) and width of median strip between left and right bridge 0.5m, as shown in Fig.1.The longitudinal length of a standard segmental precast concrete bridge deck of this project is 5m and the lateral width is 16.25m. Firstly, all lateral prestressing tendons of the prefabricated bridge deck are tensioned and anchored in the precast factory. Secondly, initial positioning of the decks are conducted after all trusses are completely assembled. Finally, weld trusses to steel panels embedded in the decks steel after all longitudinal prestressing tendons are tensioned and anchored.

Longitudinal width 1m of the bridge deck is intercepted as bridge deck model for this project to mainly study lateral stress condition of the deck. The finite element software Midas Civil is used to build model and 3D beam element is adopted. The model can be regarded as a two-span continuous beam with cantilevers at both ends. Full-bridge is separated into 41 nodes, 40 beam elements. Separated structure is shown in Figure 2.

Size parameters are as follows: the thickness of cantilever ends0.2m, the thickness of cantilever root 0.42m, the length of cantilever 2.4m, the lateral calculation span 5.5m. And material parameters of concrete are as follows:C50 concrete density 26KN / m3,standard axial compressive strength32.4MPa,standard tensile strength 2.65MPa.Prestressing tendons are made of high-strength low-relaxation strand (standard strength $f_{pk}=1860\text{MPa}$) and 15-3 prestressing tendons reused .Loads include weight, bridge deck, fence, temperature effects, vehicle load and so on. Temperature effect is as follows: overall heating and cooling ±20℃, the temperature gradient between inside and outside deck ±5℃.Vehicle load is as follows: highway- Grade I vehicle load, axle weight 140KN, and impact factor 1.3.

3. Lateral Stress Analysis of the Concrete Deck

3.1. Lateral Stress Analysis of the Deck under the Effect of Weight and Prestress

Selects the concrete bridge deck as the research object and adopts space finite element program to analyze and draw the lateral stress distribution curves. As can be seen from Fig.3, adding weight of the bridge deck the lateral stress improves the lateral stress distribution and the lateral stress value is cut by 0.6-1.4MPa.Sincethe weight of the deck is unfavorable for the longitudinal force and it will reduce the spanning capability of the assembled steel truss-concrete composite continuously ridged bridge, increasing the weight of the bridge deck to improve the performance of the lateral stress is not recommended. As can be seen from Figure 4, increasing the prestressing degree may increases the maximum lateral tensile stress of the mid-span section. Therefore, lateral stress degree is not the bigger the better when selecting the suitable lateral stress.

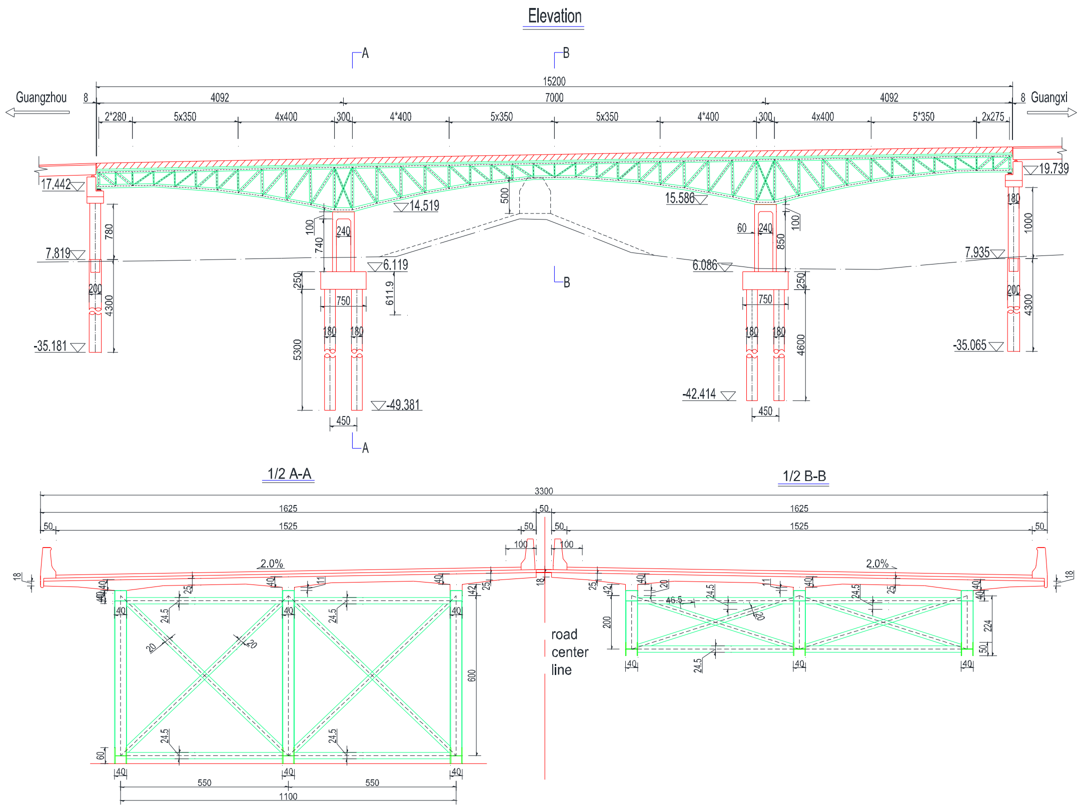

Figure 1. The overall arrangement of a bridge (unit:cm)

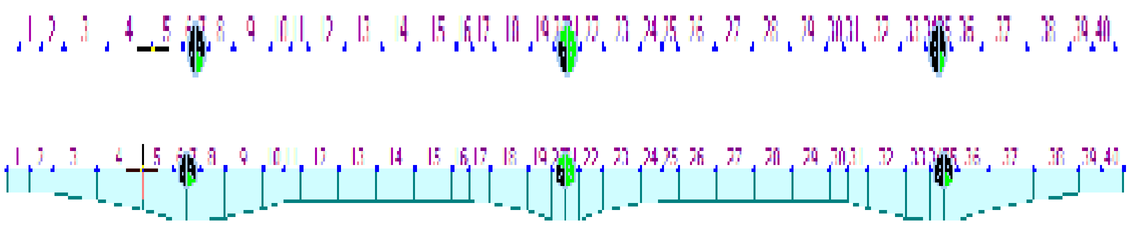

Figure 2. Structure of the separated map

3.2. Lateral Stress Analysis of the Deck under the Effect of Live Load

The lateral stress's distribution law is different when concentrated load position on the cross section of continuous beams is different, therefore load position on the cross section must be considered when the study of the lateral stress is conducted[2].The lateral deck's stress of the project obeys the same regulation law as continuous beam does. This article utilizeStructural Mechanics Solver[3]to obtain the bending moment influence lines of the deck and can determine the most unfavorable position of the live load according to the bending moment influence lines. The deck's model can be regarded as a two-span beam with two cantilevers and one redundant degree. The deck's maximum lateral tensile stress may appear on the upper and lower margin among support, mid- supported and mid-span sections. Determine the most unfavorable position of the live load according to the bending moment influence lines, as shown in Figure 5-10 below.

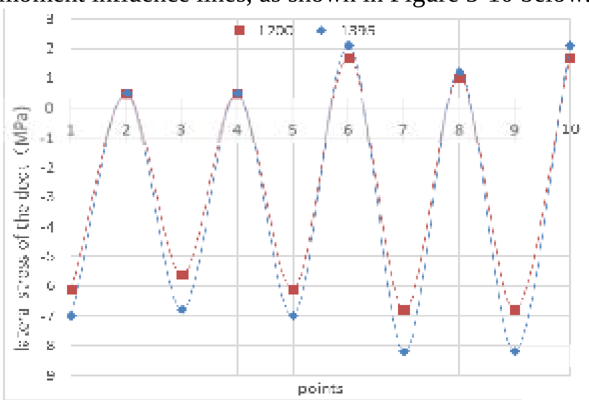

Figure 3. Contrast of the lateral stress under different degree of prestress

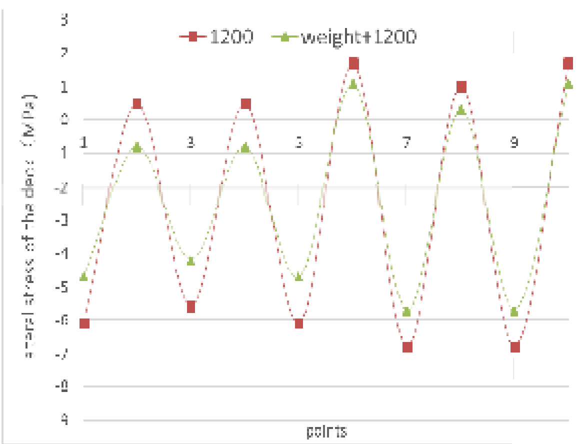

Figure 4. Contrast of the lateral stressbefore and afterincluding the weight

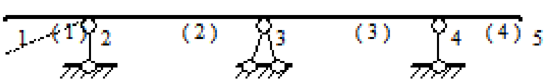

Figure 5. The bending moment influence lines of the end bearing's section

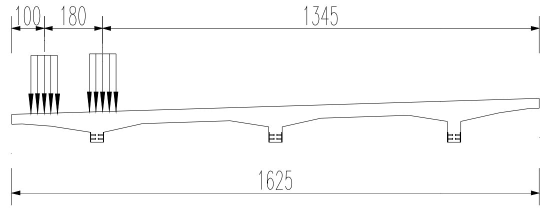

Figure 6. The worst live load position of the end bearing's section

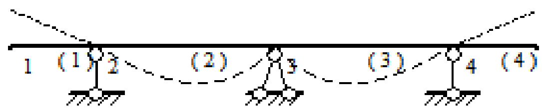

Figure 7. The bending moment influence lines of the median bearing's section

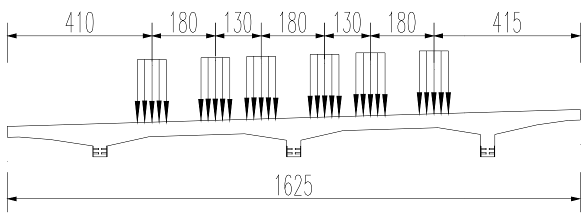

Figure 8. The worst live load position of the median bearing's section

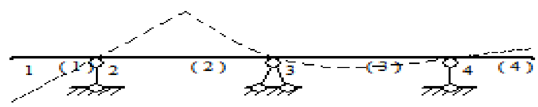

Figure 9. The bending moment influence lines of the mid-span section

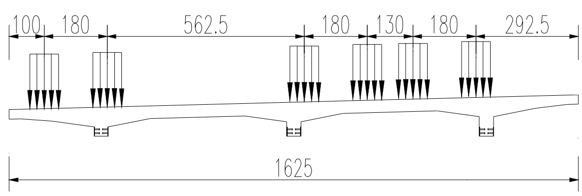

Figure 10. The worst live load position of the mid-span section

In order to conveniently describe the lateral stress of the deck on the upper and lower margin among support, mid-supported and mid-span sections, the positions of each key points are numbered as shown in Figure 11.Calculation of the lateral efficient load working breadth of the deck[4] [5]can refer back to Code for Design of Highway Reinforced Concrete and Prestressed Concrete Bridges and Culverts (JTG D62-2004). [6].By the calculation, when a>3.67m, effective distribution width for two longitudinal rear wheels, where overlaps exist.

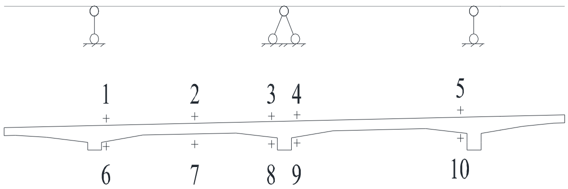

Figure 11. Locations of key-points

Condition 1, condition 2 and condition 3 are respectively defined for the above three greatest detrimental position of live load. Adopting distributing forces or concentrating ones(the dead load and effect of prestressing tendons are not considered),the wheels' effect is respectively calculated .The results of finite element analysis software Midas' calculations ,as shown in Figure 13, Figure 15, Figure 17 and Table 1.

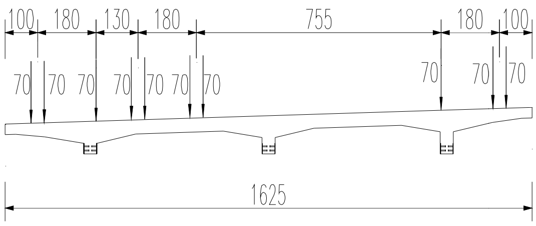

Figure 12. Lateral load distribution (condition 1) (unit:cm)

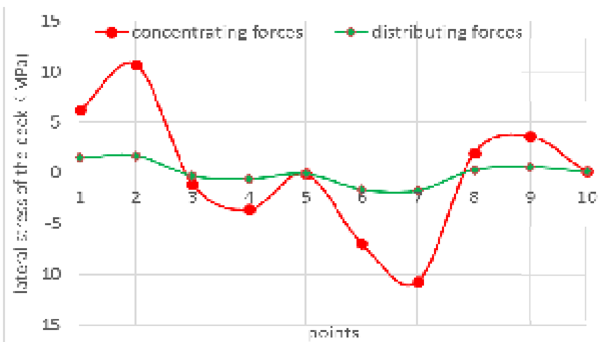

Figure 13. Contrast of the lateral stress under distributing forces or concentrating ones(condition 1)

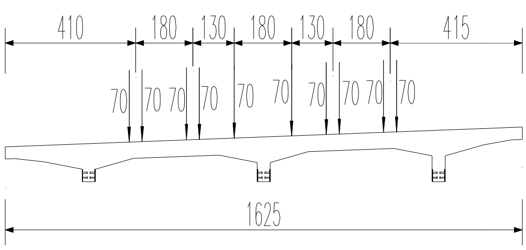

Figure 14. Lateral load distribution(condition2)(unit: cm)

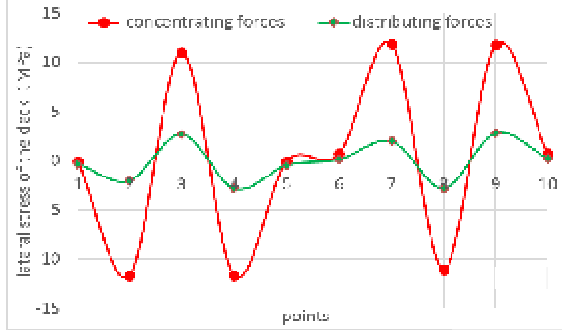

Figure 15. Contrast of the lateral stress under distributing forces or concentrating ones(condition 2)

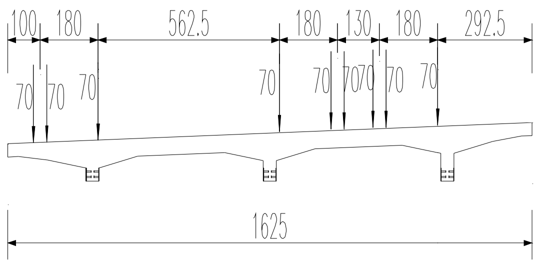

Figure 16. Lateral load distribution(condition 3) (unit: cm)

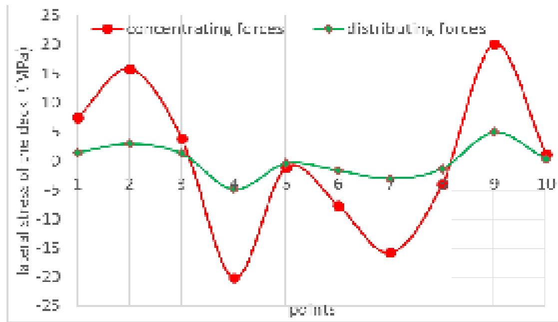

Figure 17. Contrast of the lateral stress under distributing forces or concentrating ones(condition 3)

As can be seen from Figure10, Figure12 and Figure14, for each above condition the difference is large when lateral stress of the deck is calculated adopting concentrating forces distributing ones or to simulate the wheel load and lateral stress of the deck reduces by 64%-84%.

The large difference of the lateral stress is mainly due to that the effect of distributing forces comparing with the effect of concentrating forces get smaller numeric values from the bending moment influence lines, which can weaken the maximum tensile stress peak. From another angle, it shows that lateral stress of the deck of assembled steel truss-concrete composite continuously ridged bridge is highly sensitive under the wheel live load. Therefore, adopting distributing forces to calculate lateral stress of the deck can simulate the real environment approximately.

Table 1. The deck's lateral stress under distributing forces or concentrating ones (unit: MPa)

	Point	3.4	3.1	-0.1	-0.9	1.9	-3.5	-3.1	0.1	1	-1.9
condition 4	concentrating forces	1.9	-1.3	3.3	-2.6	1.9	-1.9	1.3	-3.3	2.5	-1.9
	distributing forces	3.4	4.1	1.9	-4.9	1.9	-3.5	-4.1	-1.7	4.9	-1.9
	reduce rate	-2.2	1.1	-5.1	-0.9	-4.3	-1.9	-7	0.9	-5.9	0.1
condition 5	concentrating forces	-3.6	-4.9	-2.2	-5.6	-3.9	-0.3	-5	-2.3	-3.8	0.4
	distributing forces	-2.3	2.3	-3.6	-6.7	-4.3	-1.9	-8.8	-0.8	1.5	0.4
	reduce rate	-2.3	1.1	-6.2	0.4	-4.8	-1.1	-7.9	1.1	-6.9	0.4
condition 6	concentrating forces	-5.1	-5.8	-3.3	-6.4	-5.6	0.8	-6.1	-2.1	-5	1
	distributing forces	-3.7	2.4	-4.1	-7.3	-5.2	-1.1	-9.8	-0.5	1.7	0.7
	reduce rate	3.4	3.1	-0.1	-0.9	1.9	-3.5	-3.1	0.1	1	-1.9

3.3. Lateral Stress Analysis of the Deck Under other Effect

In order to globally analysis lateral stress of the deck under the main loads including secondary dead load and temperature load (the temperature rise 20℃), the following conditions are designed: 1)condition4: weight+ prestress + condition1+the temperature rise 20℃;2) condition5: weight+ prestress + condition2+the temperature rise 20℃;3) condition4: weight+ prestress + condition3+the temperature rise 20℃.For each above condition, curves of the maximum lateral tensile stress of the deck on the different points under different effective prestressing are drawn in the Fig.18-Fig.20.

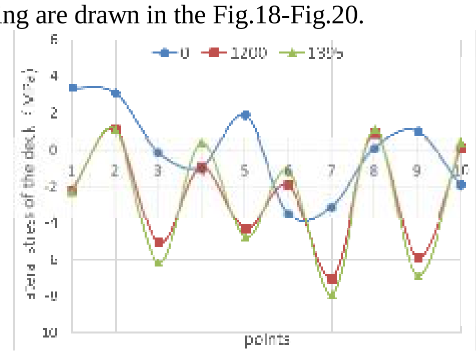

Figure 18. Contrast of the lateral stress underdifferent effective prestressing (condition 4)

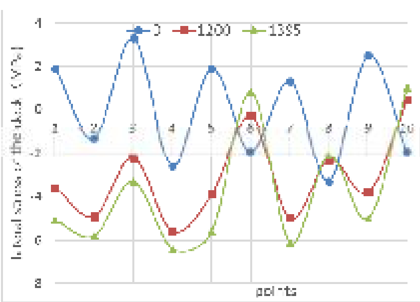

Figure 19. Contrast of the lateral stress underdifferent effective prestressing (condition 5)

As shown in Fig.18-Fig.20, effective prestressing has some improvement for the lateral tensile stress of the deck on the different points under acomprehensive condition (includingdead load, live load, secondary dead load and temperature effect). However, the maximum lateral tensile stress of the mid-span sections of the deck will increase when effective prestressing is raised to some degree (the maximum lateral tensile stress values of the mid-span sections under 1200MPaare smaller than ones under 1395MPa,as shown inFig.18-Fig.20).Therefore, the lateral stress of the deck basically meet the demand of the code under a comprehensive action including dead load, live load, secondary dead load and temperature effect and the maximum lateral tensile stress of the mid-span sections must be a key concern.

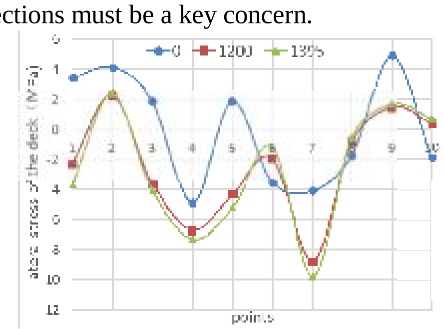

Figure 20. Contrast of the lateral stress underdifferent effective prestressing (condition 6)

3.4. Increase Bearings to Reduce the Maximum Lateral Tensile Stress of the Deck

From the above analysis of lateral stress of the deck, we can reach a conclusion that the maximum lateral tensile stress values of the mid-span sections (point 2,point 4,point 7 and point 9)easily exceed the concrete's strength design value. To solve this problem, we can increase bearings on the mid-span sections. For the condition 4, the condition 5 and the condition 6, we can draw the contrast curves of the maximum lateral tensile stress of the concrete bridge deck before and after increasing two bearings on the mid-span sections. From Figure 21-Figure 23, lateral stress states of the deck's mid-span sections becomes stressed. Therefore, increasing bearings on the mid-span sections is an effective plan to improve the lateral stress states during the design of the concrete deck with large lateral spans.

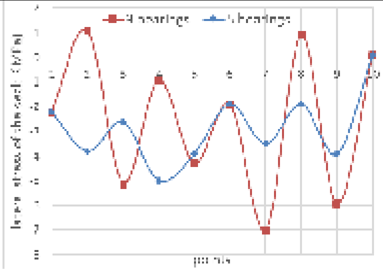

Figure 20. Contrast of the lateral stress with different constraints (condition 4)

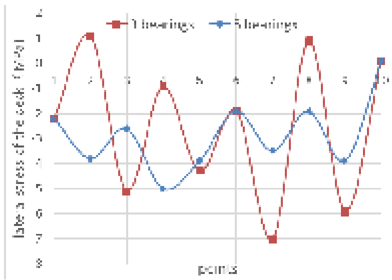

Figure 21. Contrast of the lateral stress with different constraints (condition 4)

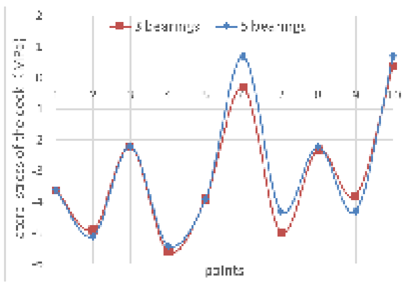

Figure 22. Contrast of the lateral stress with different constraints (condition 5)

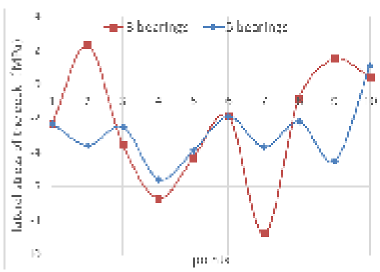

Figure 23. Contrast of the lateral stress with different constraints (condition 6)

4. Conclusion

By studying the concrete deck's lateral stress states of the assembled steel truss-concrete composite continuously ridged bridge, the following conclusions can be drawn:

(1) Increasing lateral effective prestressing can reduce the maximum lateral tensile stress values of the mid-span sections when the effective prestressing is not big enough. However, at some point, increasing lateral effective pre-stressing may increase the maximum lateral tensile stress values of the mid-span sections. Therefore, improper lateral effective prestressing must be selected for the concrete decks of he assembled steel truss-concrete composite continuously ridged bridge.

(2) When the concrete deck's lateral stress is calculated, adopting distributing forces to simulate wheel loads can simulate the real environment approximately by contrast with adopting concentrating ones.

(3) According to the bending moment influence lines of the model, closely arranging live loads in lateral directions is not the most disadvantaged load case. The most disadvantaged load case must be found on the basis of the bending moment influence lines.

(4) During designing concrete decks with larger spans in lateral directions, increasing bearings on the mid-span sections is an effective solution to improve the lateral tensile stress states.

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