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Form-finding study of Taizhou Bridge

A 3-pylon suspension bridge

Airong CHEN, Xiaoyu LUO

(Department of Bridge Engineering, Tongji University, Shanghai 200092, China)
Email: a.chen@mail.tongji.edu.cn, xiaoyuluo72@126.com

Abstract

In this paper, The special feature of 3-pylon suspension bridge is introduced and the form-finding study of Taizhou Bridge is carried out. Because of the existing middle pylon, 3-pylon suspension bridge show a difference characteristic with the 2-pylon suspension bridge. In order to find better form results for the main components, topological optimization method and the force tracing method was applied for the form finding of the bridge. Combined with other modeling method, the topological optimization method and the force tracing method proved to be an effective way in the form finding study.

Keywords: 3-pylon suspension bridge, form finding, topological optimization, force tracing, pylons, anchorages

1. Introduction

Taizhou Bridge is located in Jiangsu province, China, bwteen Runyang Bridge and Jiangyin Bridge. It is a 3-pylon suspension bridge with two main spans. Both spans are 1080m.

The pylons and the anchorages are the main components of the bridge, supporting the main loads and need to have a good capability for the load transfer, from the cable to the earth. On the other side, the shape of these components decided the style and the aesthetics views of the bridge. So, It is a key issue that how to find a suitable form for these components, achieving the aesthetics target and getting excellent performance.

2. Characteristics of the 3-pylon suspension bridge

As a result of the existing middle pylon, 3-pylon suspension bridge show a difference characteristic from the 2-pylon suspension bridge. In the case of semi-cross-loaded, a rigid middle pylon will support the main level force of the cable. In this situation, the shear force inside the pylon is huge and the vertical displacement of the loaded span is small, the cable force beside the middle pylon is difference. Requirement for the anti-slip ability of the saddle is strictly, as shown with Figure 1.

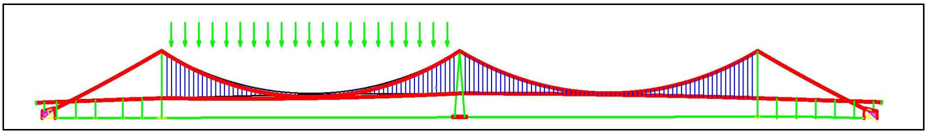


Figure 1: structural performance with a rigid middle pylon

On the contrary, a flex middle pylon will bend and transfer the level force to the cable of the unloaded side. In this case, the moment in the middle pylon is huge and the vertical displacement of the loaded span is large. Requirement for the anti-moment ability of the saddle is strictly, as shown with Figure 2.

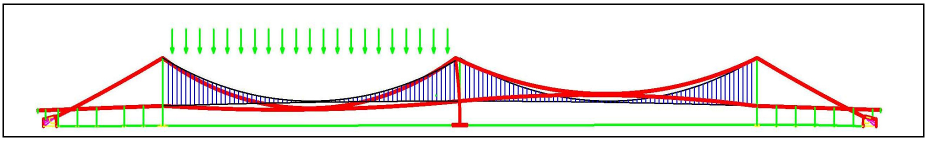


Figure 2: structural performance with a flexible middle pylon

Both the rigid and the flexible middle pylon are not so good for the whole bridge system. A semi-flexible middle pylon may be better for the whole bridge system, pursuing a stability and good performance during the day and day use.

3. Form-finding study for the pylons

2.1. Form-finding study for the middle pylon

A flexible pylon can be made by separated the lower part of the pylon. As many possibility exit, it is hard to choose the separate point to achieve a suitable flex pylon, as shown with Figure 3. Form-finding study need to be done.

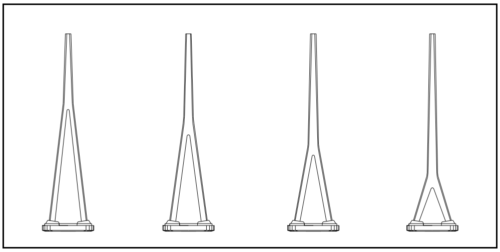


Figure 3: Semi-flexible pylon

Topological optimization helps to finding a series of suitable form. On this base, the structural optimization will be easier, enhancing the work efficiency directly.

The purpose of topological optimization is to find the best use of material for the structure under the loads. In one sense, the answer of the topological optimization means a good structure performance. It is help for finding the suitable form of the middle pylon under the complex loads.

In the case of Form-finding study for Taizhou Bridge，a finite model was established. The top of the model was defined as loads area and the bottom side of the model was defined as the fix points. The other part of the model can be optimized, as shown with Figure 4.

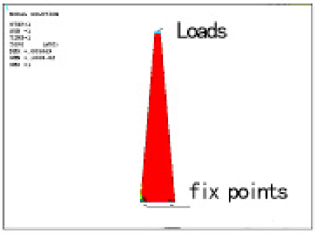


Figure 4: finite model for middle pylon

According to the results of the budget statement, loads are given as follow:

Case1: Dead load; Vertical load=14855627N/m

Case2: Dead load + live load; Vertical load=17021036.5N/m;

Level load=5413523.67N/m

The hollowing out rate of topological optimization is set from ten percent to ninety percent. The outcomes of 20% and 30% hollowing out rate were given, as shown with Figure 5-8.

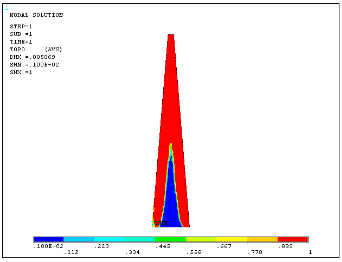


Figure 5: Case1; 20% off

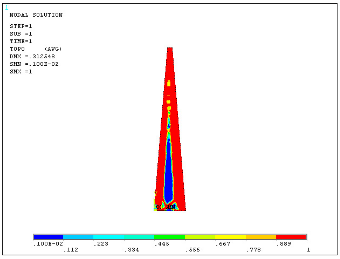


Figure 6: Case2; 20% off

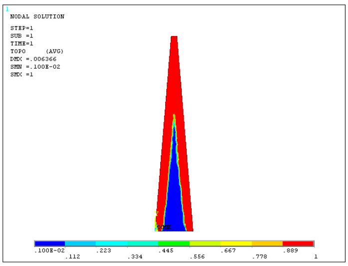


Figure 7: Case1; 30% off

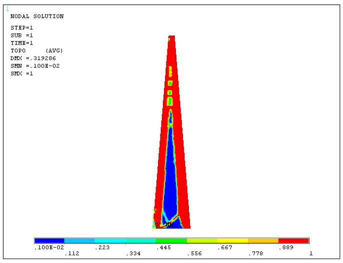


Figure 8: Case2; 30% off

When the hollowing rate higher then 30%, the outcome forms are near the rigid pylon. Depth analysis is unnecessary.

In the situation of 20% and 30% hollowing rate, the separate point is near to the two golden point of the pylon. From the aesthetic view, that is means good visual effect.

Considering the anti-slip ability of the saddle, the displacement of the beam, the shear force and the moment of the pylon itself, the final structure form was selected, as shown with Figure 9. It is close to the topological outcome of 20% hollowing rate, suitable for the middle pylon of the 3-pylon suspension bridge.

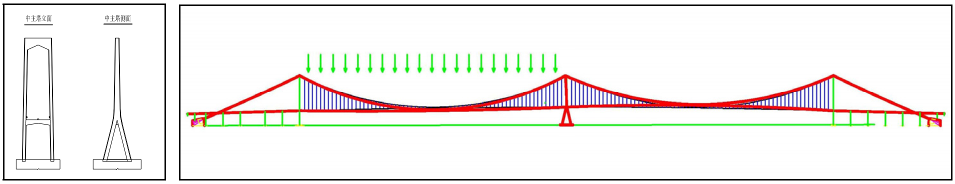


Figure 9: Semi-flexible pylon and its structural performance

2.2. Form finding study for the details of the pylon

The details of the pylon represent the style and aesthetics of the bridge. A lot of job should be done to find out the suitable details form, making the bridge style fit with the environment style.

Carrying out the form finding study only in the view of aesthetic is not enough, a novel shape may have a bad structural performance. So, the shape factor and the structure factor should be considered at the same time in form finding study, that the sustained loads in the structure can be transfer smoothly from the top to the earth.

The force tracing method may help to settle this question. After calculated and depicted the internal force flow in the structure, associating with other modeling methods, the form of bridge components, with good shape and performance, are easy to find.

According to the overall modeling method, using one cross beam upon the deck gives the pylon a simple style. So, the main question for the form finding study of the pylon focus on the shape of the top crossbeam of it. Finite model was build, force track was calculated, as shown with Figure 10.

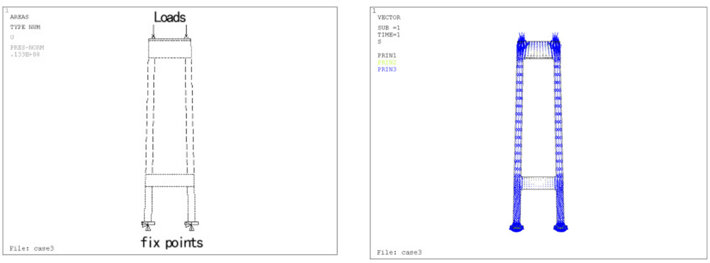


Figure 10: The raw model for the force tracing analysis

More detail result about the calculation is showed with Figure 11. The force track can be draw out according to this result, as shown with Figure 12. Phenomenon of the force tracks concentration can be seen in the conjoint point between the columns and the crossbeam.

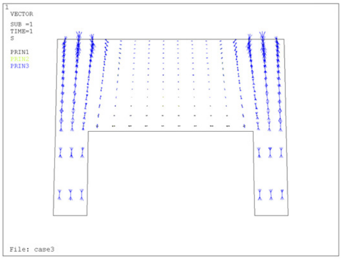


Figure 11: Detailed of the result

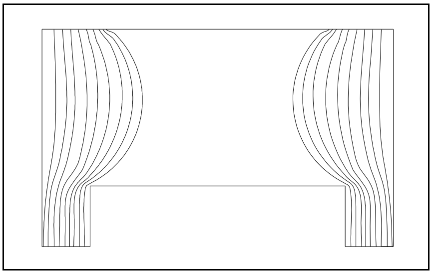


Figure 12: Force track

According to the result of the force tracing analysis, shape optimization was done, as shown with Figure 13. Phenomenon of the force tracks concentration is improved.

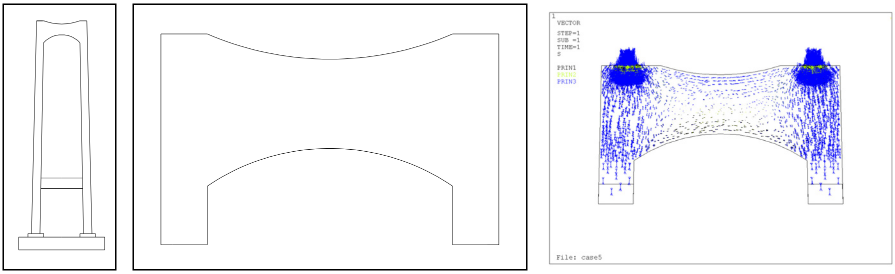


Figure 13: Optimal model and its force tracing analysis

However, Taizhou is located in the plains, there are scarce of mountains and the islands. According to the environment modeling method, a rigid style shape is fit for the bridge building there. But the optimal model shown in figure 13 did not have this style.

A rigid style architecture element is useful for modeling a rigid shape of the pylon. After comparison, the "K" shape architecture element was selected to modeling the top beam of the pylon, as shown with Figure 14. The force is smoothly transfer form the top to the columns of the pylon.

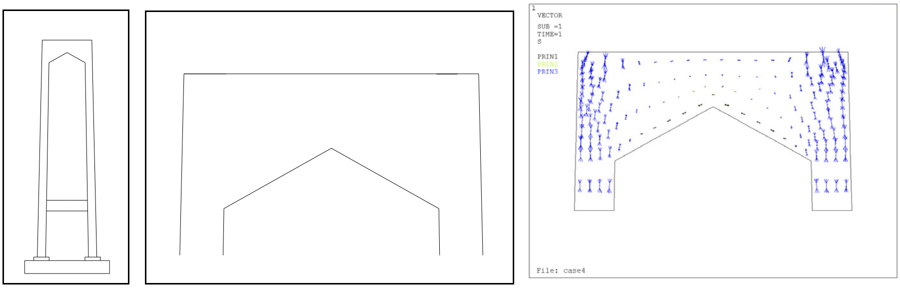


Figure 14: Final shape of the pylon and its force tracing analysis

The force tracing method did had good effects on the form finding of pylons for Taizhou Bridge, as shown with Figure 15.

Figure 15: Expected view of Taizhou Bridge

4. Form finding for the anchorages.

As similar situation with the pylons, the force tracing method can be used for modeling the shape of anchorages. A finite model was build, the saddle for turning point of the cable and the anchorage zone was definite in the model, as shown with Figure 16.

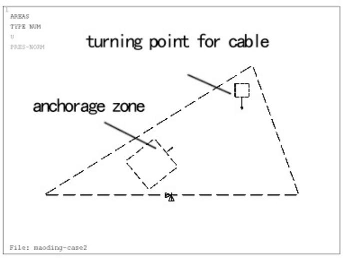


Figure 16: Finite model for anchorage

After force tracing calculation, the outcomes were got, as shown with Figure 17.

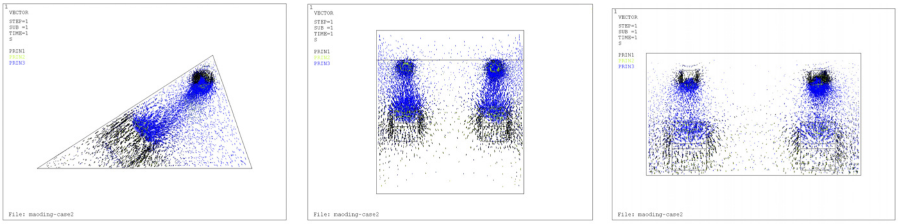
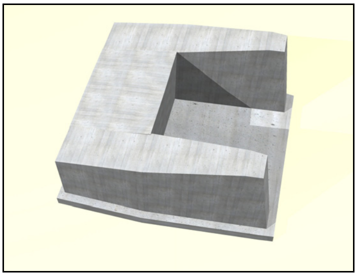


Figure 17: Force tracing analysis of the anchorage model

According to the force tracing analysis, some part of the structure can be cut, then the raw shape of the anchorage was got, as shown with Figure 18. But, from the aesthetics view, that is not enough, further modeling work need to be done.

Finally, Combined with the unit modeling method, the "K" element was added in the shape of the anchorage, as shown with Figure 19.



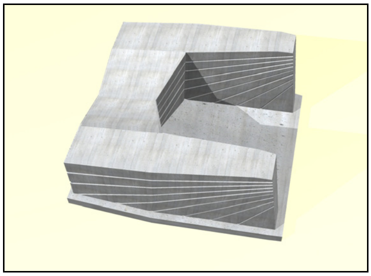


Figure 18: The raw model

Figure 19: The final model

5. Conclusion

In the form finding study of Taizhou Bridge, the topological optimization method, the form finding method were applied and some ideal results were got. Combined with other modeling method, they are efficient in the form finding study.

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