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Design and Finite Element Analysis of A Spatial Tubular Truss and Its Pin Support

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Abstract

The tubular truss is widely used in the large-span spatial structures for its good performance under various loading cases. In this paper, the design of a spatial tubular truss is presented, and its loading capacity is discussed. As well, the design of the support is very crucial for the whole structure. Because the support of the tubular truss is mostly considered as the hinge support, it is the key point that how the support can transfer the vertical and horizontal force but release all the moments. By using the software ANSYS, the solid finite element analysis is conducted to analyze the pin support of the spatial tubular truss and the results provide some useful suggestions for further design of this type of support.

Keywords: Tubular truss, Pin support, Finite element analysis

1. Introduction

For the good performance under various loading cases and the convenience of forming different architectural styles, the spatial tubular truss is widely used in many projects (Yu and Zhao [1]). In this paper, the roof design of a Logistic Center, as shown in Figure 1, is presented. Because it's very crucial of the design of the support, a finite element model is established to analyze the loading property of the pin support.

To meet the architectural requirements and the functions of the Logistic Center, the main structure is mostly three continuous spans of spatial tubular truss, with the span of 20m, 44m and 62.5m respectively. The calculation model, established by software MIDAS, is shown in Figure 2.

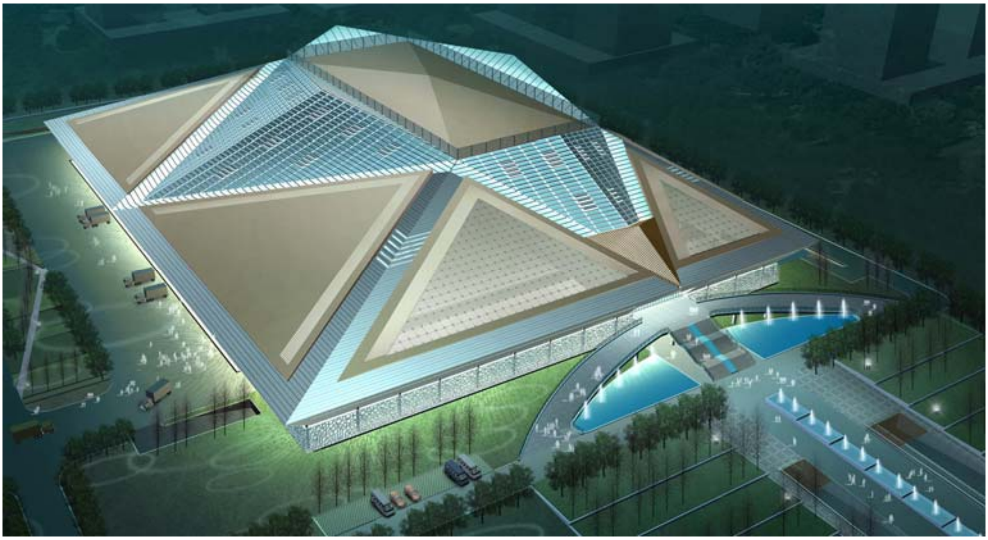


Figure 1: Prospect View of the Center

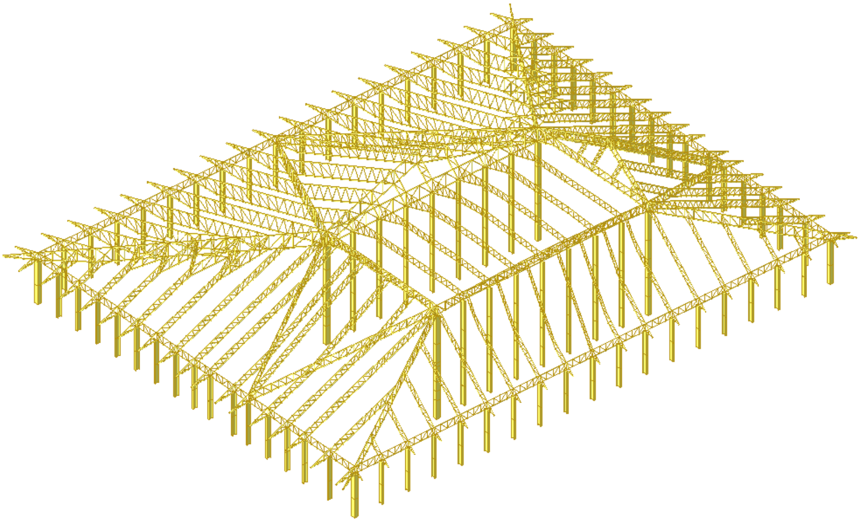


Figure 2: Calculation Model

2. Design of the Roof

By the documents provided by the owner, the architectural requirements and relative Chinese codes, the following load cases are included.

1) Dead load: 1.0 kN/m2

2) Live load: 0.5kN/m2
3) Wind load: w0＝0.35 kN/m2
4) Seismic load, and 5) Temperature load: ±20^{o}

2.1 Static Loading

It should be noticed that the effect of purlins is also consider in this model. Because for the planar truss, the out-plan stability of the up chords would be largely enhanced by the purlins which connect the up chords of the two adjacent trusses. In fact, considering the stiffness of the roof, the out-plan stability of the up chords is not a problem. But near the supports where the minus moments may exist, compression stresses will appear in the bottom chords; and in this case the stability of the bottom chords should be also considered. To ensure the stability of the whole structure, some links are set in both the up and bottom chords of the trusses.

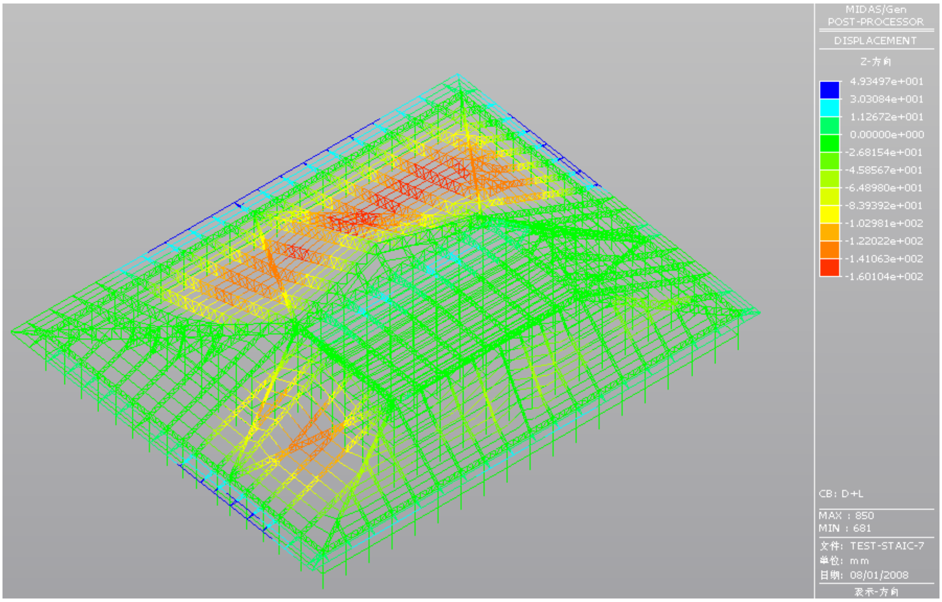


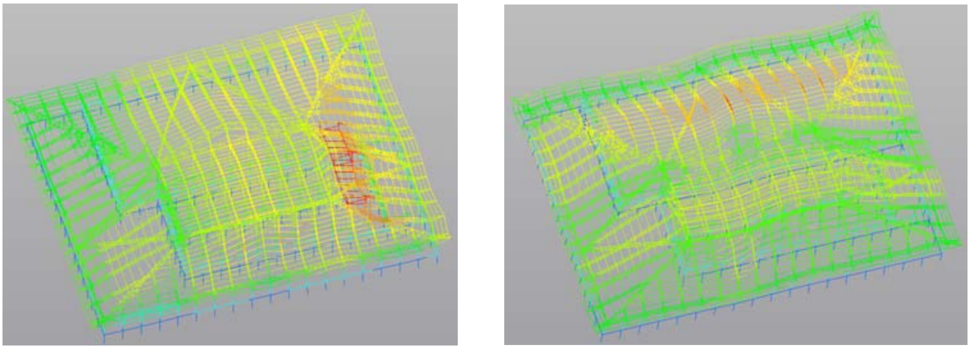
Figure 3: Deformation under the load case D+L

As well, in the actual design, many other factors should be considered, as the fire-proof walls from the ground to the roof.

The calculated strengths of the components are lower than the design value of strength under all the load cases. And for the safety seeks, in our further design, we hope the stress ratios of all the components are strictly less than 0.8 time of the design value of strength. The maximum calculated stresses of most components are under the load case D+L+T. Under this load case, all the upper components of the tubular truss are imposed a temperature of +20℃ as well as the dead load and live load applied. Figure 3 shows the deformation shape of the roof under the load case D+L. The results indicates that the maximum displacement is at the middle the largest span of the roof. For the bad shape of the trusses, as seen that a downward concave shape is in the middle of the span, the displacement is much larger than expected.

2.2 Dynamic properties

For the roof high is comparatively large with the peak of 42m from the ground, and considering that the fire-proof walls is very high and heavy, the dynamic properties of the structure should be carefully analyzed. Figure 4 shows the first two modes of natural frequencies.



First period = 1.006s   Second period = 0.985s

Figure 4: First two modes of natural frequencies

It can be seen that the first period is small, which indicates that the structure is relatively stiff. The results show that local vibration caused by the fire-proof wall is very obvious. And because the out-plan stiffness of planar tubular truss is small; even though the effect of the purlins is considered, the truss tends to the lateral vibration.

3. Pin support

3.1 The design of the pin support

The pin support will efficiently release the moments of the supports and the calculation results shows that the out-plan lateral reaction forces are very small. So in the design of the pin support, only the vertical reaction force and the in-plan horizontal force are considered. By the height of the support, the additional moment will be introduced at the bottom of the support. By the following steps, the design of the pin support could be included(Bao and Yao [2]).

(1) By the combination of the maximum horizontal and vertical reaction forces, the diameter of the pin bolt could be decided.

(2) Considering the shear loading capacity, the thickness of the connection plates is calculated.

(3) By the local stresses of the backplane, its thickness can be worked out.
Finally, the main type of the pin support is as shown in Figure 5.

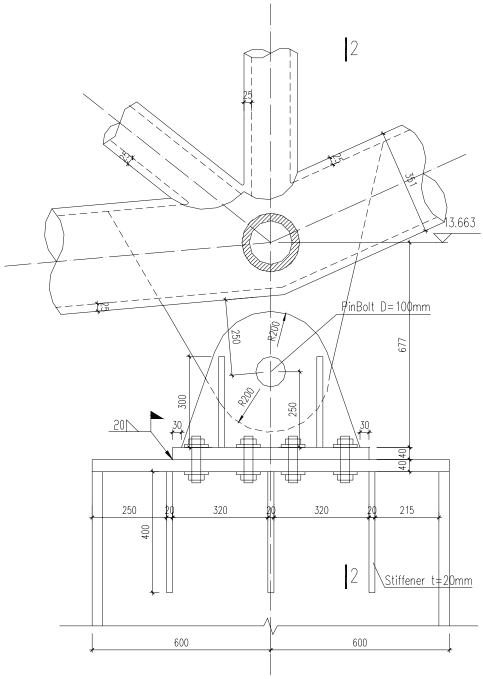


Figure 5: The plan of the pin support

3.2 Finite element analysis of the pin support

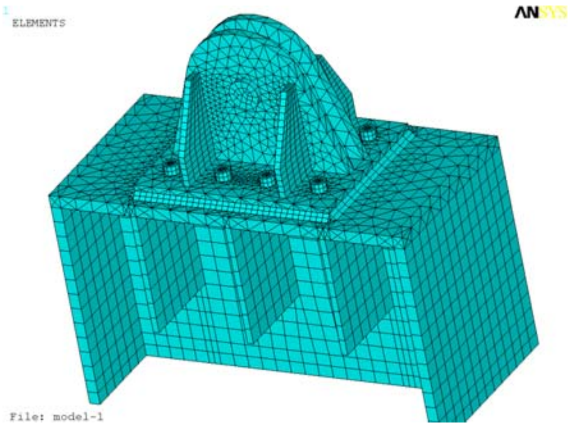


Figure 6: Finite element model of the pin support

By the software ANSYS, a solid finite element model (as shown in Figure 6) is established to analyze the loading capacity of the pin support and ensure the safety of the design. The ideal elastic-plastic material model is used in this finite element model and all the welds between each plate are established to ensure the accuracy of the model; as well, several contact pairs are modeled.

The loads are applied in the middle of the pin bolt. And two load cases are considered in finite element analysis: (1) the maximum horizontal reaction force, and (2) the maximum vertical force. The distribution of von Mises stresses is shown in Figure 7. As seen, the maximum stress is only 137MPa, much less than the yielding stress 305MPa, which indicates that the pin support is safe in an ordinary level. The maximum stress appears at the vicinity of the pin bolt.

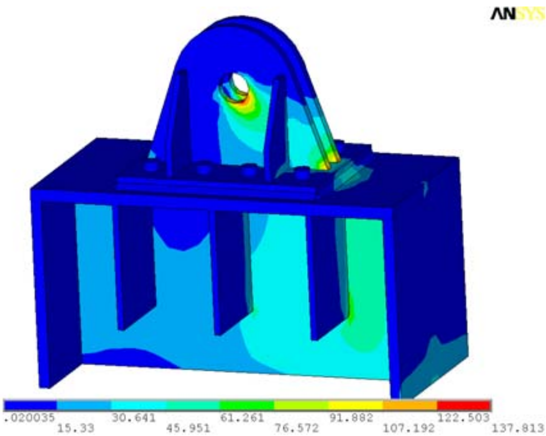


Figure 7: von Mises stresses

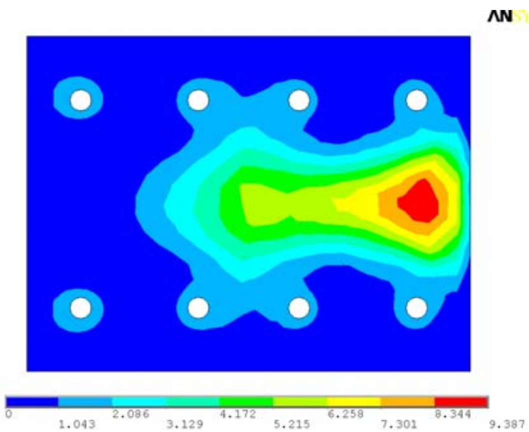


Figure 8: Compression stresses between the backplane and the column plate

By the contact pair, the local compression stress between the backplane and the column plate, as shown in Figure 8. At the tip of the connection plates to the backplane, the compression is maximum, about 9.387MPa, which indicates that the reaction force is mostly conveyed from the pin bolt to the column by the angle between the horizontal force and the vertical force.

Because the local stresses in the column is very large and the thickness of column web is comparatively small, local buckling of the web may happen and the three pairs of stiffeners are very crucial. Also, by considering that in some cases, the out-plane lateral forces may impose on the joint, two pairs of stiffeners are applied to enhance the lateral stability of the connection plates.

4. Conclusion

(1) The spatial tubular truss is efficiently satisfying the architectural style and the functional requirements of the Logistic Center. And component stresses are at a moderate level under various load cases.

(2) By the finite element analysis, the maximum von Mises stress of the pin support under all load cases is 137MPa, less than the yielding stress of the material.

(3) The force conveying path of the pin support is mostly directly from the pin bolt to the column through the connection plates, by the angle of the horizontal and vertical forces. The compression stress is comparatively large at the tip of the connection plate.

(4) Stiffeners should be considered in the high stress level zone to prevent the local buckling of the plates and to enhance the lateral out-plane stability of the pin support.

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