Construction Simulation and Analysis on the Prestress of Suspend-dome structures

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Abstract. As Jining City integrated gymnasium suspend-dome structure an example, the prestress tension process was carried out finite element simulation analysis by using inverse analysis of construction. The vertical displacement of the control joints and the top rod maximum stress ratio of roof were comparably analyzed with the change of tension position, tension grade and tension sequence. Suggestions were put forward about prestress applying method of suspend-dome structures, in order that similar projects provide reference.

Introduction

The suspend-dome structure is the roof system of center area of integrated gymnasium in Jining City, Shandong Province. Suspend-dome is large-span prestress spatial structure, planar projection is long hexagon, the span of long axis is 99.6 meters, the span of short axis is 69.6 meters, suspend-dome arounded has a total of 96 bearings which support on the surround concrete columns. Suspend-dome system is designed with latitudinal cable of three laps and the radial cable of three laps, In the middle of area is equipped with a long hexagon truss. As shown in Figure 1 and Figure 2.

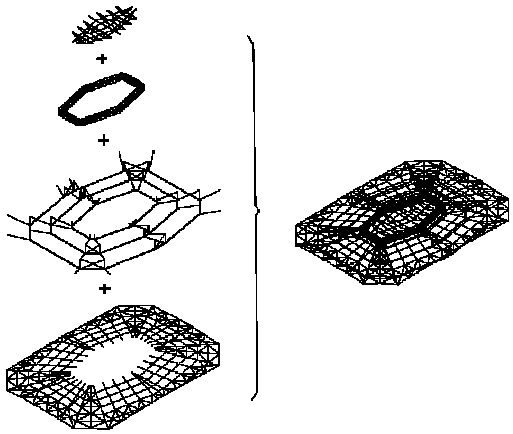


Fig. 1 Sketch of suspend-dome roof composition

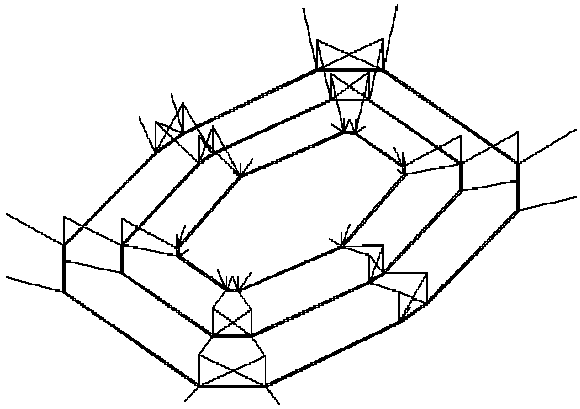


Fig. 2 Sketch of suspend-dome cable and strut layout

In the whole construction process simulation, choosing the three unit types, namely the truss element, beam element and cable element. The bar element released in the process of analysis, bending moment of the both ends of bar is released, beam element need not release "unit"; tension and compression is qualified in the cable, the cable is only set pull unit and define active and passive cable, cable unit is the same definition as "unit release".

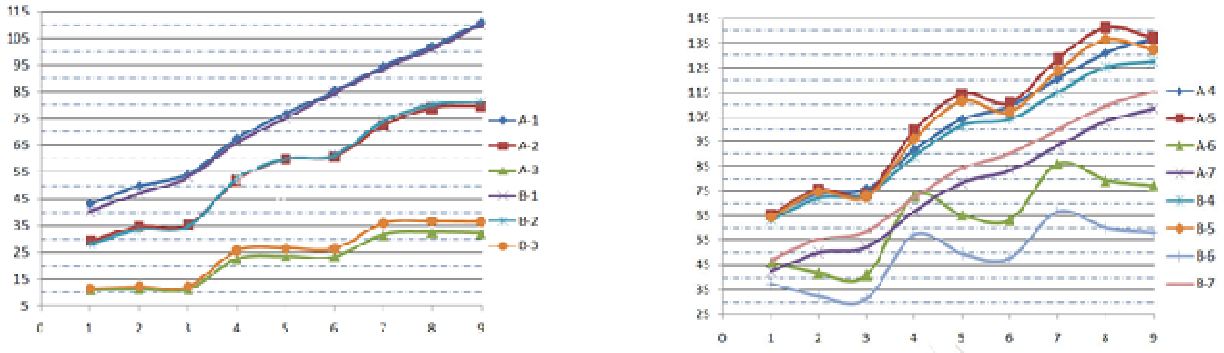
Tension Scheme Simulation Analysis

Respectively regarding radial or latitudinal cable as active cable is tensioned, simulating prestress construction process and judging the different tension position of structure response. Tension schemes as shown in table 1.

Table 1 Tension scheme of different tensioning position

steps	one	two	three	four	five	six	seven	eight	nine
A	outer radinal cable 30%	middle radinal cable 30%	inner radinal cable 30%	outer radinal cable 70%	middle radinal cable 70%	inner radinal cable 70%	outer radinal cable 100%	middle radinal cable 100%	inner radinal cable 100%
B	outer latitudinal cable 30%	middle latitudinal cable 30%	inner latitudinal cable 30%	outer latitudinal cable 70%	middle latitudinal cable 70%	inner latitudinal cable 70%	outer latitudinal cable100%	middle latitudinal cable100 %	inner latitudinal cable100 %

As to 7 control nodes in scheme A and B, the vertical displacement of different construction steps are drew as show in figure 3. The maximum stress ratio of different construction steps in scheme A and B is listed in table 2



（a） （b）

Fig. 3 Tensile displacement diagram of control node

Table 2 Maximum stress ratio of upper member under scheme A and B

scheme	step 1	step 2	step 3	step 4	step 5	step 6	step 7	step 8	step 9
A	0.767	0.762	0.762	0.688	0.649	0.627	0.699	0.633	0.632
B	0.766	0.756	0.755	0.672	0.640	0.617	0.714	0.649	0.638

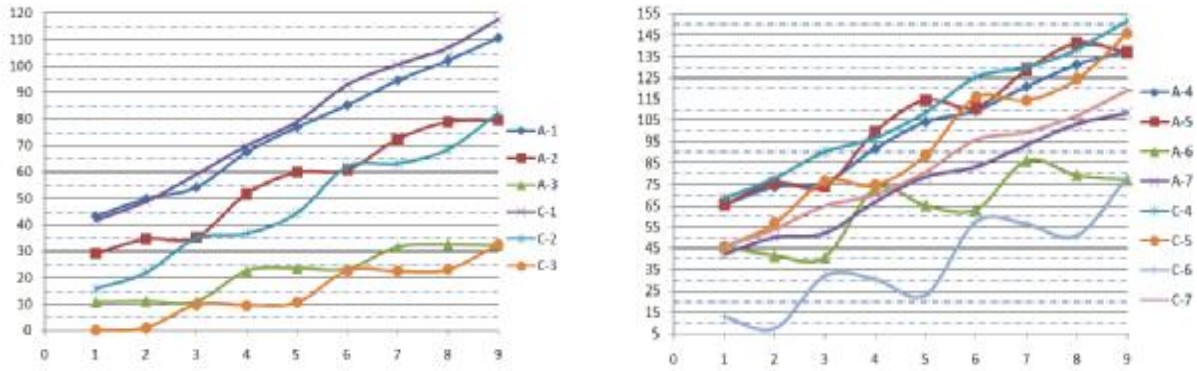
From the above analysis, tension position have a little influence on suspend-dome structure form-shape, However, the vertical displacement of suspend-dome are larger in the process of tension radical cable. Response is more positive, but the upper bar stress ratio is much smaller, which indicate that the tension radial cable is more reasonable tension way, it is recommended that the project prestress cable position select radial cable.

The tension displacement cure of control nodes in scheme A and scheme C, as shown in figure 4. As to tension sequences are different in the process of the same construction, it is similar to the control node displacement, The upper bar maximum stress of different construction steps is listed in tabled 3. The difference is very small and less than 7% of the nodes eventually displacement. the maximum stress ratio of bar is more than 0.8, which can be concluded from step 1 to step 4 in the scheme C, margin degree of security is insufficient to suspend-dome, which can bring potential risk. The scheme A is not more than 0.8 in all the construction steps and finally the maximum stress ratio of the bar is 0.632 and is reduced by 17.6%, it is advantageous to structural molding.

Table 3 Maximum stress ratio of upper member under scheme A and C

schem	step 1	step 2	step 3	step 4	step 5	step 6	step 7	step 8	step 9

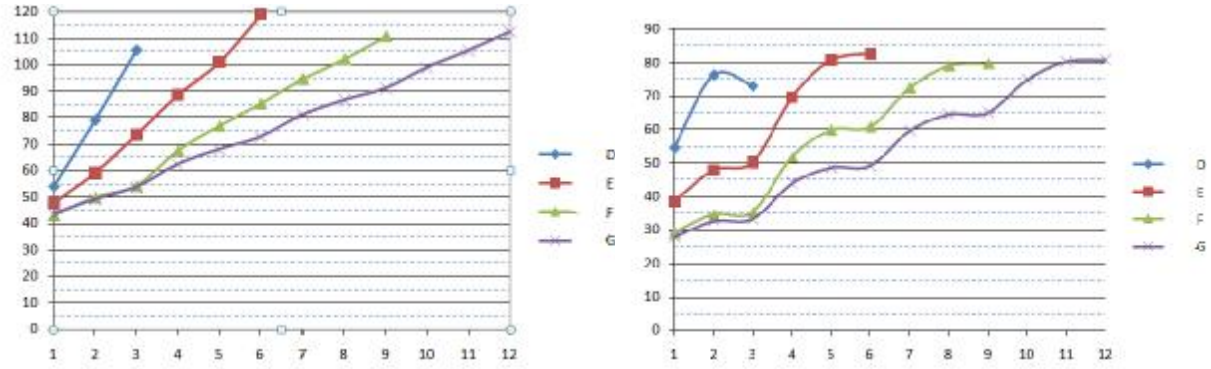
e									
A	0.767	0.762	0.762	0.688	0.649	0.627	0.699	0.633	0.632
C	0.954	0.897	0.832	0.830	0.755	0.690	0.686	0.697	0.705



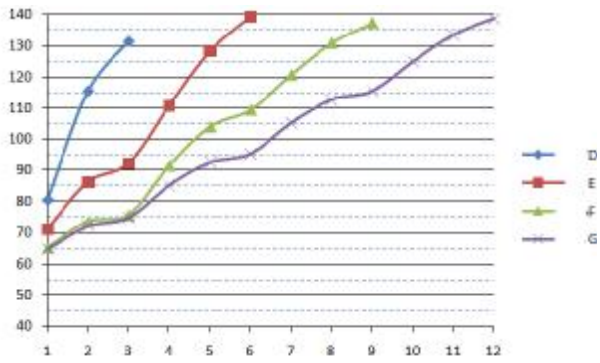
（a） （b）

Fig. 4 Tensile displacement diagram of control node

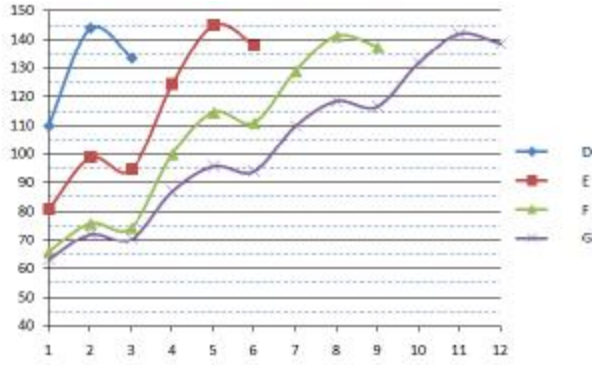
In order to study different tension classification effect suspend-dome, four tension scheme D, E, F, G is established for simulation analysis. respectively for level 1, level 2, level 3 and level 4 tension from outside to inside the radial cable， specific tension was classified as 0 - 100%, 0 - 50% - 100%, 0 - 30% - 70% - 100%, 0 - 25% - 50% - 75% - 100% the tension displacement curve of control nodes in scheme D, E, F and G, as shown in figure 5. The final reference nodes curve is similar affect to level 3 and level 4 tension in the vertical displacement and tension curvature, which indicate tension classification is not much excessive in suspend-dome structure and based on the existing tonnage or four tension devices choose tension prestress by three levels or four levels. With the increase in the number of tension classification, vertical displacement of node is slowly increase, structure deformation gradually smooth which can make structural internal force redistribution as fully as possible fully, which is favorable to eliminate residual stress on the structure.



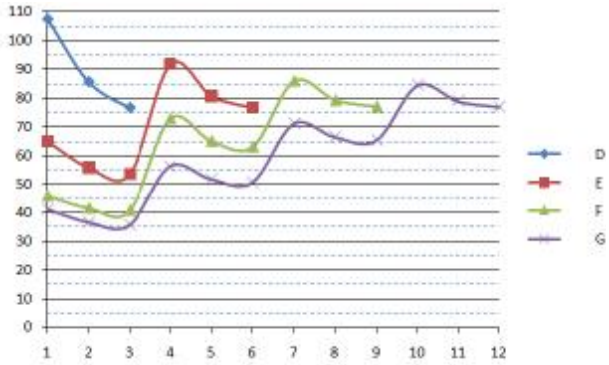
（a）node 1 （b）node 2



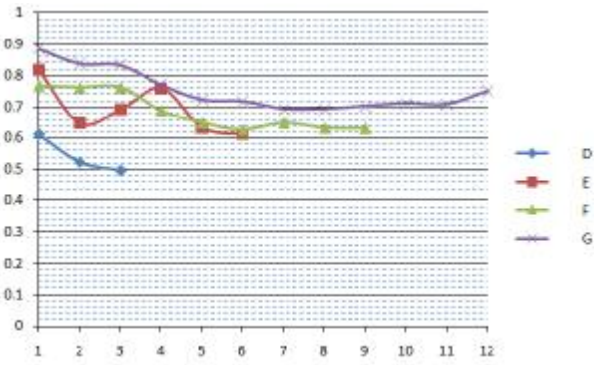
（c）node 3



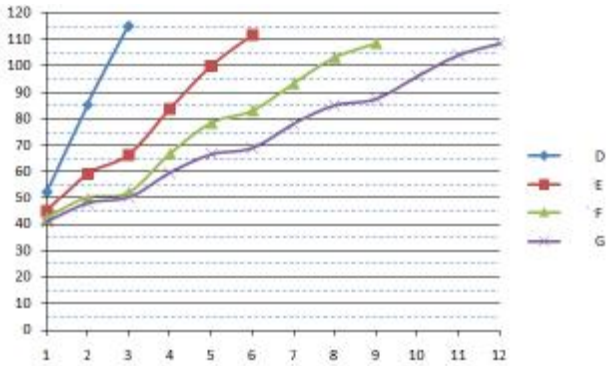
（d）node 4



（e）node 5



（f）node 6



（g）node 7

Fig. 5 Tensile displacement diagram of control node

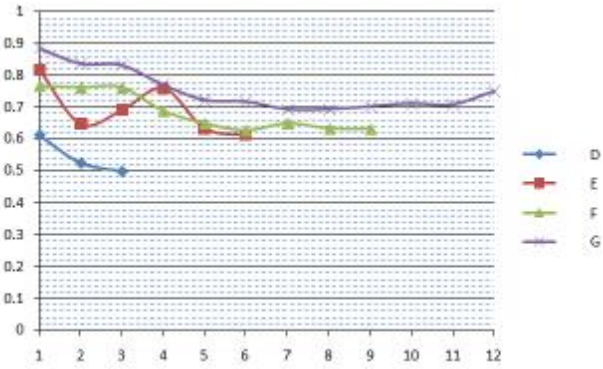


Fig. 6 Maximun stress ratio curve of upper member

The upper bar maximum stress of suspend-dome in different tension classification such as shown in table 4, maximum stress ratio changes with the construction step curve, as shown in figure 6. As to scheme D, the upper bar is relatively small maximum stress, but construction steps are few. scheme E stress ratio curve curvature changes greatly and easy to cause the stiffness of structure distribution changes is too fast, which is disadvantageous to structure, maximum stress of the upper bar is slightly larger in scheme G, the initial stage will produce stress ratio is more than 0.8, while the scheme F maximum stress gentle curve is gentle and the maximum ratio is small.

Table 4 Maximum stress ratio of upper member under different tension grade

scheme	step 1	step 2	step 3	step 4	step 5	step 6	step 7	step 8	step 9	step 10	step 11	step 12
D	0.611	0.523	0.497									
E	0.818	0.647	0.691	0.759	0.633	0.613						
F	0.767	0.762	0.762	0.688	0.649	0.627	0.699	0.633	0.632			
G	0.885	0.837	0.832	0.770	0.722	0.717	0.693	0.693	0.702	0.711	0.708	0.750

Conclusion

As an example of suspend-dome of gymnasium in Jining City, Shandong Province. According to the different tension schemes suspend-dome control node vertical displacement and the upper member maximum stress ratio of the finite element analysis, obtained the following suggestions for construction. According to control nodes vertical displacement and the upper bar maximum stress ratio of suspend-dome structure process by finite element analysis. obtained the following suggestions and construction.

(1) Suspend-dome select the prestress tension location of radial cable or latitudinal cable have little difference. Selecting the radial cable or latitudinal be available, the project based on the available equipment select radial cables.

(2)Prestress tension sequence of suspend-dome is in-outside, it can be make the upper single-layer net shell bar is too layer (more than 0.8).

(3)Tensioning classification choice for level 3,single-layer latticed shell maximum stress ratio curve is slope and maximum value is smaller (0.767), the number of construction step is 9 steps, the internal force redistribution for single-layer latticed shell, which is suitable for the internal force redistribution single-layer reticulated shell.

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