Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(6):2000-2005

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Finite element analysis based on the section size optimization design of cable-truss

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ABSTRACT

Pretension cable – truss is applied widely in the pretension steel structure. The paper analyses the structure of cable-dome by the optimization of sectional dimensions, and the materials strength is given full play, the performance of structure is more superior.

Key words: cable-truss, section size optimization, Cable pretension

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INTRODUCTION

The economic, advancement and reliability of pretension steel structure have been undoubted by fifty year's development and practice [1] [2] [3] [4] [5]. Pretension plane structure can save 10%～20% of the steel material[6], pretension space system can reach 40%～50%[7][8]. All of above are a deal of unelectable resource and wealth. The stress performance of steel structure are higher required with the development of the society and productivity. The optimal structural layout and stress performance by optimization analysis has been a hot issue for scientific workers nowadays. Pretension steel structure can make full use of elastic strength of steel, improve component or structures' carrying capacity, and reduce their deformation by applying pretension, achieving the aim of saving steel and reducing cost.

Pretension cable – truss is a type that used widely structure system among pretension steel structures. It is important to carry out optimization analysis for the purpose of making full use of materials, achieving safety and economic. The paper analysis's the influence on the stress performance that pretension values produces, and calculates the steel consumption; eventually get the maximum saved amount of the steel. Based on this we can get better economic benefits and safer structure forms.

Figure1 shows the main model. And the node numbers are shown.

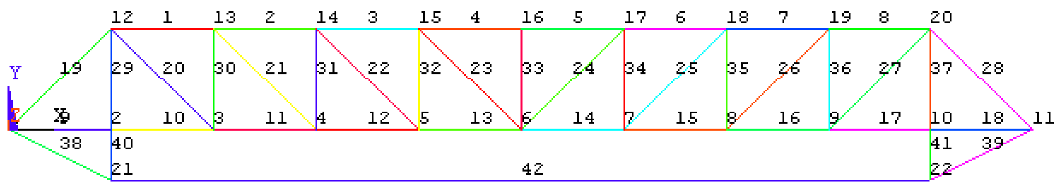

Fig.1:.Calculated model

Performance Analysis

2.1 Optimization of Section Size

As be shown in figure1, there is a pretension steel truss that is 10 meters in span length with two simple supported ends, section areas group as follows: top chord is A1, bottom chord bar is A2, tilted belly pole is A3, shaft abdominal bar is A4, slant rod joined by cable is A5, vertical stick is A6, section area is A7. each node of top chord have plumb downward concentrated load which is 20 KN, choosing initial section area is 8 cm2,elastic modulus of bars and cables are all 2. 06e11Pa, allowable stress of cable [ ] =600Pa, arrangement of cables is linear cable, and the distance is 0.5m to bottom chord bar linear. The minimum value of each bar section area is 0.5 cm2 and the minimum value of cable's section area is 2cm2. The results of optimization structure are shown in Table1.

Table1: the optimization results of section area

	Section area(cm^2)							structural weight(kg)	Cable pretension(KN)
	A1	A2	A3	A4	A5	A6	A7		
Non-prestressed	13.445	10.336	5.823	4.118	2.819	1.261	2.000	277.59	0
Exiting prestressed	11.569	4.706	5.823	4.118	7.015	3.137	2.000	230.67	40.21

2.2 Performance Analysis of Cable-truss

The section areas of most components are reduced due to optimization of the section size. Especially the area of bottom chord bar A2 reduces in large amplitude. This way certainly can reduce more weight of the structure, and the cost can greatly be reduced. Because the load selected by this mode cable is symmetric, we can just choose nodes and unites of the left section to analysis, the codes of node and unite are from left to right. Then it can be calculated by the mode figure1.

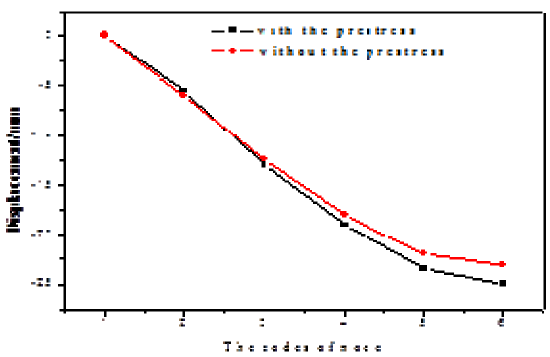

Figure2. The displacement of top chord

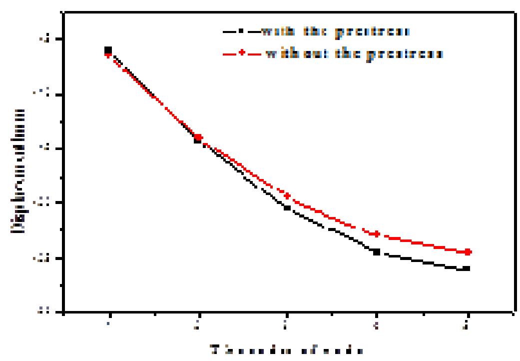

Figure3. The displacement of bottom

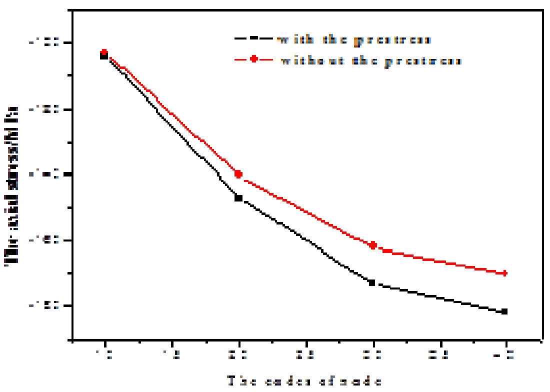

Figure4. The axial stress of top chord

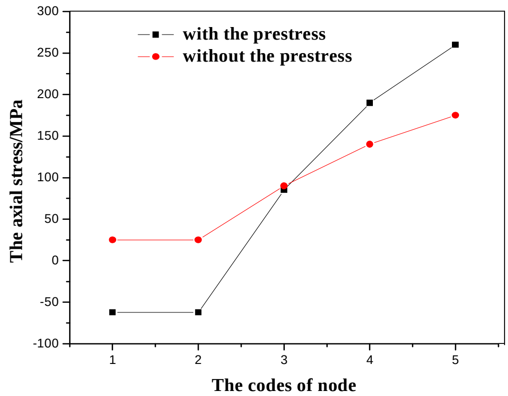

Figure5. The axial stress if bottom chord

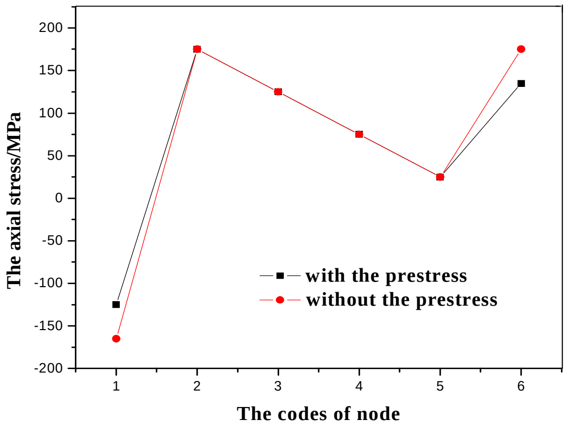

Figure6. The axial stress of tilted belly pole

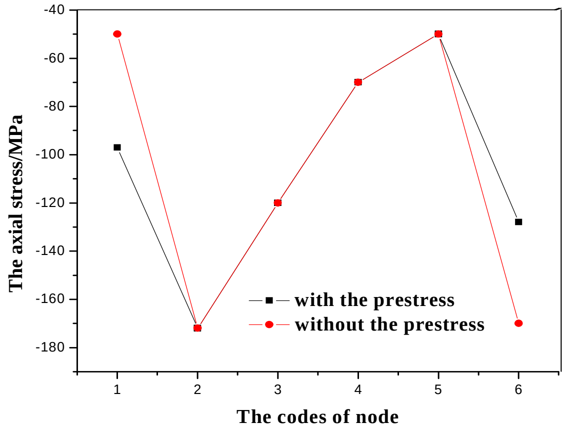

Figure7. The axial stress of shaft abdominal bar

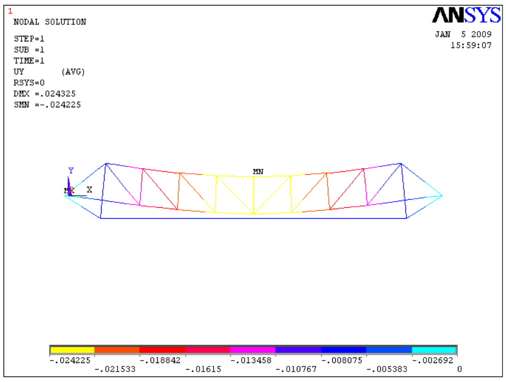

Figure8. Deformation map of non-cable force

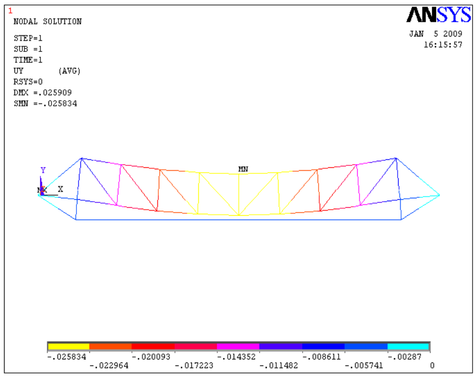

Figure9. Deformation map of non-cable force

The displacement and deformation diagram of the nodes show that the displacement of each node is larger and larger from the edge to middle, and after optimization, the displacement variation of each node is small, that's to say the optimization meet the displacement and deformation conditions.

That will be compressed when the axial stress of the top chord bar is negative. After optimization the value of the stress has some change, however it is not apparent, and they all meet the bar allowable stress. On the other hand the top chord bar can fully play its tensile and compressive strength after optimization. The Figure5 shows the axis stress change of bottom chord bar. The internal forces of the 9 unite and 10 unite is from tension before optimization to compression after optimization. The 13 unite is located in the middle of the structure, and the corresponding node displacement is the maximum. The internal force increases when the optimization is performed. However, in the allowable range, all in all opponent optimized can fully play its tensile strength and compression strength.

The Figure6, Figure7 show the internal force of the 20 unite and 30unite is the maximum. The cross sectional areas should be larger as far as possible when selecting the section and the rest conditions are met simultaneously. So the optimized tensile and compression strength of the steel component can be better fully played.

3. The cable-truss performance analysis after optimized

3.1 The Optimization of Section Size

Figure10 shows the calculation model that is a pretension steel truss, 10 meters in span length with two simple supported ends. And the number of each bar is shown in Figure10. Each node of top chord have plumb downward concentrated load which is 20 KN. Initial section area is set 8 cm^2, elastic modulus of bars and cables are all $2.06e^{11}$Pa, allowable stress of bar[σ]=170MPa, allowable stress of cable[σ]=600Pa, arrangement of cables is parallel to linear cable , the minimum value of each bar's section area is 0.5 cm^2 , and the minimum value of cable section area is 2cm^2. The distance between cable and bottom chord bar, cable arrangement locations and section size are set as optimization parameters. The Fig.11 shows the relationship between cable locations and structure weight after optimized. And the Fig.12 shows the relation between cable arrangement location and cable prestressed after optimized. The optimal cable arrangement location is 1.08m distant to bottom chord bar, the optimized section size of this point is shown in Table2. The cable prestressed is 4.718KN, and the structure weight is 140.520kg after optimization

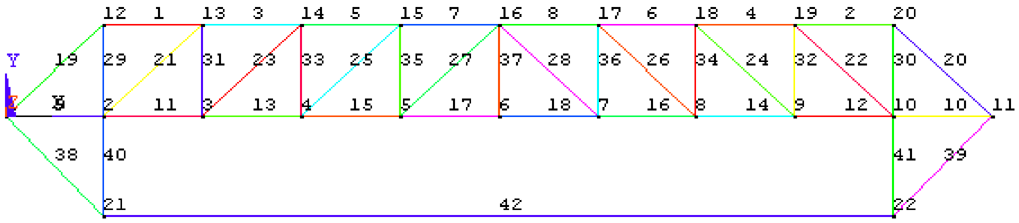

Figure10. Calculated model considering the cable arrangement

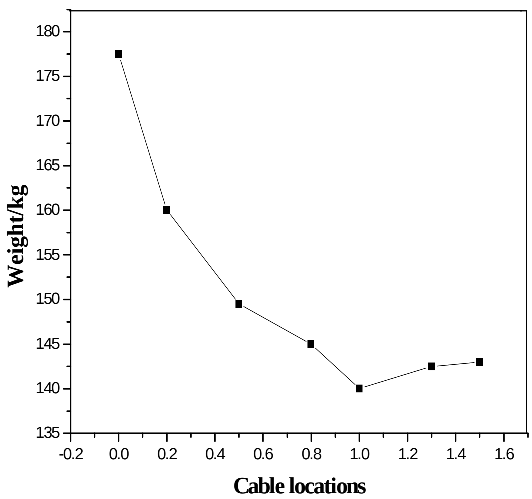

Figure11. The relation between cable location and structure weight

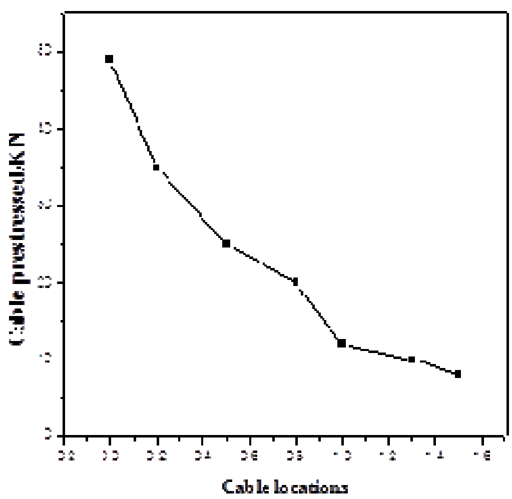

Figure12. The relation between cable arrangement location and cable prestressd

Table2: The section size with the best cable arrangement location

Unit number	Cross sectional(cm^2)	Unit number	Cross sectional(cm^2)
1, 2	1.0516	23, 24	4.1596
3, 4	5.1692	25, 26	2.4957
5, 6	8.1104	27, 28	0.8319
7, 8	9.8751	29, 30	0.5
9, 10	2.8767	31, 32	2.5
11, 12	1.2409	33, 34	1.7647
13, 14	4.1821	35, 36	0.5882
15, 16	5.9468	37	0.5
17, 18	6.5351	38, 39	5.7819
19, 20	1.4871	40, 41	4.2425
21, 22	5.8232	42	1.1130

3.2 Performance Analysis of Cable-truss

The Figure13, Figure14 shows the comparison of two conditions of node displacement. From the Figure13, Figure14, the cost of structure can be reduced after optimized the cable section area.

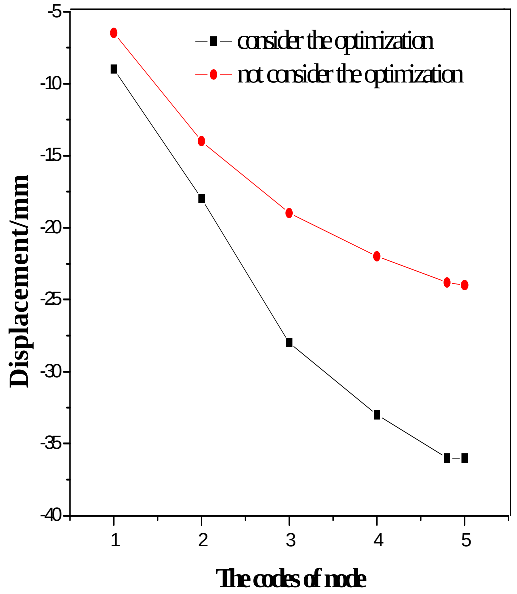

Figure13.the comparison of two conditions of the displacement of top chord

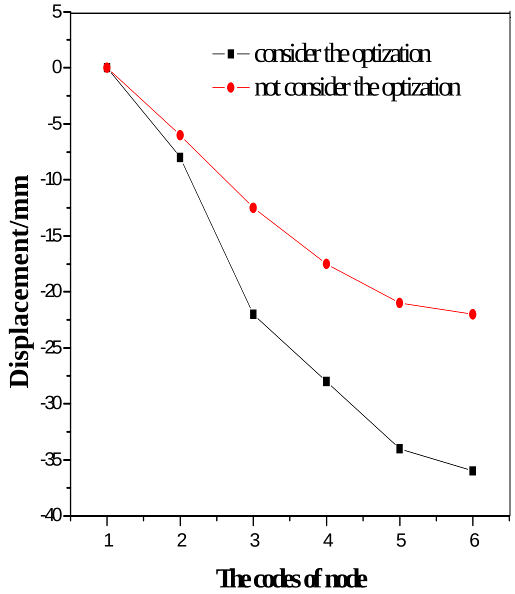

Figure14.the comparison of two conditions of the displacement of bottom chord

Table2: Distribution of axial stress

Upper chord bar		bottom chord bar		tilted belly poles		Shaft abdominal bar	
Unit number	Axial stress(Mpa)	Unit number	Axial stress(Mpa)	Unit number	Axial stress(Mpa)	Unit number	Axial stress(Mpa)
1	-213	9	-139.6	19	-213	29	48.2
3	-178	11	240	21	-170	31	200
5	-176	13	191	23	-170	35	-73
7	-175	15	185	25	-170	37	-49
		17	183	27	-170	40	-170
				38	159		

The Table3 shows that the distribution of axial stress. It can be seen that the distribution of axial stress are uniform. The optimized structure weight is 140.52kg, and the weight of the structure and the cost are reduced greatly.

CONCLUSION

The relationship between the change of cables location, pretension of cables and pretension of cables is achieved by the optimizations. The distance of cable to the lower chord, pretension of cables and the section size are optimization variables. And the optimal section size is achieved simultaneously. The analysis of optimal performance shows that the components are not satisfied with strength requirement, and can fully make use of the material properties, which can fully play the material strength.

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