

Experimental Study of Vertical Deflection of Suspended Cables under Static Loads

Pooja Sati¹, Vaneeta Devi² and Sunil Kumar³

¹*P.G. student in Structural Engineering
Civil Engg Deptt, College of Technology*

^{2,3}*Civil Engg. Deptt., College of Technology*

G.B. Pant University of Agrill. and Technology Pantnagar Uttarakhand, INDIA.

Abstract

The ability to design large spans with little self weight and high load capacities, as well as exploring new architectural expression, made cable structures very popular, though their structural behaviour is unique and unconventional compared to common structures. A cable roof can be define as one in which a system of cable is used as load carrying structural element. The objective of the present study is to represent the deflected behaviour of pre-tensioned cable suspended roofs under static loads experimentally. The study has been carried out in two parts, namely (i) single cable suspended at middle position of the steel frame and (ii) 3x3 cables net. To study this, a steel frame of square plan has prepared and cables are suspended from opposite edges to make various forms of net. Vertical load at various points/ nodes are applied by placing weights on hangers and vertical defection at nodes are measured using the dial gauges. Node is a connection at which two cables intersect (fig1).

Keywords: Cable; Node; Pretension.

1. Introduction

The capacity of cable net roofs to cover long spans without intermediate supports and to carry large loads for various types of applications, stimulate the interest of engineer and architects in the sixties. Since the loads are transmitted through tension of the cable, these structures are very stable and efficient. Cable net roofs are used to cover stadiums, swimming pools, exhibition hall, theatres, hanger or even factories. An

infinite number of shapes can be produced by pretensioned cable net roofs that depend on the geometry of their boundaries, the curvatures, the levels of cable pretensioned and the eventually internal supports.

Cable roofs structures can be divided into categories based on whether the roof cladding is supported by (i) simple suspended cable roofs, (ii) pretensioned cable trusses (iii) pretensioned cable net and grids (iv) tensioned straight cables and (v) tensegric shells (Fig 2to 5).

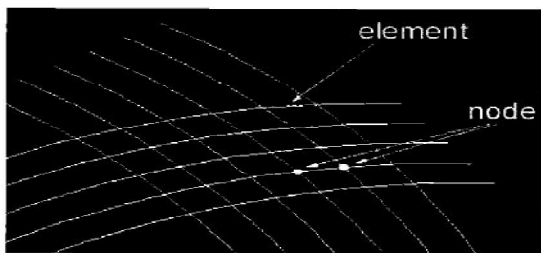


Figure 1: Nodes and elements in cable net.

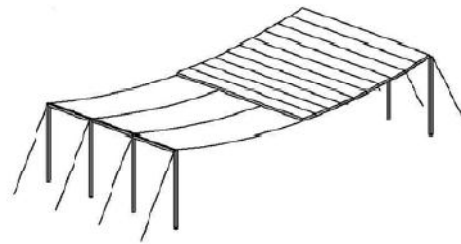


Figure 2: Simple suspended cable.

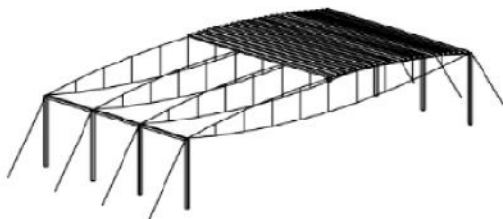


Figure 3: Pretensioned cable trusses.

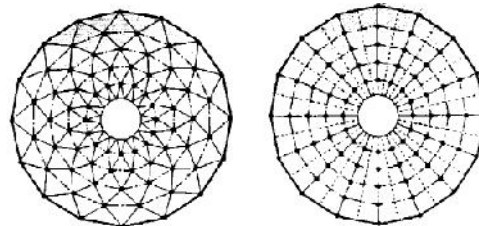


Figure 4: Tensegric Shells.

A shape assumed by a steel cable when suspended freely between two points under its own weight is known as catenary. But for practical purposes its shape assumed to be parabolic (Krishna 1978).

Many researchers have studied the behaviour of cables suspended roofs under static as well as dynamic loads during last five -six decades. To name a few, Krishna(1964), Mittle(1971),Tottenharm and Khan (1971), Buchholdt (1974) and Ahuja(1979) studied the response of cable truss under static load. However very few limited studies on cable suspended roofs have been made by Agrawal(1968), Jenson(1971) and Krishna(1964).

2. Experimental Details

In order to study the static response of cable roofs system under static load, a steel frame of internal plan dimension 800 mm x 800 mm was made up using 25 mm x 25 mm square pipes. There are twenty eight numbers of holes made at a spacing of 100 mm on all four top horizontal member of the frame to pass the cables and twenty eight

numbers of pulleys placed in front of cable position. A thin spinning high strength steel wires cable having diameter 1.82 mm and weight 15.5 gm/m is used in the present study. Cables were suspended from opposite edges to make various forms. Hangers were used for placement of load at node as well as end of the cables. Dial gauges were used for measurement of vertical deflection under node. The pre-tensioning loads considered in this study were varied as 5.5 kg, 8.5 kg and 10.5kg.

2.1 Single Cable Response

A single cable unsupported span of 800 mm was suspended at the middle position of the frame and been analysed. Fig 5 & 6 shows the arrangement of the pre-tensioning the cable. The pre-tensioning load applied vertically at two ends of the cable to study the effect on the deflection. For each case of pretension, vertical loads of 1kg, 1.5kg, 2kg and 2.5 kg were applied at the point on the cable and corresponding vertical deflection were measured at point 1, 4 and 7. Latter, same set of vertical loads was applied at node no. 2 and corresponding vertical deflection were measured at point 1, 4 and 7. Lastly, same procedure was repeated by applying load at node no.3. Experimental results are reported in table no. 1 to 3.

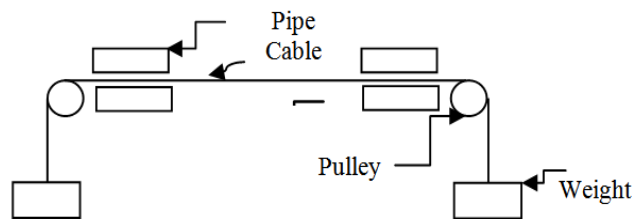


Figure 5: Pre-tensioning arrangement for cables.

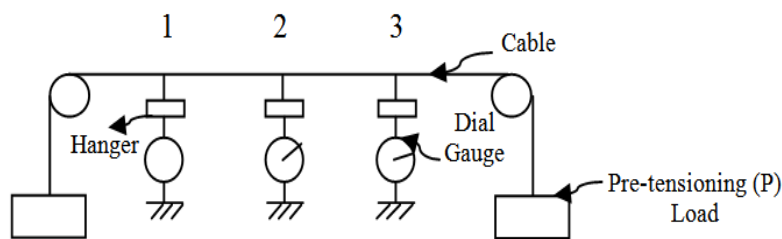


Figure 6: Arrangement for measurement of vertical deflections on single cable.

Table 1: Deflection in mm at various nodes on single cable, loads applied at node no.1.

Load (kg)	Pretension load=5.5 kg			Pretension load=8.5 kg			Pretension load=10.5 kg		
	1	2	3	1	2	3	1	2	3
1.0	09.20	04.45	01.65	04.21	02.2	1.96	02.31	0.48	0.23

1.5	14.01	08.16	04.42	10.61	6.89	3.14	08.26	04.83	2.24
2.0	21.79	14.12	08.21	15.20	9.14	5.11	12.45	06.50	4.76
2.5	29.67	20.82	10.52	19.55	12.2	7.94	16.12	19.86	5.39

Table 2: Deflection in mm at various nodes on single cable, loads applied at node no.2.

Load (kg)	Pretension load=5.5 kg			Pretension load=8.5 kg			Pretension load=10.5 kg		
	1	2	3	1	2	3	1	2	3
Node no.									
1.0	1.63	05.41	09.11	01.55	01.65	03.48	0.07	01.18	2.78
1.5	4.28	09.55	14.91	03.43	05.16	09.50	02.91	04.67	07.53
2.0	7.08	15.71	20.51	04.01	08.15	13.21	04.51	07.39	11.61
2.5	10.1	19.11	29.12	06.75	11.31	18.81	05.35	10.44	15.78

Table 3: Deflection in mm at various nodes on single cable, loads applied at node no.3.

Load (kg)	Pretension load=5.5 kg			Pretension load=8.5 kg			Pretension load=10.5 kg		
	1	2	3	1	2	3	1	2	3
Node no.									
1.0	01.75	04.65	09.75	02.16	02.28	04.98	0.30	00.75	02.75
1.5	04.86	08.89	14.15	03.50	7.19	11.11	2.72	05.31	08.56
2.0	08.78	14.75	22.23	05.51	9.89	15.89	5.11	06.80	12.65
2.5	11.23	21.32	29.85	08.24	12.75	20.12	5.91	20.11	16.55

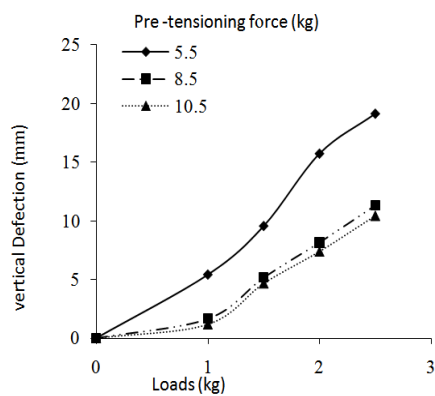


Figure 7: Deflection at node no 1 with load at node 1 of single cable.

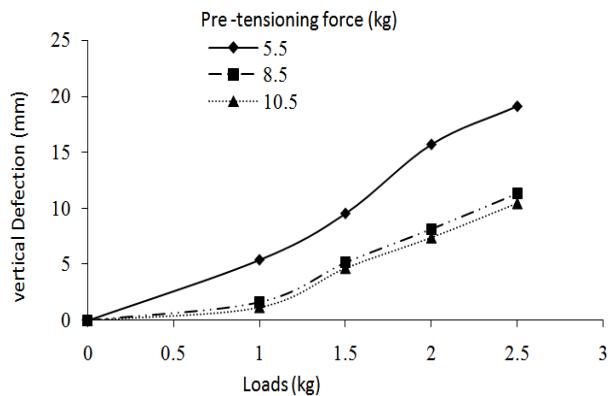


Figure 8: Deflection at node no 1 with load at node 2 of single cable

Load deflection curves for two cases of loading are shown in fig7, 8 and 9. It is observed for the curve that deflection decreases exponentially, as the pretensioned load increased. Further, at small value of pretension, cable being flexible and shows geometrical non-linearity. Its behaviour tends to become linear as pre-tensioning load increases.

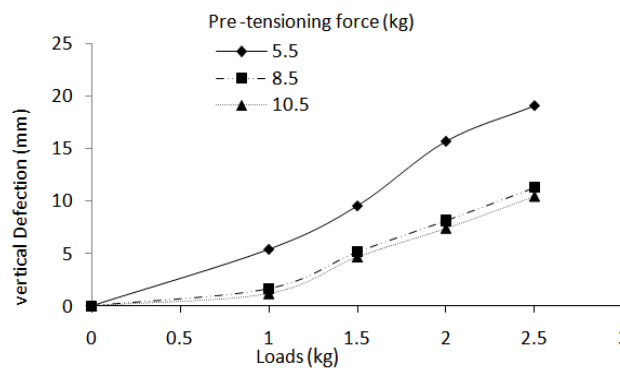


Figure 9: Deflection at node no 2 with load at node 2 of single cable.

2.2 Three by Three Cable Net System Responses

To study the response of a cable net system, three cables were suspended in perpendicular direction to each other at spacing of 200 mm on the top of frame. Fig 9 shows the arrangement of the pre-tensioning parallel cable system. The response was studied for the three cases of loading. In the first case load were applied at only at center point i.e. node no.5. Latter, loads were applied at nodes no. 1, 5 and 7. Lastly, loads were applied at all nine nodes. Table 4 to 6 gives the experimental observations.

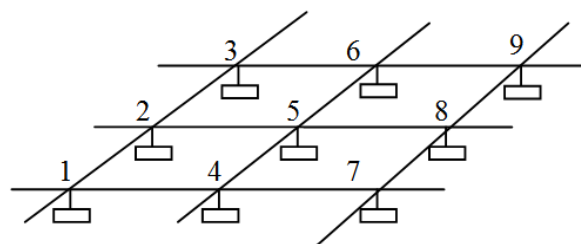


Figure 9: Positioning of hangers on 3x3 cable net system.

Table 4: Deflection in mm at various nodes, loads applied at central node no.5.

Load (kg)	Deflection in mm at node no.									Average at node	
	1	2	3	4	5	6	7	8	9	1,3,7&9	2,4,6&8
1.0	0.02	0.33	0.05	0.23	0.18	0.01	0.02	0.29	0.01	0.025	0.215
1.5	0.25	0.88	0.12	0.33	2.94	0.65	0.25	0.99	0.21	0.207	0.713
2.0	0.45	1.61	0.37	1.29	8.61	1.25	0.43	1.66	0.38	0.408	1.453
2.5	0.62	2.20	0.50	1.70	12.0	1.26	1.57	2.36	0.50	0.798	1.880

Table 5: Deflection in mm at various nodes, Load applied at node no. 1, 5&9.

Load (kg)	Deflection in mm at node no.									Average at node	
	1	2	3	4	5	6	7	8	9	3&7	2,4,6&8
1.0	1.74	0.13	0.06	1.07	3.52	0.50	0.06	0.70	0.69	0.060	0.60
1.5	2.57	0.98	0.30	2.10	8.08	1.34	0.31	1.60	3.24	0.305	1.508
2.0	5.45	1.83	1.46	3.43	11.25	2.80	1.49	2.80	5.15	1.475	2.715
2.5	6.79	2.64	1.98	4.30	19.01	3.01	1.69	3.20	7.33	1.835	3.288

Table 6: Deflection in mm at various nodes, Load applied at all nodes.

Load (kg)	Deflection in mm at node no.									Average at node	
	1	2	3	4	5	6	7	8	9	1,3,7&9	2,4,6&8
1.0	2.79	3.81	2.09	4.53	8.01	4.15	2.77	3.31	2.19	2.46	3.95
1.5	4.73	6.62	4.09	8.10	16.2	8.44	5.07	6.60	3.55	5.19	7.44
2.0	6.93	10.32	6.09	9.59	23.2	11.11	7.36	10.89	6.36	6.69	10.48
2.5	9.71	12.9	9.09	16.4	30.1	19.8	9.65	16.4	6.59	8.76	16.38

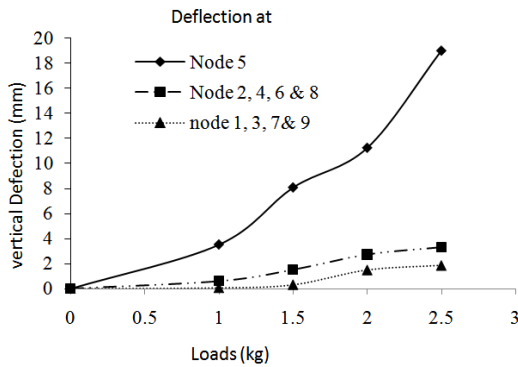


Figure 10: Deflection at various nodes due to load at node 5 of the cable net

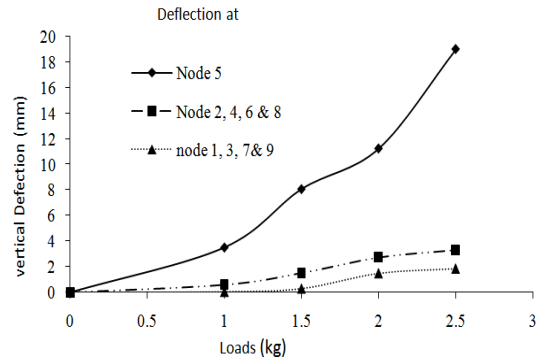


Figure 11: Deflection at various nodes due to load at nodes 1, 5 & 9 of the cable net

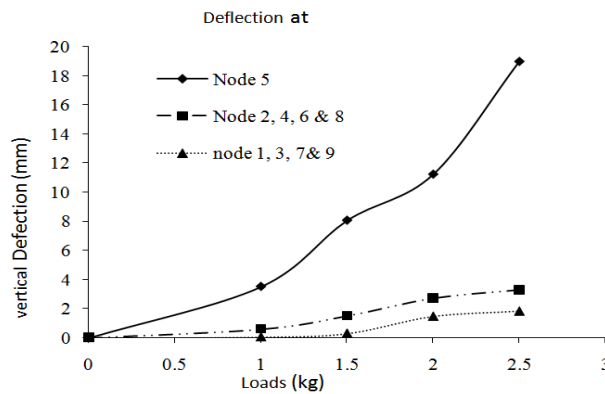


Figure 12: Deflection at various nodes due to load at all nodes of the cable Net.

Load deflection curves for three cases of loading are shown in fig 10, 11 and 12. It is seen from the fig 9 centrally applied load point, maximum deflection is occurs under the load with comparatively small values of deflections at other points. From the fig 12, load applied at all nodes, deflections observed at all nodes points are comparable.

3. Conclusion

From the study presented in this paper following conclusion are drawn.

1. Deflections in cable net at various nodes are largely influenced by the force of pretension in cables. Deflection values reduce with increase in pretension. Further, the cable net roofs show non-linear behaviour for small value of force of pretension.
2. The response of cable net roof is also affected by number of cables present in a roof of fixed dimension i.e. to say that the spacing of cable does influence the behaviour of cable nets.

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