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Measurement of Structural Cable of Membranes

Petr Fajman[1], Michal Polák [2]

Abstract: The paper shows a way of measurements of forces in cables on the standing fabric textiles. The measurement is nondestructive and is based on geometrical nonlinearity.

Keywords: Textile composites, cable, cable force, measurement.

1. Introduction

Czech investors prefer traditional materials due to better durability. We can find a lot of buildings from bricks, concrete, steel and wood. The most widespread opinion is that textile structures are short-term solutions. Recently the behaviour of Architects changed and they try to design unusual and original structures use fabric textiles for airy roofing.

The advantages are lower acquisition costs, potential replacement of fabric textile and various shapes.

The disadvantages are limited usage, complicated structural design theory and high production requirements.

Building companies, which specialize in textile structures, are small. Competitive ability does not permit to check prestress in structure cables during construction and to inspect after some years. Next problem is influence of temperature changing. We try to design simple measurement equipment for cables and textiles. At first its verification took place in laboratory and then it was used on a real structure.

2. Principle of measurements of forces

The second order theory is used for nondestructive measurement of cable forces. If the cable is considered as perfectly flexible, then axial forces N can be calculated from the measured transverse displacements Δw and forces F_p. We can use a simple equation:

$$N = \frac{F_p}{2}\sqrt{\left(\frac{L}{2\cdot\Delta w}\right)^2 + 1} \qquad (1)$$

[1] *Doc.Ing. Petr Fajman, CSc; Department of Mechanics, Fac.of Civil Engineering, Czech Technical University in Prague; Thákurova 7, 166 29 Prague, Czech Republic; fajman@fsv.cvut.cz*

[2] *Doc.Ing. Michal Polák, CSc; Department of Mechanics, Fac.of Civil Engineering, Czech Technical University in Prague; Thákurova 7, 166 29 Prague, Czech Republic; polak@fsv.cvut.cz*

$$N = \frac{F_p}{2}\sqrt{\left(\frac{L}{2\cdot\Delta w}\right)^2 + 1} - \frac{E\cdot A}{2}\cdot\left(\sqrt{\Delta w^2 + L^2/4} - L/2\right)/L_c \qquad (2)$$

Where L is the original measuring length of the cable, L_c is the original length of the cable The quantities from equations are evident from fig. 2.1.
The first formula can be used for structure, where one joint is free and the second for both fixed joints.

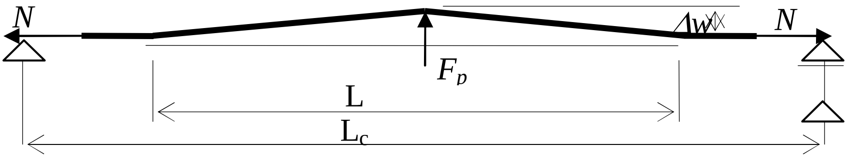

Fig. 2.1 Principle of measurement of forces in a cable

By experiment the equipment is connected to the investigated cable, which is subjected to deflection. Values of transverse displacements Δw and forces F_p in some steps (fig. 2.2) are obtained. The miniature force transducer and two inductive displacement transducers are used for measuring of F_p and Δw.
In reality the bending stiffness of the investigated cable (diameter bigger than 10mm) has an influence on the value of axial force. That effect can be eliminated by trial test. The calibration measurements were provided in the Experimental Center of CTU laboratory. We got values N, F_p and Δw. Obtained dependencies among the type of cable N, F_p and Δw were used during the below mentioned practical measurements on real structures.
In compliance with expectations the cable forces obtained from measurements were smaller than theoretical forces calculated from equation 1 or 2. Difference is about 8.8%.

Fig. 2.2 The application of equipment for the cable forces measurement

Structural design of cable membrane structure has to use the geometrical nonlinear method. This method is called the 2nd order method and internal forces are obtained from real element size during loading steps. It is possible to use a special cable and membrane element [1,2]. The next process is the relaxation method [1].

3. Results

Designed method was used in practice. The roof of tram stop Barrandov in Prague was checked. The structure is shoven in Fig. 3.1. A stop was built in 2002 and the maintenance of prestress in cables was made in 2004. The measurements took place in 2009 [3] and 2012. Although the measurements were carried out in the same time 21march, the temperature was different in 2009 about 4°C in 2012 14°C. Considering that we did not have structural proposal, we could not find out influence of temperature difference on cable forces.

We obtained dependencies of axial forces on transverse displacements, which were taken into account when were bigger than 10mm. Evaluated force values are in tables 3.1 and 3.2.

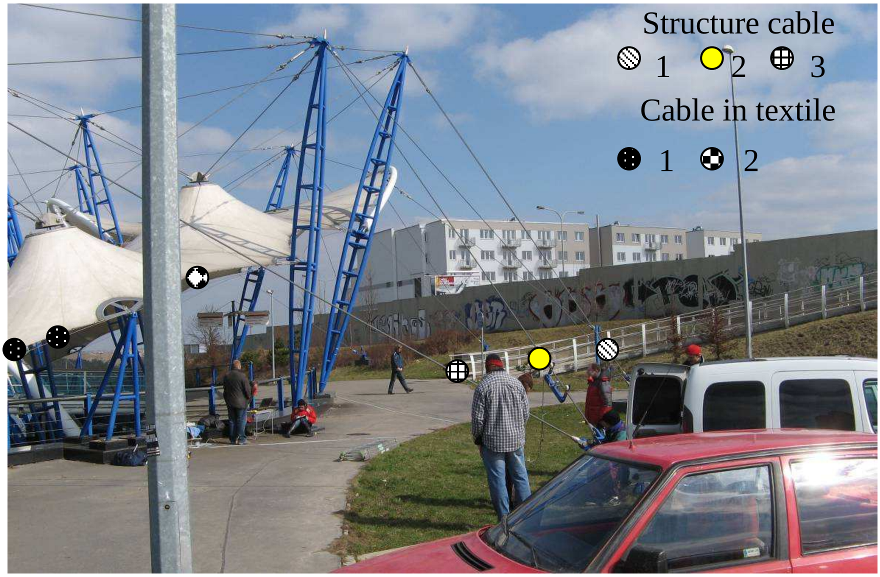

Fig. 3.1 The measurement points

Tab. 3.1 Forces in cables in textile

Measuring in 2009

cable in textile	point	Average value [kN]	Standard deviation [kN]
1	1	4,00	0,05
1	2	4,03	0,18
2	3	4,48	0,05

Measuring in 2012

cable in textile	point	Average value [kN]	Standard deviation [kN]
1	1	3,87	0,02
1	2	3,79	0,03
2	3	4,50	0,02

Tab. 3.2 Forces in structure cables

Measuring in 2009

Structure cable	Average value [kN]	Standard deviation [kN]
1	13,79	0,10
2	18,34	0,50
3	14,51	0,11

Measuring in 2012

Structure cable	Average value [kN]	Standard deviation [kN]
1	11,96	0,06
2	17,10	0,40
3	13,26	0,08

4. Conclusions

- The designed method for cable forces measurement is simple and sufficiently accurate. The error without calibrating is 8% with calibrating 2%.
- From the results comparison we can find out decrease values of axial cable force. The difference can be caused by pulling of cable (time dependency) or, how it was mentioned above, changing of temperature. The correct cause cannot be found out from two carried measurements and some new ones will have to be done. After that the time and temperature dependencies can be discovered.

The results were obtained with help of GAČR P105/11/1529.

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