New load monitoring method for pretensioned Structures

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Summary

Cable structures are very sensitive regarding design, calculation, manufacturing and installation methods. All elements have to work together to receive a proper result at the end. To eliminate one more point of inaccuracy in this chain, a new method for measuring and monitoring of the Cable forces was developed. The ultrasonic load monitoring method with a pin equipped with ultrasonic sensors and an unique id chip. Accuracy of measuring the cable forces raise to an exactness of +/- 1.5%.

Keywords: pin, pretension, cables, cable structure, bridges, stadium, glass wall, ultrasonic sensor

1. Cable Structures, design and production

Cable structures are to be found all over the globe. Since the construction of the Munich Olympic Parc, The projects are impressive examples for the aesthetics and grace of modern cable structures and provide insight into the variety of possibilities that are at our disposal employing cables in architecture. Both the profound knowledge of the use of cables and years of experience provide the basis for success – for every building requires the highest dimensional accuracy when it comes to construction, production and installation. Project examples:

- Sports facilities
- Bridges
- Glass facades
- Roof structures
- Widespan structures
- Zoological and botanical gardens

Figure 1: project examples

The structural calculation of cable structures is carried out with 3D FEM programms like R-Stab or Sofistik. Because of the big movements in the calculated structures it is necessary to run the calculations with Theorie 3rd order. The formfinding of the structure is done by a virtual pretension in the structural calculation.

After running the structural calculation with all necessary loadcases the form of the structure is found. With this geometrie and the corresponding force in the load case self weigth and pretension the Cable element can be manufactured.

The exact cutting of cables to length requires also the consideration of seating of the cone in the cable socket after cooling down and loading cable, the cable creep, cutting temperature and design, temperature, additional elongation due to cable fittings or clamps. To reach a linear elongation behavior of the cables they have to be prestretched.

There is no structural system without tolerances. Therefore the following fabrication tolerance for structural spiral strand and locked coil cables is recommended $\Delta L = \pm\sqrt{L}$ [m] + 5 mm.

2. Installation of Cable Structures, equipment and load measuring

Cables come to site shorter than in the prestressed situation, because of that they have to be elongated by pretension equipment. The elastic elongation can be determined with the equation $\Delta L_{elast} = (F_{sys} * L_{sys})/(E*A)$. The equipment has to be chosen according to this value and the required pretension forces.Common methods for load measuring are Rope Tension meter, hydraulic jacking systems and heavy lifting systems. The biggest disadvantage of this systems is the handling problem. Lifting equipment and scaffold is always necessary.

3. Ultrasonic load monitoring method


Figure2:handheld device

The new method is an ultrasonic load monitoring technology that uses a well known physical phenomena called the 'acoustoelastic effect'. This phenomena has been widely used to measure the effect of stress on materials for decades. An example of this is the measurement of bolt tension using ultrasonic sensors. Pfeifer developed methods to instrument the pins from fork and plate connections used in structural bar and cable products and can monitor the load through these components when used in a variety of applications. Once instrumented the pin is calibrated against a known load cell and the calibration is stored on the pins ID chip.The new ultrasonic load measuring technology has been tested at the university of Leeds, UK and Braunschweig, Germany as well as in the Pfeifer testing laboratories. During this testing it has achieved an accuracy of $\pm$1.5% of the design loads. For temporary monitoring Pfeifer has developed a handheld load monitoring device. For Permanent Monitoring Pfeifer has developed electronics that can be permanently installed to monitor the Load on components. The electronics record the measurements of load and can be programmed to report as often as required over a GSM network allowing the user to access the data via a website.This components allow to develop cost effective and reliable installation/maintenance concepts for nearly all pretensioned structures.

4. Project Example, London Olympic Stadium


Figure 3, Olympic Stadium

The London 2012 Olympic Main Stadium was originally meant to be a temporary item, at least for the most parts of it. Now the City of London has suceeded in finding a user for the stadium and has also secured the Rugby World Championship 2015 and the track and field world championship 2017. For these reasons the stadium will be refurbished according to the valid regulations. Which means that there has to be a new, wider roof on it.Erecting the new roof for the London Legacy Stadium will be a multi-discipline process. It starts with the installation of the complete cable net by a full big lift operation with pinning and prestressing the the upper and lower back radials in the engineered sequence. The cable net has to be prepared for the installation of the steel structure by a system of tie down cables These tie downs have to be adjusted and force controlled over the complete installation period.

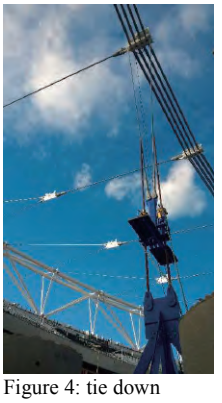
Figure 4: tie down

For controlling the forces the **new ultrasonic load monitoring system** was installed and successfully used.The load monitoring could be done after every installation step of the steel structure without holding available the complete hydraulic jacking system and without installing and reinstalling the jacking system at the required positions. There was just one cable specialist necessary who walked around the stadium and measured and monitored the forces in the Tie Down Cables. All in all it was a reliable and cost saving solution for our client.