

## Development of Bridge Deflections in the 24-hours Cycle

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### Abstract

Prestressed concrete bridges are very sensitive to the increase in long-term deflections. Reliable forecasts of deflections of bridge structures during construction and durability are crucial for achieving good durability, therefore a periodic geodetic measurement observing progression of the deformations should be implemented. The main results of measurements are the changes of the deflection line of the bridge structures, which places special demands on the measurement procedure. In order to reliably determine the deflection curve of the bridge structure, it is necessary to minimize the effects of temperature. Development of air temperature and bridge construction is generally different. To determine the optimum time for measuring the deflection, the analysis of the bridge structure was made in 24-hours cycle. Development of deflection was measured by trigonometric method and method of laser scanning.

**Key words:** bridge, deflection, trigonometry, laser scanning

## 1 INTRODUCTION

In the last five years, the deflection line was measured on bridge near Litoměřice in Czech Republic. The bridge over the river Labe near Litoměřice is part of the road II/247 – it is a connection between the industry area Prosmky and D8 highway. The superstructure is designed as a continuous beam with box girder cross-section. Total length of the structure is 584.5 m. It is divided to 7 spans with lengths 43 + 64 + 72 + 90 + 151 + 102 + 60 m.

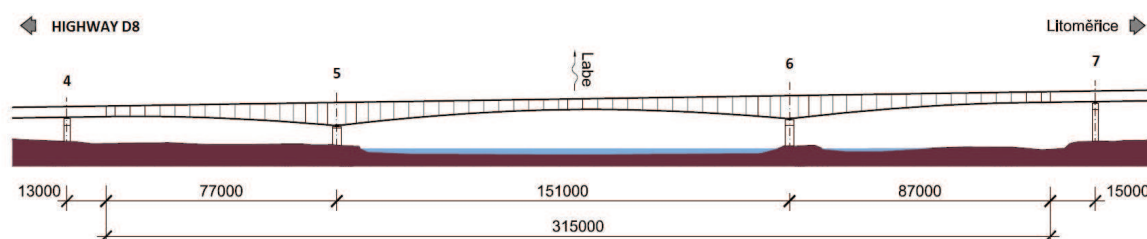


Figure 1a Longitudinal section of superstructure

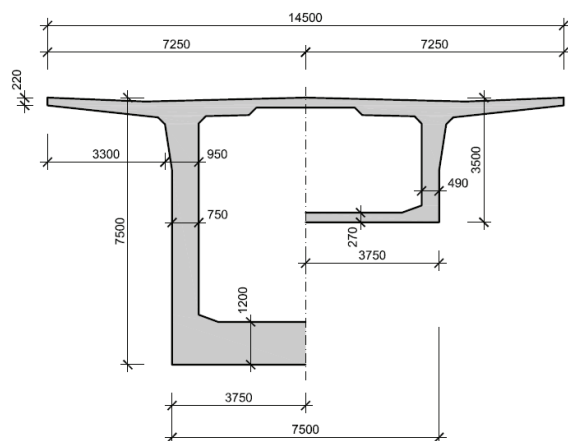


Figure 1b Cross section of superstructure



Figure 1c The bridge near Litoměřice

The width of the bottom deck is 7.5 m; the width of the upper deck is 14.5. The main structure span (length 151 m) and neighbour spans (length 90 and 102 m) were constructed by balanced cantilevers method. These spans are made by two cantilevers with tapered cross section height (varies from 3.5 m in the middle of the span to 7.5 m above supports) and changing thick of the bottom slab (varies from 270 mm to 1200 mm) – see Fig. 1. The left cantilever beam is symmetrical, with the length of 150 m. The right cantilever beam length is 160 m. Approaching spans are designed as continuous beam with constant cross section height 3.5 m and the thick of the bottom slab 270 mm. Long-term deformations are measured at fixed points on the structure (above supporting for analysis of their long-term settlement and in the intermediate points of the end span and middle span for observing long-term deformations of the prestained concrete structure caused both by rheological signs of concrete - creeping and shrinkage, and by other possible effects, e.g. decreases in prestress etc.). The results of such measuring are time development of the real shape of the structure – comprising both the starting shape and the deflection line – in the analysed points (Vráblík, 2012).

## 2 THE MAIN EXPERIMENT

When the atmospheric condition was really good and the refraction was not big, during last five years the measuring of vertical deformation of the main span was made (Urban, 2013). Time for measurement was determined from midnight to three o'clock in the morning based on experience. The main idea of the experiment was to analyse vertical deformation of the main span in 24 hours cycle for better understanding of the structure.

### 2.1 THE PLAN OF THE MEASUREMENT

Near the bridge there was a standpoint selected for measurement of a vertical deformation using trigonometric levelling (Urban, 2013). During the experiment, measuring of the vertical distance to a nearby elevation reference point was done to determine the stability of instrument. The measured points were made on the side of the bridge (only on the main span) see Fig. 2 and were stabilized by reflecting targets. The main field is above the Elbe River and it was not possible to stabilize station for instrument directly to the bridge. At the same time laser scanner was used for the similar measurement, where the station was under the bridge

(Štroner, 2013). The results from both measurements should correspond. The measurements were divided into 24 stages after one hour each.



Figure 2 Measured points on the side of the bridge, standpoint and reference point

### 2.1.1 The trigonometric measurement

The trigonometric levelling was made by Leica TCA 2003 (Fig. 3) instrument. Informations about precision of instrument are shown in Tab. 1.

Table 1 Leica TCA 2003

Measurement	Accuracy
Angle	0.15 mgon
Distance (standard mode)	1 mm + 1 ppm



Figure 3 Leica TCA2003

### 2.1.2 The laser scanning

The laser scanning was realized by Leica HDS 3000 (Fig. 4). Informations about precision of instrument are shown in Tab. 2.

Table 2 Leica HDS 3000

Positional accuracy	6 mm
Distance accuracy	4 mm
Range	300 m
Scan rate	4000 points/s
Modelled surface precision/noise	2 mm
Minimum point spacing	1.2 mm



Figure 4 Leica HDS 3000

## 2.2 THE MEASUREMENT OF TEMPERATURE AND PRESSURE

During the experiment the temperatures of structure and air were measured and so was an air pressure (Fig. 5). Partial research of experiment was to determine the temperature development for better understanding of the deflections of structure. The experiment was planned to take place during sunny and very hot days for the biggest vertical deformation of construction.

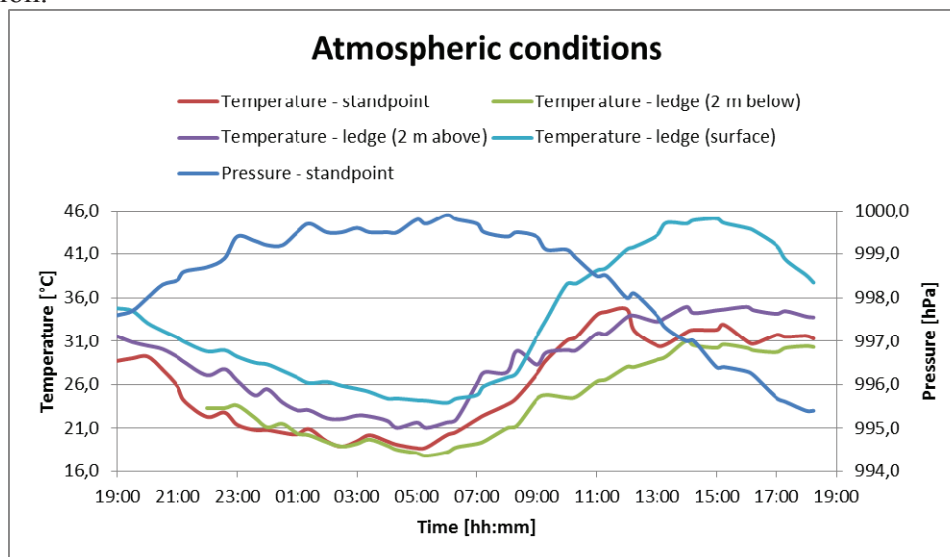


Figure 5 The temperature of air and structure with air pressure

## 3 THE RESULTS

The results from the experiment were significantly affected by vertical atmospheric refraction, which is in compliance with our pre-experiment expectations. The first half of the points was measured only over the river and vertical refraction rendered the results worthless. Therefore they were not used for further evaluation. The results from measured points number 1 (points farthest from the standpoint, stationing 0 m), 8 (point in the middle of the span, stationing 65 m) and 16 (point nearest from the standpoint, stationing 142 m) are shown on Fig. 6.

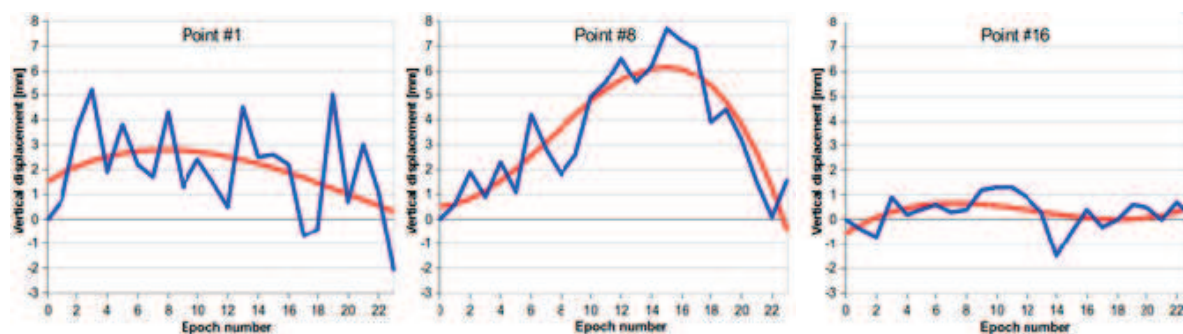


Figure 6 The results from measured points

### 3.1 THE TRIGONOMETRIC LEVELLING VERSUS THE LASER SCANNING

The trigonometric levelling was applied on measured points, unlike the laser scanning that was applied directly on the structure (Koska, 2010). It was necessary to recalculate the points from laser scanning to a curve of deflection. Both of the methods were compared. The best matches were at 9 am (Fig. 8) and the worst at 2 am (Fig. 7). All values in figures are relative to the zero stage at 7 pm.

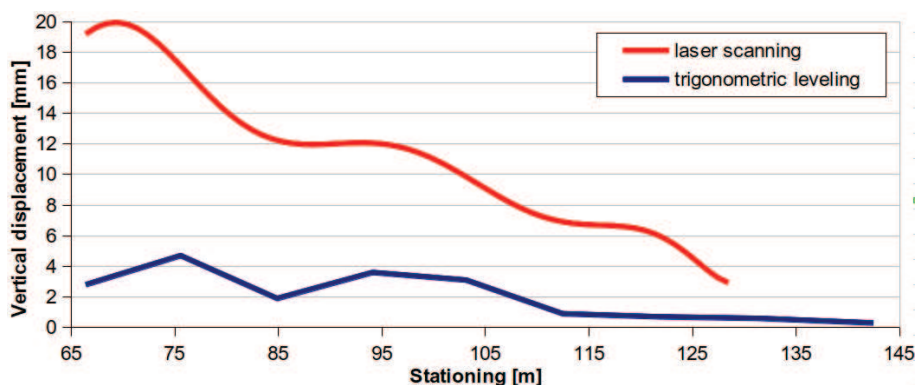


Figure 7 The comparison of methods at 2 am

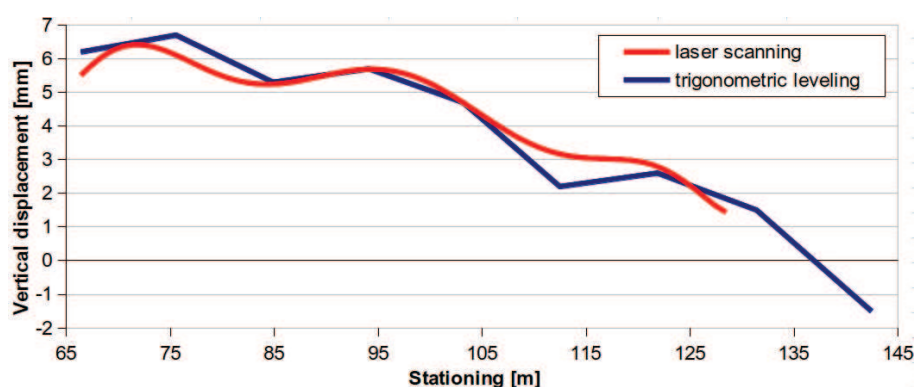


Figure 8 The comparison of methods at 9 am

### 3.2 THE PERIOD OF THE GREATEST STABILITY OF THE CONSTRUCTION

The Fig. 9 shows the average vertical movement of surveyed points in one hour interval with regression curve and temperature of ledge surface. The period of the greatest stability is probably between 5 am and 11 am, when the vertical movements are the smallest. The interesting information is delay of temperature curve versus curve from vertical movements. The delay takes about three or four hours. It is probably due to the influence of heat spreading. It is important to consider the influence of heat for planning the measurement. Usually the measurement plans are directed to thermally stable part of the year where the influence of heat is very small and the period of the greatest stability is relatively big. But for finding the maximal vertical deformation of structure it is necessary to plan the measurement on very hot days.



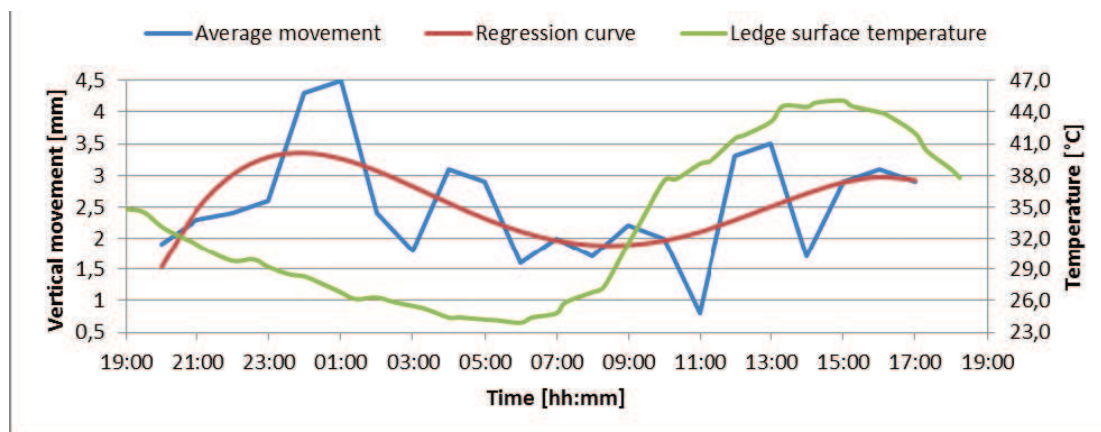


Figure 9 The vertical movement of measured points

## 4 CONCLUSION

The experiment for analysis of vertical deformation of the main span in 24 hours cycle was conducted with a goal of better understanding of bridge structure. Trigonometric levelling and laser scanning methods were chosen. The results from trigonometric levelling were significantly affected by vertical atmospheric refraction. Both of the methods were compared and the best matches were in 9 am. The period of the greatest stability is probably between 5 am and 11 am, when the vertical movements are the smallest. It is important to consider the influence of heat while planning the measurement.

*The article was written with support of the internal grant of Czech Technical University in Prague SGS14 "Optimization of acquisition and processing of 3D data for purpose of engineering surveying".*

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