

IABSE SYMPOSIUM

VENICE 2010

*Large Structures and Infrastructures
for Environmentally Constrained
and Urbanised Areas*

REPORT

RAPPORT

BERICHT

International Association for Bridge and Structural Engineering
Association Internationale des Ponts et Charpentes
Internationale Vereinigung für Brückenbau und Hochbau

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Long-term monitoring of temperatures in steel box girders

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Summary

During a period of several years, temperature variations have been monitored at several points of a cross section of the Vilvoorde Viaduct, which is one of the most important steel box girders of the Belgian highway network. Analysis of the monitoring data indicates that substantial temperature variations exist, during a 24-hour cycle of heating and cooling. Values of more than 30 degrees or more are found to be quite common. In addition temperature gradients have been measured of more than 20 degrees between both sides of the steel box girder, which could result in additional displacements and warping of the cross section.

Although thermal loads are not often considered during the first design steps of steel box girders, their influence can be quite substantial. When the thermal loads and more specifically the thermal gradients within the steel box girders reach considerable values, a number of other effects are influenced. High thermal gradients will reduce the cohesion of waterproofing layers and wearing courses, thus reducing the composite behaviour of these layers with the deck plate.

Hence, the quantification of the thermal loads working on steel box girders becomes quite important. While this was previously done using detailed finite element models, including solar radiation, cooling, convective airflow, etc. this research paper will give tangible design values for thermal gradients in steel box girders, based on actual measurements, which are in some cases higher than those values given by the current design codes, especially when looking at the temperature difference between two points of the same cross-section.

Keywords: steel box girder, temperature load, monitoring

1. Introduction

Steel box girders, equipped with an orthotropic bridge deck and constructed using stiffened plates are one of the most frequently used concepts for road bridges and flyovers spanning between 80 and 160 m. Similar sections are often applied for arch cross-sections of bridges spanning 200 m or more. They are a very economical solution and are easy to build thanks to the modern construction techniques. A new problem has arisen in recent international research, that was not taken into account for the design until now, which can heavily influence the behaviour of the bridge.

The heating and thermal regime of closed steel box girders has been measured experimentally on the steel part of the 'Pont de Normandie'. These tests clearly indicate at the existence of considerable temperature effects in these types of box girders, although they were not considerably larger than design values in this specific case. The cross section of the bridge has a small height, which means that it isn't a typical example of the classical box girder. The forces in higher boxes will be much higher. The thickness of the wearing course is only 40 mm on top of that, so the heat absorption and the delayed temperature effect because of the warm air inside of the deck will not be strong enough when compared with the overall cooling effect of the bridge.

2. Experimental verification

All of the above considerations have been used to develop a finite element model of a typical steel box girder. The geometry is comparable to that of the Vilvoorde viaduct.

Studying the a top view of the deck plate of the bridge, the influence of the underlying structure is quite obvious. Since the parts at the side of the box girder are completely surrounded by air, and the able to cool down by way of a convective air flow with the environment, they remain fairly cool. The middle part however starts to heat up, partly because the convective flow at the inside of the box girder is almost negligible, and partly because mutual radiation between the steel parts of the box will keep heating the deck plate from the inside out. It is possible to introduce these temperatures, as thermal boundary conditions into a finite element model and perform a classic linear elastic calculation.

3. Experimental measurements

During the spring months of 2008, an autonomous monitoring system for temperatures was implemented in the southern box girder of the Vilvoorde Viaduct. Instead of using classic thermocouple sensors, the choice was made to use small-scale integrated circuits, with an in-built temperature sensor, normally used to monitor temperatures in computer and network systems.

The location of the cross-section along the length of the viaduct was chosen in such a way that the section is relative to the movement of the sun so that it would be subjected to the largest temperature effects, based on the finite element calculations mentioned above.

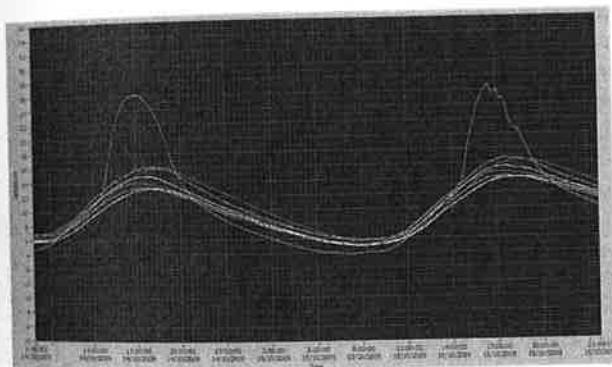


Fig. 9: Continuous temperature measurements during October 2009 on the Vilvoorde Viaduct ($^{\circ}\text{C}$)

combined with a temperature gradient of about 13°C . This final figure also displays the optimised monitoring software.

4. Conclusions

This paper tries to focus on the importance of temperature effects and thermal loading for the design and behaviour of steel boxes. In box girder as well as in closed arch sections [7, 8], solar radiation will result in important temperature differences between parts of the cross-section. This thermal loading will have an important impact on the cohesion of wearing courses and the fatigue effect in steel box girders.

The measurements have been continued all through the winter and are still running continuously. When a very cold period is combined with sunny weather, it can be seen the temperature gradient in one cross section can reach values of almost 15°C , while the temperature variation over one period of 24-hours, can be more than 20°C . This is purely due to the influence of direct solar radiation on parts of the box girder resulting in immediate heating, while most of the rest of the cross-section remains close to environmental temperature. This effect becomes even more important during autumn and spring, as is shown in figure 9, displaying a temperature variation of 23°C in 24 hours