Monitoring during Refurbishment of Port Infrastructure

Hans DE BACKER
Professor
Ghent University
Ghent Belgium
Hans.DeBacker@UGent.be

Amelie OUTTIER
Post-doctoral Researcher
Ghent University
Ghent Belgium
Amelie.Outtier@UGent.be

Ken SCHOTTE
PhD Student, Researcher
Ghent University
Ghent Belgium
Ken.Schotte@UGent.be

Dries STAEL
PhD Student, Researcher
Ghent University
Ghent Belgium
Dries.Stael@UGent.be

Wim NAGY
PhD Student, Researcher
Ghent University
Ghent Belgium
Wim.Nagy@UGent.be

Philippe VAN BOGAERT
Full Professor
Ghent University
Ghent Belgium
Philippe.VanBogaert@UGent.be

Summary

Monitoring of structural parameters during construction can be an important aid for execution. Especially when studying the long-term behaviour of structures, e.g. build-up of ground pressures or fatigue effects, it can become necessary to resort to monitoring. This research paper discusses two such projects.

A first project deals with the refurbishment of a lock door of the Port of Zeebrugge, Belgium. In order to allow for refurbishment, the ground water level in the door chamber had to be lowered considerably, resulting in a variation of the ground pressure on the concrete walls of the lock chamber. As a safety measure large steel struts were added, going through the lock door. Since much uncertainty existed concerning the size of the ground pressure variation, a monitoring system was installed to measure the normal forces in the struts and alarm levels were defined. Initial results pointed out that temperature variation in the longitudinally constrained struts took up a considerable part of the capacity of the struts.

A second project is concerned with the refurbishment of part of the counterweight structure of one of the bascule bridges crossing the Van Cauwelaertsluis, which is one of the most important locks allowing entrance to the Port of Antwerp, Belgium. Because of uncertainty about the size of the stress cycles in the movable part during bridge operation, a number of strain gauges are installed during renovation before any of the axles connecting the bridge to the bascule system are installed. Afterwards, stress build up will be monitored during the remaining construction phases, as well as during test operation of the bridge to verify design assumptions. Monitoring will continue afterwards during the first few months of operation.

Keywords: lock doors, movable bridges, strain gauges, non-destructive testing, monitoring, wireless, autonomous monitoring.

1. Lock doors

The results of the first two weeks of the measurement programme are shown in figure 1. Daily variations of about 1000 kN seem to be quite normal for the steel struts, which was quite an unexpected surprise for the client. While the measured variations were initially considered to be due to flaws in the measurement setup, it was proven later on that they were caused by temperature variations, influencing the stress field in the steel struts which are longitudinally restrained between the concrete lock room walls. Assuming such a boundary condition for the struts, the daily as well as more long-term variations are proven to be quite logical, although they were not considered by the designers. The variations of forces as well as the variation of the local temperature are shown in figure 1 for a two week period, showing a remarkable correlation. In addition, this theory was proven when one of the hardwood wedges started moving after a few weeks when low values of forces as well as temperatures were registered. It could be concluded that this was caused because of daily temperature variation and not because of unequal variations of the ground pressures. When studying these results, it is important to notice that the measurements were zeroed after the pretensioning was already applied.

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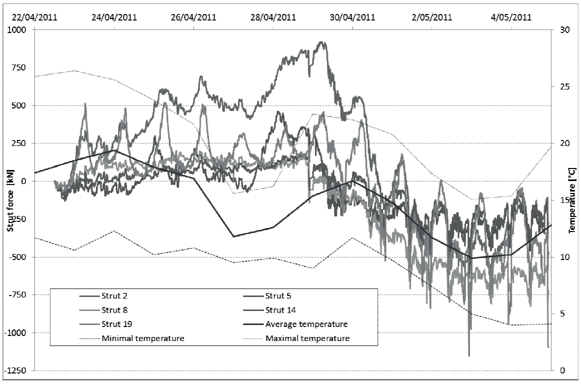

Fig. 1: "Pierre Vandamme" lock in the Port of Zeebrugge: measured normal forces (kN) and environment temperature during the first two measurement weeks

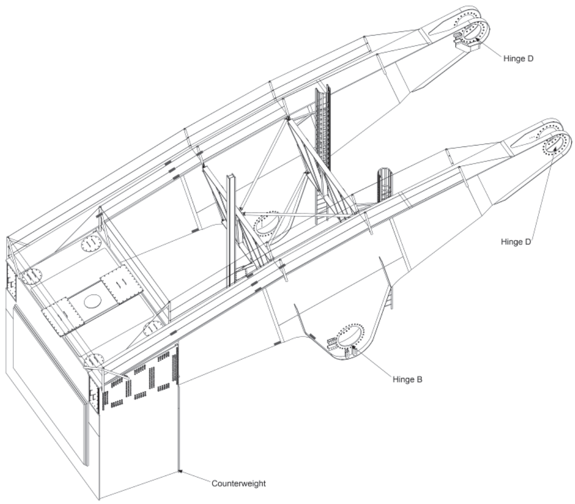

Fig.7: "Kruisschans" Bridge in the Port of Antwerp: 3D-view of the balance beam (strain gauges are marked) and frontal view of the bridge system

2. Bascule Bridge

One of the determining factors in the redesign of a trunnion bascule bridge is low-cycle fatigue due to the movement of the bridge. In order to verify all design assumptions, it was decided by the client to install 36 strain gauges, mainly on the balance beams, but also on the hoist beams and gear rods. In addition, it was decided to install most strain gauges at the steel construction plant where all the parts are strengthened and repainted in an unloaded condition. This allows for monitoring the stress cycles during normal bridge operation and also for registering the stress build-up during assembly of the bridge.

3. Conclusions

When studying the long-term behaviour of structures, it often becomes necessary to resort to monitoring of certain structural parameters. This research paper discusses two such monitoring projects which are used to verify design assumptions.

A first project deals with monitoring the normal forces in the horizontal struts of lock doors under renovation to safeguard against extensive ground pressures. The monitoring programme proved useful in pointing out a load combination which was not considered in the design phase and was shown to be an adequate warning system.

As a second example, deals with verifying the stress cycles for fatigue verification in a movable bridge. This can lead to an adequate estimation of the remaining fatigue life after renovation. In addition, the measurement results can be used to verify the unbalance of the bascule system.

This article gives an overview of these experiences and on the lessons learned concerning power supply and possible electromagnetic interference in harsh construction site conditions. Furthermore, the most important results of both test cases are discussed in short.