Safely renovating ship locks

by Heiner Gillessen and Uwe Sowa

The Kiel Canal is the most travelled artificial waterway in the world. In 2014, an average of 89 ships per day passed through the canal. It is almost 100 kilometres (62 miles) long, from Brunsbüttel to Kiel-Holtenau, and links the North Sea to the Baltic, enabling ships to save a distance of some 250 nautical miles (or roughly 450 kilometres) to bypass the northernmost tip of Denmark at Skagen. Though nautical strategic factors may have been crucial at the time of its construction, the canal is currently used exclusively for the exchange of goods between countries in the Baltic region and the rest of the world. The Kiel Canal opened after eight years of construction on 21st June, 1895 and after an additional eight years, it was necessary to widen the canal due to the amount of traffic passing through. Each end of the Kiel Canal is closed off from the fluctuating water levels of the Elbe River and Baltic Sea by four locks: one double lock from 1895 (the small locks) and those built in 1914 (the large locks).

During a regular structural inspection, water from the 220 metre (722 feet) long by 10 metre (33 feet) deep south chamber from one of the small locks was pumped out in March 2013, with the chamber remaining dry for two and a half months. Since the water in the north chamber presses against the lock wall of the south chamber, the south chamber was monitored geodetically for safety reasons using a Leica TCRP 1201 total station and other sensors. The data collected from this monitoring provided information on the behaviour of the structure and protected inspectors and workers during the renovation.

■ **A Leica Geosystems total station takes measurements to observe possible movements of the chamber wall.**

Surveying required a measuring program to be prepared in advance for specifying the type and scope of the required measurements. Based on this program, the small locks of Kiel-Holtenau were set up to monitor the south chamber during the pumping out period and the dry phase. An immediate response to any emergencies which might have arisen was made possible by the ability to send out information on the change in the structural behaviour at any time during renovation work.

Monitoring with a total station

The Leica TCRP1201 total station, connected to the Leica GeoMoS monitoring software for data collecting and processing, was installed on top of the lock's control station, located on the partition wall of the two lock chambers. Since the location of the sensor was in an area subject to possible movement, the monitoring method known as free stationing was undertaken. This meant measuring six different stabilised reference points attached to surrounding buildings in the area that were not subject to movement in order for the hourly program-controlled data measurements to be possible. The measurement points on the lock were then determined in 3D. In this way, the ten measuring points from which the chamber width can be derived, served as "virtual sensors". These hourly measurements of the north and south sides of the chamber walls, as well as the control of the fjord and chamber water levels, was carried out using the highly customisable Leica GeoMoS family software programs. In addition, the coordinates of the six head-base points, the three chamber-base points and the two points on the inspection covers were also recorded. The values of each of the six groundwater measuring points on the north side and the south side, as well as the level of the fjord and chamber water level, were recorded hourly and transferred to the GeoMoS software.

Integrating geotechnical sensors into the Leica GeoMoS portfolio

A crack on the chamber wall of the southern side corridor was monitored using tilt sensors and fissurometers, and these also sent data to the Leica GeoMoS program. Any changes in the length and cross directions were displayed and analysed in easy-to-understand graphics by Leica GeoMoS Analyzer. The

■ **Ready for safe renovation: The empty ship lock gets inspected while the structure is being monitoring.**

standard deviation tolerance of the points measure was ± 2.2 milimetres (± 0.09 inches) and controlled by Leica GeoMoS Monitor.

"A special challenge was to integrate the geotechnical sensors into the monitoring system, which ended up working flawlessly. Even under extreme weather conditions like snow, freezing rain and storms, the system worked perfectly. This ensured a high degree of reliability regarding the information on the structural behaviour during the dry period," explained Heiner Gillessen, Technical Product Manager for monitoring at Leica Geosystems.

Dipl. Ing. Uwe Sowa of the Kiel-Holtenau Water and Shipping Authority assessed the movements which occurred during the renovation and the results after successful usage: "Each sensor has its own recorded data limit levels specified in the processing software that resemble the colours of a traffic light. Should a value exceed the defined tolerance it would appear in the red range, resulting in immediate notification via text message and email and ensuring that safety measures could be implemented. Except for a few exceptions in the yellow range requiring more in-depth analysis, all of the target values were always in the green range."

Meanwhile the lock has since been flooded, and the north chamber pumped out, renovated and monitored also using the same procedure. The level and movement behaviours of the locks will still be checked using digital tilt sensors and position sensors, and the data from these sensors sent to and evaluated by the GeoMoS software programs. ■

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