SMARTER MOVES

Anemometers, strain gauges and accelerometers provided real-time data from the MSS

An enhanced monitoring system for movable scaffolding systems has been tested during construction of a highway bridge in Slovakia, write Pedro Pacheco, André Resende and Filipe Magalhães

The 2.9km Danube Bridge is a highway crossing over the Danube River, 10km from the centre of Bratislava, Slovakia. The structure is part of a major highway project, known as D4R7 (*Bd&e issue 97*), which is being undertaken to ease traffic on existing radials and roads in and around the Slovak capital.

The Slovak Ministry of Transport and Construction and main contractor – DR47, a joint venture between Ferrovial and Porr – signed a public-private partnership contract in 2016, and construction began in 2017. The crossing consists of a 900m-long main bridge and two access viaducts: the 12-span 784m-long west viaduct and the 18-span 1,250.5m-long east viaduct. Both viaduct decks have very similar cross sections and were designed to be built by similar movable scaffolding systems (MSS) provided by Berd.

For simplicity, the superstructure was built in two phases. The first consisted of the fabrication of the central box girder on the approach viaducts, which was built as a full-span continuous beam using MSS, and the main bridge's central box girder, which was built using the balanced cantilever method and form travellers. In both instances, the lateral sections were built during the second phase by auxiliary equipment designated as wing travellers.

Both MSSs used for the construction of the viaducts between the final quarter of 2018 and the first quarter of 2020 are model M1-70-S.

An advantage of using this MSS model on the Danube Bridge was that it allowed for the construction of the decks to take place close to the ground, which in turn permitted minimal interference and excavation volumes. This was key during the MSS's deployment over a dike on the western side of the bridge.

On both MSSs, the main girders were strengthened by an organic prestressing system (OPS), which features continuous mid-span deflection monitoring and compensation system. For the main girder deflection measurement, a system based on the 'communicating vessels principle' is used, with pressure transducers at the supports and at mid-span. The deflection at mid-span causes pressure variation on the mid-span transducers from the reference defined by the alignment of transducers at the supports. When the mid-span deflection of the MSS reaches a predetermined threshold, the OPS algorithm transmits instructions to the OPS hydraulic cylinders which compensate the deflection.

While the OPS provided continuous and real time monitoring for both MSSs, a complementary monitoring system was installed exclusively on the MSS used for the construction of the 12-span west viaduct. This system conducted data gathering and analysis with the aim of developing a Smart OPS, which can be applied broadly on MSSs. The benefits are better knowledge of the behaviour of the MSS, and making this information available in real time to operators and stakeholders at all phases. This complementary monitoring includes three subsystems, comprising sets of anemometers, strain gauges and accelerometers, which allowed for the characterisation of loadings.

While the permanent loads were obtained by the sum of the weight of the individual elements, the static structural response was determined by measurement of strains on representative elements, and the dynamic response (vibration) was measured by accelerometers. The monitoring of wind characteristics – which have the biggest effect on the deployment of an MSS, along with the characteristics of the MSS – provides validation of design assumptions and the correlation between the structural response and the excitation, to better define the interaction between the air flow and a flexible structure. The time series are processed by algorithms that allow the real-time identification of the dynamic modal parameters that define the dynamic response of the structure.

Since the natural frequencies are a function of the structure stiffness, any damage, incorrect assembly or structural deterioration that imply a reduction of the stiffness is identified by a reduction of the natural frequency. The precise measurement of the natural frequency variation with time enables the detection of small structural changes. However, since natural frequencies are also affected by the temperature, wind speed and operating conditions, these effects must be mitigated with statistical models. The measurement of strains at a fast sampling rate is also a tool used for structural monitoring, namely for the stress state and fatigue assessment. This last component of the monitoring system is very important in the determination of the residual life of the structure.

The Danube Bridge is scheduled to be delivered in full by the D4R7 JV in 2021 ■

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