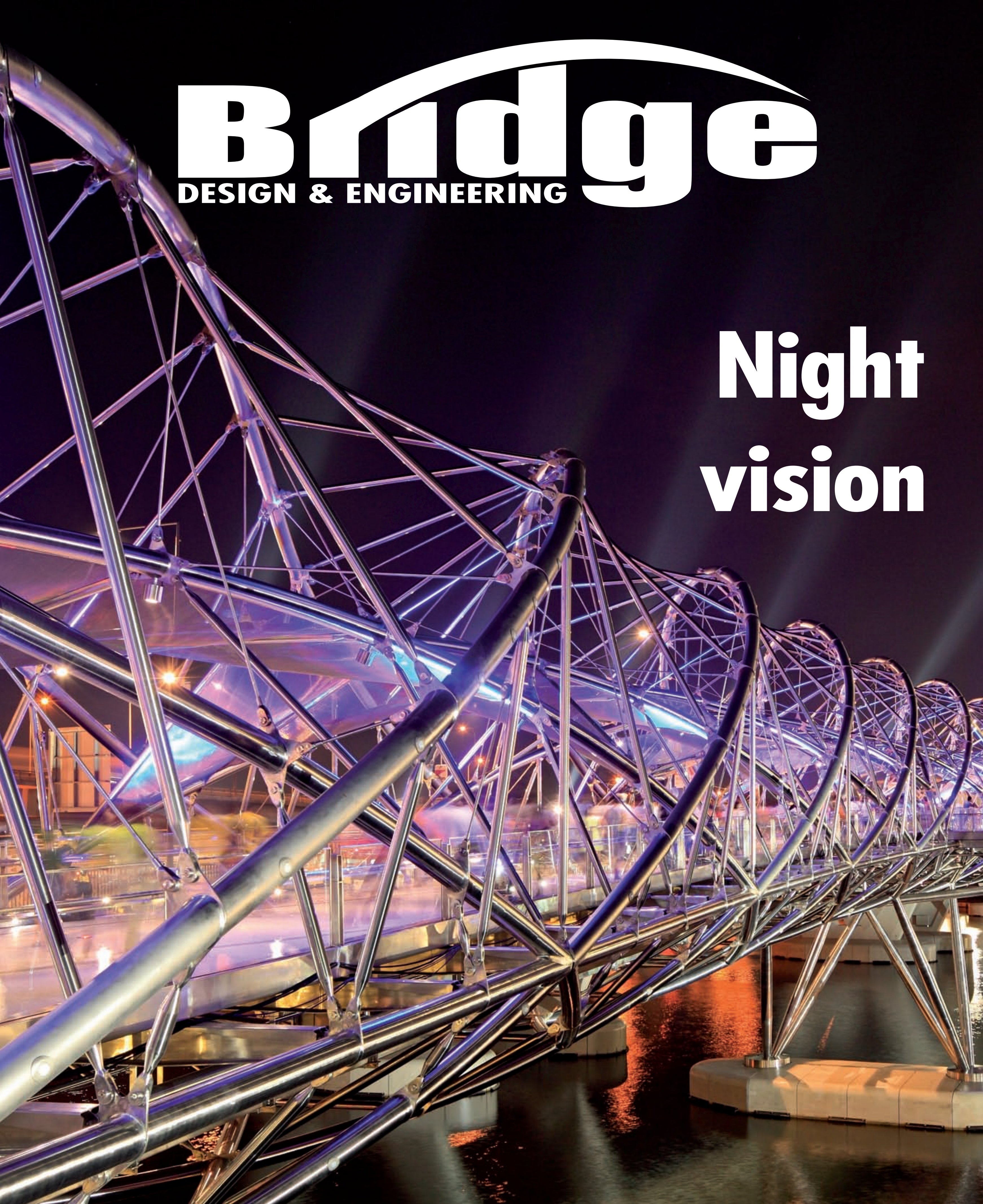
Bridge
DESIGN & ENGINEERING

Night vision



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WATCHING BRIEF

Installation of a major structural monitoring system on one of London's busiest highway routes has just finished. Jon Watson reports

One of the UK's earliest examples of post-tensioned segmental viaduct construction is the Hammersmith Flyover in west London. The structure has just had a comprehensive structural health monitoring system installed so that engineers can more effectively manage its maintenance.

The viaduct, which was built in 1961, is 630m long and has sixteen spans varying between 33m and 47m. It is managed by Transport for London and is a strategic highway route carrying a high volume of traffic, including a large percentage of heavy goods vehicles. The superstructure consists of a series of 3m long triple-cell spine box beam units with 75mm in situ concrete joints to 300mm cantilever diaphragm units. The longitudinal post-tensioning consists of two sets of four tendons of 16, 19-wire strands either side of the two internal webs encased in in situ grout boxes.

The UK Highways Agency initiated a programme of special inspections for all post-tensioned concrete bridges in the early 1990s. On the Hammersmith Flyover these revealed a general and sustained decline in the condition of the structure and, in particular, the post-tensioning system.

This prompted TFL to undertake a full structural assessment. A detailed special inspection was carried out and assessments made of actual section losses found by exposing the tendons at critical locations. These were used in a three-dimensional finite element load assessment model to determine the flyover's current live load capacity.The results showed that despite the evident corrosion, the structure passed full 40t highway loading in accordance with BD21/01.

While this gave reassurance that the structure was safe and fit for purpose, to manage the structure effectively TFL needed to know whether the deterioration was continuing and if so at what rate.

To establish this, a structural health monitoring system was required with a very demanding specification. The system had to detect wire breaks, identify the individual tendon group and its location within 500mm. TFL also required information on the movement of the roller bearings, since resistance to movement could induce unwanted forces in the superstructure, continuous monitoring of deflections of each span and measurement of strains across critical segment joints.

Physical Acoustics was awarded a contract to design, manufacture, install and commission an integrated structural health monitoring system. With more than 450 sensors it is believed to be the largest bridge monitoring system in the UK. Installation and testing was carried out over ten weeks beginning in April and coming into operation at the end of last month *(July)*. Monitoring will be carried out for a minimum of five years.

Left: Carrying out the blind wire test. Right: Total station prisms inside the box monitor movement.

Acoustic wire break monitoring is deployed over the nine spans on the east side of the flyover to detect and triangulate wire breaks linearly along the structure and define the location to specific tendon groups.

The specified accuracy of the system required a high frequency acoustic emission sensor in each 3m segment. Sensors are bonded to the surface of the concrete with structural adhesive and cabled back to the monitoring system in the instrument cabinet.

Detection of the wire breaks uses the signature data collected during third party Japanese Public Highways Corporation trials and those detected on other structures. The distinct signature and signal transmission from breaks allows automatic detection and instantous wire break alerts. Signal location uses time of arrival of the energy wave (released during wire break) at acoustic sensors. This data is cross-correlated with an acoustic map of the structure developed during the commissioning of the system that confirms the exact location, even were tendon groups are in close proximity. This method takes into account complex wave paths caused by mortar condition and variable contruction.

Once installed, the wire break system operation was verfied by TFL by cutting a single exposed wire in a blind test. This was done by incrementally reducing the section of a single wire over a period of time using a grinder until the wire yielded and broke. Physical Acoustics remotely detected and triangulated the break to within 100mm of the physical break and to the correct tendon group.Physical Acoustics also supplied two structural monitoring systems which log data from 30 displacement gauges monitoring bearing movement and pier rotation (in plan), 18 strain gauges over concrete joints, 15 pier inclinometers and 16 temperature gauges which measure internal and external air and concrete temperature along the flyover. Data is continously logged with the average/maximum/minimum readings over each 15 minute period being displayed graphically. The system also allows time-synchronised and detailed measurement of the structural response over a short time period in the event of a wire break.

Three networked laser total stations monitor the entire length of the flyover, with reflective prisms at midspan and piers. These measure longitudinal movement and deflections, potentially due to loss of compression.

The monitoring is part of TFL's asset management plan which will maximise the safe operational life of Hammersmith Flyover and allow planning and budgeting for future structural maintenance.

Not only will the monitoring warn of significant changes in the condition of the structure, but using the results of the special inspection and load assessment as a baseline condition, the results of the monitoring will be incorporated into the structural assessment model to inform decisions regarding the future management of the structure. TFL will be able to develop a deterioration model which will be used to predict where and when intervention may be required, where further intrusive visual investigations may be required and also provide valuable information about the effectiveness of any works intended to improve durability

Jon Watson is structural monitoring specialist for Physical Acoustics Ltd, part of the Mistras Group

BRIEFING

David Jeakle has joined Canadian bridge engineering firm Infinity Engineering Group as principal. Jeakle has nearly 20 years of long-span bridge engineering experience with URS Corp. He is the engineer of record for several cable-stayed, segmental, composite steel bridges and high-level interchanges.

Physical Acoustics has been awarded a contract to install a wire-break monitoring system for the main cables of the Humber Bridge in the east of England. The bridge, which opened to traffic in June 1981, is the fifth-longest suspension span in the world, with a main span of 1,410m and a total length of 2,220m. The Humber Bridge Board carried out internal cable inspections in 2009 which uncovered evidence of wire corrosion in several locations. The wire-break monitoring system is part of a proactive bridge management strategy used by the Humber Bridge Board which will allow monitoring of cable deterioration and will direct future invasive inspection works. Installation will begin this month *(August)*, with the system due to be fully operational before the end of the year. It will monitor the main cables for at least five years and is claimed to be the largest ever deployed on a suspension bridge.

Transport minister Patrick Vlacic announced last month *(July)* that Slovenia is planning to build an expressway to link the country's Korosko region to Austria by 2017. Vlacic emphasised the significance of transport infrastructure for the Korosko region, as poor links have hampered the region's development potential. Possible alignments are currently being studied.

Mott MacDonald has been appointed as the category III design checker by Sunderland City Council for its new River Wear bridge in the north east of England. The new bridge, which is being designed by Techniker, Hewson Engineering and Roughan O'Donovan, is part of Sunderland's strategic transport corridor. It is designed to open up more of the city's riverside land for regeneration and improve transport links from the city to the main highways routes. Mott MacDonald will be responsible for the complete verification of all elements of the bridge, including the stability and stress checks, review of designer's design statements, 3D modelling and wind tunnel work.

Schréder Lighting USA has appointed Michael N Maltezos as DOT, Transit & Tunnel Specialist. Maltezos will be responsible for overseeing lighting activities for transit and tunnel projects throughout North America and will work very closely with municipalities, DOTs and transit agencies.