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The innovative bearing solution engineered for the Forth Road Bridge’s modified deck-to-tower connections

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The Forth Road Bridge (total length 1822 m, main span 1006 m) across the Firth of Forth estuary in Scotland was opened to traffic in 1964. Until today traffic volumes had more than doubled to approximately 70,000 vehicles per day, with design vehicle loading of 44-tonne articulated truck. In December 2015 the bridge was closed to traffic due to a failure of a so-called Truss End Link, which linked the bottom of a section of steel deck truss, at its end, to the tower that supported it.

Following the evaluation of various options to implement a long-term solution, it was decided not to replace the truss end link with a similar element, but rather to develop a more reliable solution with the bottom of the partially renewed truss supported by a bearing. (Figure 1)

Figure 1. Illustration showing developed solution (highlighted) with part of deck truss replaced and supported by a new bearing on a new support bracket which projects out from the tower

An innovative solution was developed, incorporating free-sliding bearings designed to resist high uplift forces and accommodate large deck movements and significant rotations, with adequate durability considering the bearings’ very long cumulative sliding path of 16 km per year. (Figure 2)

Figure 2. A guided sliding spherical bearing

The four main span bearings each required to be designed for downward forces of 6,680 kN and uplift forces (very infrequent) of 2,755 kN, with longitudinal movements of +/- 1,015 mm and transverse movements of +/- 70 mm arising. Rotations of 0.007 rad about the x-axis, 0.042 rad about the y-axis and +/- 0.0487 rad about the vertical z-axis also had to be allowed for.

The design of these special bearings presented a significant challenge in optimising solutions that would meet all specified performance requirements (in terms of forces, movements, rotations, etc.), and ensure the highest quality and durability, while also minimising weight and thus avoiding unnecessary loading on the main structure and the support connections, and reducing installation difficulties. (Figure 3)

Figure 3. Completed solution, with new bearing installed and supporting the deck truss. One end of the bearing’s T-beam, at the tower, is enclosed in a protective expanding/contracting shroud

The weakest part is the sliding material, so the strength and durability of the entire bearing depends on that of the sliding material. The use of Robo-Slide can substantially increase the load carrying capacity of the bearing, and offers further benefits.

Robo-Slide is a patented sliding material of modified UHMWPE (ultra-high-molecular-weight polyethylene), was specially developed and certified for use in bridge bearings and expansion joints. It has a high characteristic load capacity of 180 N/mm^2, double that of PTFE. It also offers far higher resistance to wear and lower transverse forces on the connecting structures compared to PTFE. The material can also be used at a broad range of temperature (-50°C to approximately 50°C). With grease dimples and high-performance grease, a durable, low-friction sliding surface can be ensured. (Figure 4)

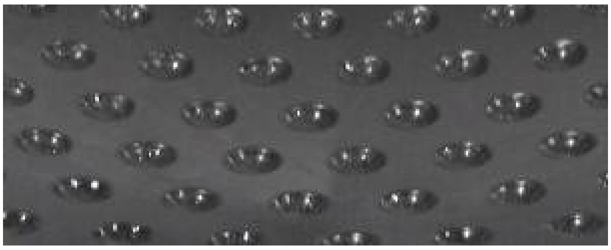

Figure 4. Close-up view of Robo-Slide (with grease dimples) – a high grade alternative to PTFE for bearings and expansion joints

It was also specified that sensors for a structural health monitoring (SHM) system be integrated in the bearings' design and fabrication. These sensors, measuring the depth of remaining sliding surface, the bearing rotation (about both axes) and movements, and the loads (downward vertical) would then require to be connected to the bridge's existing overall SHM system. (Figure 5)

Figure 5. Following installation, connection of a bearing's integrated sensors to the bridge's existing SHM system by means of suitable cabling