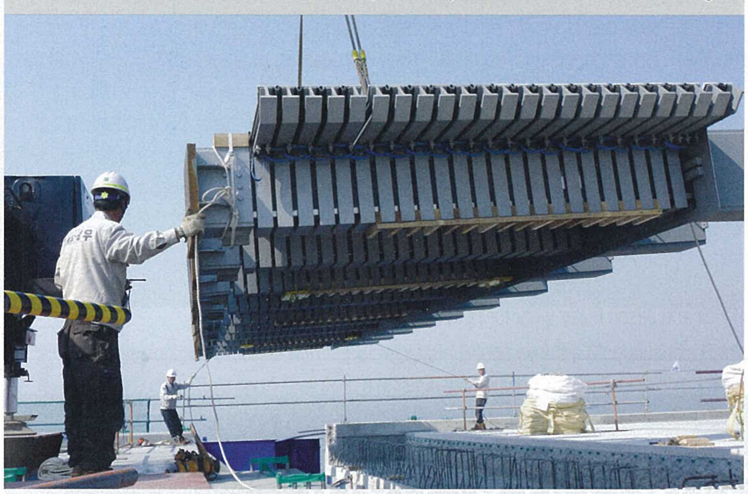
Above: The completed Incheon Grand Bridge *(Amec)*
Above right: Transportation of joint from Austria to Hamburg by road
Below: Installation of LR24 modular expansion joint on Incheon Grand Bridge



SIZE MATTERS

Performance and durability are key considerations for the huge expansion joints that feature on the new Incheon Grand Bridge in South Korea, say **Gianni Moor** and **Colm O'Suilleabhain**

Expansion joints must be designed to bridge the gap between a bridge deck and the bridge's abutments, which is continually opening and closing under different loads, or to span between two sections of bridge deck, often allowing movements in all three directions and rotations about all three axes while being subjected to millions of axle loads.

The Incheon Grand Bridge, which opened last month in South Korea, features some of the world's largest and most technologically-advanced expansion joints. As one of the longest bridges of its type, the crossing places particular demands on the performance and durability of its structural elements.

Large bridges naturally require expansion joints which allow correspondingly large movements of the bridge deck relative to its abutments, and as the field of bridge engineering develops, with ever-increasing spans, the demands on expansion joints for such bridges continue to increase.

Modular expansion joints are often best suited to satisfy these demands, but in the case of very large bridges, they face a number of particular challenges, as demonstrated on this recent project. The 12.3km long Incheon Bridge with its cable-stayed main span of 800m, is one of the five longest bridges of its type in the world. Its 33.4m-wide steel/concrete composite deck will carry six lanes of traffic 74m above the main shipping route in and out of Incheon port. It will link the new Incheon International Airport on Youngjong Island to the international business district of New Songdo City and the metropolitan districts of South Korea's capital, Seoul.

The bridge was built by design and build contractor Samsung Construction joint venture, with project management by Amec and design services provided by Halcrow, Arup and local consultant Dasan. It will be financed and managed for 30 years by an Amec-led concessionaire in joint venture with the City of Incheon, before being turned over to the Korean government.

The cable-stayed section of the crossing is 1,480m long, made up of five spans measuring 80m, 260m, 800m, 260m and 80m respectively, and the height of the inverted Y-shaped towers is 230.5m. A 1.8km-long approach span and 8.7km-long viaduct, both built with prestressed precast concrete box girder decks, complete the crossing. Foundations are drilled piles, each 3m in diameter and the total cost of the crossing is more than US$1.4 billion, which has been funded through a private partnership investment, the first in South Korea to involve an overseas investor.

After a comprehensive evaluation process to determine the most appropriate solution for this significant structure, the client decided on modular expansion joints, to be supplied by specialist Mageba. The design of this expansion joint is based on extensive laboratory and field testing and on complex linear and non-linear dynamic finite element analysis, and it has been in use on many of the world's largest bridges over a period of several decades.

A number of special features were added to the expansion joints, after consideration of project-specific factors including working life, loading, movement characteristics and life-cycle costs.

The sliding material traditionally used on the moving parts of a modular expansion joint would not withstand the extreme movements of some very large expansion joints, and a suitable alternative had to be specified. A material which met the demands is Roboslide, a high-grade sliding material which has excellent abrasion resistance and very low friction characteristics. This material has also been shown to be 20 times more durable and 2.5 times stronger in compression than the commonly-used PTFE.

The symmetrical control systems generally used in modular expansion joints to regulate the widths of the gaps between the joint's lamella beams are not sufficient when the movement is very large, due to the friction and other forces which arise as the joint opens and closes. To overcome this problem, and ensure that the movement of the joint will be evenly distributed across the individual gaps, an alternative, asymmetrical control system was ▶

The central computer of the Robo Control monitoring system

developed. This incorporates a staggered layout of the control springs, with the number of springs being increased at one end of the joint to counteract the build-up of friction forces.

The control springs used to regulate the gap width are subject to additional loading when installed in an expansion joint that must accommodate extreme movements, and hence they must be adapted to suit. For instance, the rubber mixture of Mageba's control springs has been optimised to improve overall performance and durability by a factor of 2.5, and has been verified by testing at an independent institute. These control springs were used for the expansion joints of the Incheon Grand Bridge to ensure satisfactory performance even under the demanding conditions endured by this structure.

As the span of a modular expansion joint increases, so too does the distance a vehicle will have to travel across the joint with reduced ability to brake, especially in wet weather conditions. Large expansion joints therefore require some form of surface treatment to improve tyre grip. Robogrip anti-skid surface is a five-layer laminate coating that is applied cold in liquid resin form. Originally developed for use on the aircraft carrier ships of the British Royal Navy, this special surface treatment has a friction coefficient of up to 0.9 and is guaranteed to drop no lower than 0.5 over its full service life, even under the most adverse traffic and weather conditions. It is also resistant to pollution and ultra-violet radiation.

Modular joints of such dimensions are complex structures and their operation must be assured at all times, particularly on such important structures. Automated structural health monitoring can provide continuous records of almost any variable in a bridge's condition, and can be configured to analyse the data gathered and make it available to an authorised user anywhere in the world via the internet. Automatic notification of the reaching of predefined alarm values can also be provided. Such systems can also be used to provide engineering and usage data – information which may be of particular interest to the owner of a very large bridge.

The expansion joints supplied for the Incheon Grand Bridge included four joints of type LR24 (24-gap modular joints), four joints of type LR10 and 64 joints of type LR5. The total length of expansion joint delivered came to 1.13km – an enormous amount by any standard.

Once completed, each of the four largest expansion joints weighed more than 42t, with dimensions of 16m by 4.9m by 0.8m. The large dimensions and the high load meant that special measures were needed to transport them from the factory in Europe to the bridge in South Korea. To enable the joints to be lifted and transported safely, without risk of damage to the joint or injury to those responsible for the transport, special transportation frames were detailed and fabricated. The road journey from the factory in Austria to the sea port of Hamburg required special permission due to the length and width of the loaded vehicles.

Due to the difficulties posed by transportation of such large structural elements, the joist box was assembled on site. The joints were then installed, using a 250t crane, with consideration of the effect of temperature on the pre-setting value, the block-outs of the bridge and seismic effects. For the LR24 joints, one edge profile was welded to the steel deck of the bridge, while the other was connected by concreting to suit the bridge deck construction.

The design and manufacture of a major bridge's expansion joints requires careful assessment and consideration of movement characteristics and all other relevant factors. Manufacturers must continue to strive towards improved designs and quality of individual components, in order to deliver a product which will remain serviceable over the intended lifetime of the joint, with a minimum of maintenance and repair. ■

Gianni Moor is deputy general manager and Colm O'Suilleabhain is business development manager of Mageba