SIZE NO OBJECT

This picture: Computer-generated image of Ba Lin He Bridge in Guizhou Province

Right: Construction of the Chongming Bridge over the Yangtse River

Manufacturers of expansion joints are putting great efforts into developing systems to cope with the world's ever-lengthening bridge stock, say Gianni Moor and Colm O'Suilleabhain

Large bridges require expansion joints which can accommodate correspondingly large movements of the deck relative to its abutments. With the continued development of the long-span bridge sector, the demands on expansion joints continue to increase. In recent decades the length of the bridges that are being built has increased dramatically, resulting in a greater demand for expansion joints which can facilitate extreme movements.

Modular expansion joints are often best suited to satisfy these demands, but face a number of specific challenges related to scale in the case of very large bridges.

Extreme loading and large movements are probably the most significant factors influencing the overall performance and life cycle cost of a large expansion joint. With traffic volumes constantly rising, expansion joints are exposed to large loads at an increasing frequency. Axle loads also continue to increase, especially in highly-populated countries.

Assuming a bridge carries 6,000 vehicles a day on each traffic lane, the total design traffic volume per lane during a working life of 40 years will be likely to exceed 200 million axle loads. This enormous figure indicates why fatigue is a major consideration for designing durable expansion joints and why many joints start to fail after only a few years.

Under normal circumstances, bridge decks move in a steady and predictable manner influenced by temperature changes, traffic loads and wind. However large bridges, which these days may have longitudinal movements exceeding 2m, usually have quite complex movement characteristics which are sometimes very unpredictable. In addition to the normal daily and seasonal movements, micro movements that occur every time the sun is blocked by a cloud, for example, can easily result in a total movement requirement of several hundred kilometres over the lifetime of an expansion joint.

Expansion joints which must accommodate these extreme movements may require particuar solutions. The sliding material normally used for the moving parts of a modular expansion joint may not be able to withstand such extreme movements, and a suitable alternative must be specified. One material which meets these demands is Robo Slide, a high-grade sliding material with excellent abrasion resistance and very low friction characteristics. Tests carried out on this material showed that over a sliding distance of 2.5km, the friction level is approximately five times lower than that of PTFE. It has also been shown to be 20 times more durable and two and a half times stronger in compression than PTFE.

Modular expansion joints generally include symmetrical control systems which are used to regulate the width of the gaps between the joint's lamella beams. But these systems are not effective when the movement capacity is very large, due to friction and other forces which arise as the joint opens and closes. An alternative, asymmetrical control system developed by Mageba incorporates a staggered layout of the control springs, with the number of springs being increased at one end of the joint to counteract friction forces.

Similarly, these control springs are subject to additional loading in an expansion joint experiencing extreme movements, and must be adapted to suit. For instance, Mageba has optimised the rubber mixture in its control springs, in order to improve the overall performance and durability by a factor of 2.5. This improvement was verified by independent testing. Another problem with large scale joints is the increase in noise generated by traffic crossing the joint, caused by the increased duration of contact between the vehicle's wheels and the joint. In many cases, for example on elevated highways in urban areas, it may be necessary to apply suitable surfacing to reduce the noise.

One solution involves fixing profiled steel plates - so-called 'sinus plates' due to their shape – to the top surface of the joint. These plates eliminate any straight edges perpendicular to the direction of travel, and ensure that vehicles travelling over the joint continuously grip the surface, greatly reducing the noise generated by traffic on the joint.

Noise measurements carried out by an independent body have shown that modular expansion joints with sinus plates can cut the amount of noise generated by traffic by up to 70% compared to other types of expansion joints.

Large expansion joints require some form of surface treatment to improve tyre grip, particularly in wet weather. One such proven anti-skid surface is Robo-Grip, a five-layer laminate coating that is applied cold in liquid resin form. It was originally developed for British Royal Navy aircraft carriers, and offers a friction coefficient of up to 0.9. It also guarantees that this coefficient will be at least 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.

In addition to using modern and high quality expansion joints it is also important to reinforce the adjoining asphalt surfaces, for example using a system such as Robo-Dur. Vertical slots are cut at a 45° angle to the joint's edge profiles and filled with the Robo-Dur high strength epoxy mortar, forming support ribs which strengthen the road surface and protect it against deformation. These support ribs absorb the vertical forces of the traffic and the shear forces caused by braking vehicles, preventing deformation of the road surface. They improve driving comfort, and increase the service life of the joint, guaranteeing proper functioning of the joint for many years and reducing maintenance expenditure.

Depending on their location, large bridges may also be affected by earthquakes, which can destroy the bridge's expansion joints and may even cause severe damage to the structure itself. Mageba's 'Fusebox' system allows the connection between the expansion joint and the main structure to break in a controlled manner in the event of an earthquake. This permits the expansion joint to close during an earthquake without being destroyed, and to settle afterwards in such a way as to allow emergency vehicles to cross the joint.

Large expansion joints are proportionately more complex and have more moving parts than smaller joints, and are likely to be installed on major bridges where the condition of the joint and the bridge itself must be guaranteed at all times. Therefore a bridge owner may wish to incorporate an automated monitoring system into the expansion joint to provide real-time information on the condition of the joint or the bridge, or other data.

Remote monitoring can provide continuous records of almost any variable relating to a bridge's condition, such as the position or length of any part, or the force acting on that part. Modern automated systems can also be configured to analyse the data gathered, present it in tabular or graphic format, and make it available to an authorised user anywhere in the world via the internet. Automatic notification by email or SMS if a defined alarm level of any measured variable is reached, can also be provided.

The initial cost of expansion joints for large-scale bridges is usually a very small percentage of the total cost of the bridge. But data from bridges around the world shows that maintenance and repair costs during the lifetime of an expansion joint can easily amount to several times the initial cost, even without considering additional costs such as traffic disruption. Therefore it is important that bridge owners and designers consider total life-cycle costs in selecting expansion joints. A more expensive joint of higher quality can offer a longer life and require less maintenance, resulting in a reduction of overall costs. A higher quality expansion joint can also protect the main structure, for example by absorbing impact loads, or by eliminating damage caused by water ingress into the structure.

Installation of the world's largest expansion joints was carried out by Mageba on the Runyang Bridge in Jiangsu Province *(see box)*. But similarly-sized joints now being manufactured and planned for other projects in China and South Korea. Construction of the new Zheng Shen expressway in Guizhou province involves the construction of the Ba Lin He Bridge, a suspension bridge which will link the towns of Bai Shui and Cheng Guan. The bridge crosses a very deep gorge, and its deck will be 370m above the river. Its total length of 2.2km includes a main span of 1,088m and side spans of 248m and 228m. Four expansion joints for this bridge will be installed next year, and they will be of type LR21, capable of accommodating movement of up to 1,680mm.

Meanwhile, planning is also under way for the installation of four expansion joints on the Chongming Bridge, which is part of the 25km-long Shanghai-Chongming expressway in China. The cable-stayed bridge crosses the estuary of the Yangtse River between mainland China and Chongming island, and it will be 8.8km long in total, with a main navigational span of 730m. It will cut the travelling time to the island by about 30 minutes, and is expected to stimulate rapid development. Mageba is manufacturing expansion joints of the type LR22 for the bridge, with a maximum movement of 1,760mm, to be installed in 2008.

The following year, three different types of expansion joints will be installed on the Incheon Grand Bridge that is currently under construction in South Korea. This 12.3km-long bridge crossing will provide a connection between the new Incheon Development Area on the mainland, and the country's international airport, which is on Incheon Island. The cable-stayed bridge which crosses the shipping channel has a main span of 800m.

The structure will feature 77 expansion joints from Mageba, including four type LR25 expansion joints with a movement capacity of 2,000mm each, and four type LR11 with a capacity of 880mm. The remaining 69 joints are type LR5 and have a capacity of 480mm of movement. The expansion joints will all be equipped with Roboslide high grade sliding material, Robogrip anti-skid surfacing, and with rubber hump sealing profiles which will help keep the gaps between lamella beams free of debris. A Robocontrol monitoring system will also be installed

South Korea's Incheon Grand Bridge, which will be 12.3km long

FIT FOR FIFTY

Design of Mageba's joints for the Runyang Bridge had to fulfil certain requirements, including a design life of 50 years with design in accordance with BS5400, movement in all directions and rotational capacity about all three axes. The client wanted high durability of all components as well as the expansion joint as a whole, 100% water-tightness and low maintenance requirements, and easy exchangeability of all components.

To meet these requirements, Mageba's modern 'Fourth generation' modular expansion joint was proposed. In particular, the load-carrying structure of the joint and several individual components and materials of the expansion joint were subject to redesigns and improvements. Quality standards for expansion joints have been continuously developed over the last 15 years or so, taking into account experience showing that premature failures can be caused by a lack of quality control in general, inappropriate fatigue design or aspects of critical welding. Mageba used the most advanced high-grade sliding materials, control springs and anti-skid material available in the fabrication of the expansion joints.

Each of the expansion joints for the Runyang Bridge had a total length of 16.25m and weighed more than 55t, which made it impractical to transport the joints fully-assembled from the workshop in Europe to the construction site in China. Instead they were delivered in parts and assembled on the bridge, a process which required precise workmanship. A team from Switzerland supervised the complete process in order to guarantee the highest quality of the final product.

Assembly was completed within three months of the arrival of the goods on the bridge. More than 20 fitters were required to assemble the four enormous expansion joints.

Gianni Moor is deputy general manager and Colm O'Suilleabhain is international project manager at Mageba Switzerland