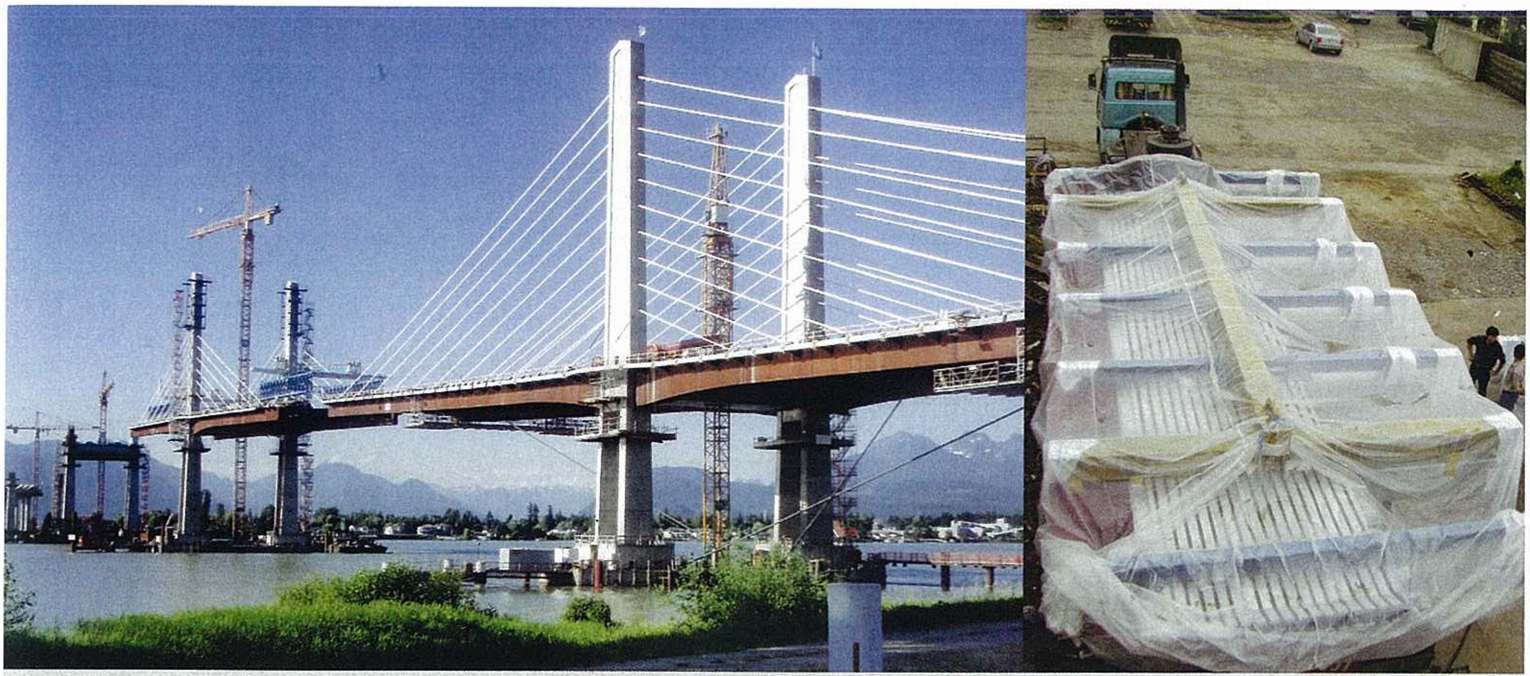
ESTABLISHED ELEGANCE



Left: The Golden Ears Bridge under construction *(Matthias Götz)*. Right: R17 modular expansion joint during transport, with the Fuse-Box earthquake protection nose visible at the left of the joint

North America's longest extradosed bridge posed special challenges for the bearing and movement joint designers

An elegant and innovative new low profile five span crossing of the Fraser River near Vancouver, British Columbia is due to be opened next year. The Golden Ears Bridge takes its name from twin mountain peaks to the north of the site and when it opens, the crossing will create a vital link between communities on both sides of the river and speed economic development in he region. Its low profile design minimises its interference with local air traffic. The bridge has three main spans each 242m long, which are partially supported by harp-configured cable stays and relatively low towers. Its composite steel/concrete deck is integral with the towers, and the cables act to prestress the deck as well as support the central area of each span. Although extradosed bridges are comparatively rare, particularly in North America, the Golden Ears Bridge is said to be a structurally-efficient solution to the various design constraints, particularly the poor ground conditions and seismic risks *(see box)*.

The fixed connections between the deck and each of the towers mean the entire bridge will act as a single unit, with deck and towers swaying together under the action of external forces. All movements, whether from seismic events, wind, thermal expansion and contraction or live loads moving across the bridge, will have to be accommodated by joints and bearings at each end of the near 1km-long deck. Specialist Mageba was esponsible for designing and manufacturing the bridge bearings and expansion joints.

A grid of 2.7m-deep longitudinal steel box beams and 1.6m-deep transverse steel loor beams at 5m centres is topped with 250mm-deep high strength precast concrete units to form the bridge deck. Six lanes of traffic run within the line of the longitudinal beams: there are cantilevered pedestrian and cycle ways on each side, bringing total width up to almost 32m. Analysis of potential movements at the main span bearings showed them to be unusually demanding: 3.1m longitudinally, 50mm in the transverse direction, coupled with rotations of 0.039 radians about the transverse axis and 0.010 transversely. Furthermore, as the bridge responds to external loads and forces, the ends of the deck try to move up and down, so the bearings had to be capable of holding the deck down. The vertical forces acting on each bearing are significant, calculated as 4,170kN downward and 2,790kN upwards. These are demanding parameters which, in combination, are beyond the range of conventional bearings.

The requirement for a bearing to resist uplift is not unusual, and effective bearing designs have been evolved to cope. However in the case of the bearings for the Golden Ears Bridge, there was another factor, potentially the most challenging. Load reversals may occur many times a day under the influence of normal traffic, raising the spectre of fatigue failures, or premature wear at the sliding interfaces of the bearings, as the stainless steel surface impacts repeatedly on the PTFE surface.

Normally when deck uplift is a potential problem, a standard pot or spherical bearing can be adapted with clamps or bolts to resist the uplift. On Golden Ears this was simply not possible, due to the combination of load reversal and large rotations the bearing had to be designed for. To fulfil the design requirements, Mageba developed special uplift bearings with pre-compression of the sliding interfaces. The sliding surfaces are pressed together at all times to avoid any separation in the uplift phase, which would result in hammering and possible failure of the sliding materials. This solution required testing of the pre-compressed elastomeric pads to confirm their performance in terms of stiffness, compressibility and transverse deformation.

Another key decision was to bolt the main longitudinal steel members together rather than weld. On fabrications of this size – 17t per bearing – welding always carries the risk of plate distortion due to the extreme heat involved. Although bolting takes extra time and effort, it was deemed the best option in this case to avoid the risks of reduced quality, programme delays and the wasted materials and effort that plate distortion from welding might cause.

The basic design of the bearing also took into account potential seismic forces. Special precautions had to be taken with the main deck expansion joints, however. Coping with a longitudinal movement of 1,360mm at each end of the main span ▶

was achieved with Mageba's Tensa LR17 modular expansion joints – the number 17 in the product name refers to the 17, 80mm gaps between the transverse elements or lamellae that make up the joint's driving surface. Earthquake resistance comes from the Fuse-Box system, which not only prevents catastrophic damage to the joint or the bridge deck structure in the event of seismic forces above the design capacity, but also maintains access for emergency vehicles after an earthquake event.

The Fuse-Box system consists of a triangular 'nose' at one side of the expansion joint, resting on an inclined ramp that is permanently fixed to the main structure. Joint nose and ramp are connected by a sacrificial fixing. Should a major seismic event take place, and the joint movement capacity be exceeded, the sacrificial connection fails, allowing the Fuse-Box and the joint to which it is connected to move independently of the main structure at one side of the bridge gap, preventing damage to joint or structure. In one direction the joint is designed to ride up the ramp but remain intact, in the other it will simply open up. When the event is over, the joint should remain in place across the bridge gap, and with little or no effort will be capable of permitting the passage of emergency traffic. It can also be easily reconnected to the bridge to allow normal traffic flow to resume, says Mageba.

As bridges become longer and lighter, the actual installation of the movement joints becomes ever more challenging. Predicting the dimensions of the gap into which the joint must be dropped is virtually impossible, as it will vary according to temperature, wind loads and so on. And the very size of these joints makes the logistics of transporting and handling them on site much more critical. The solution adopted was to design special transport frames for the joints which would not only make lifting and transport of the joints easier but also enable adjustment of the joint on site during installation.

Such frames can also be used to compress a modular joint down to its minimum dimensions to make handling easier. For smaller joints this approach may permit transportation in standard open-top shipping containers, preferable to alternatives such as flat rack or bulk shipment in terms of costs, logistics and exposure to the elements during transport

FOUNDATION FORCE

Ground conditions in and around the Fraser River at the crossing point ar deep, soft and liquefiable river deposits. The site is in an area classifie as being subject to moderate to high seismic activity, and the design brie was that the bridge should remain elastic under a 475-year seismic even with a peak acceleration of 0.55g and remain standing after the 0.80g of 2500 year event.

To minimise seismic forces on the foundations, a flexible twin wall pie concept was developed. There was a particular problem with the first mai pier on one side, which is significantly shorter - and therefore stiffer - tha the other three. This extra stiffness would have made the seismic force transmitted too high, even after the pier had been slimmed down as far a possible. The answer was to introduce a vertical steel hinge plate to th bottom of the legs, which will flex in any seismic event.

Final foundation choice was groups of 12, 2.5m-diameter drilled shaft under each pier, up to 98m deep. Concerns about potential long-ter settlement in the soft ground led to the adoption of settlement slabs at th foot of the piers, anchored to but debonded from the pile caps. These permi adjustments for settlement of plus or minus 250mm by jacking as required.

Client: Greater Vancouver Transportation Authority
DBFO contractor: Golden Crossing Construction Joint Venture
Structural engineer: Buckland & Taylor
Geotechnical consultant: Trow Associates
Roads designer: McElhanney Consulting Services
Independent checker: Leonhardt, Andra & Partner
Main span bearings & expansion joint supplier: Mageba