Installation of an expansion joint on the Audubon Bridge

TIPS FOR A LONGER LIFE

Life-cycle analysis is a useful tool to apply to vital bridge components such as expansion joints as well as bridge structures as a whole, say **Thomas Spuler** and **Colm O'Suilleabhain**

A bridge's expansion joints are generally considerably lighter and less robust that the structure which supports them, and at the same time must facilitate deck movements and rotations while subject to dynamic, fatigue-inducing loading from traffic. The expansion joints of a bridge which is crossed by 50,000 vehicles a day, for example, will be subjected to well above a billion axle loads, or mini-impacts, during a 40-year service life. This enormous figure explains why expansion joints require proper maintenance and why they will have to be replaced several times during the lifetime of the main structure. It also illustrates well the importance of careful consideration, during selection and design of the bridge's expansion joints, of the complete life-cycle of the main structure and of the joints themselves.

Life-cycle cost analysis represents a great improvement on the traditional approach often used in the construction of bridges or any other infrastructure, which considers only the initial direct costs to the owner/agency of design and construction. The further owner costs of maintenance and rehabilitation, and the user costs primarily associated with the traffic disruption caused by such works, are often neglected, even today. The life-cycle cost of a bridge may be defined as the sum of the costs of its design, construction, maintenance and rehabilitation, plus user cost and salvage cost. This definition from the Transportation Research Board of the American National Research Council was published in Report 483 of the National Cooperative Highway Research Program in 2003. Even this definition omits certain considerations that should be included in an analysis of the total costs related to bridge expansion joints, such as the costs to the environment and society in general. Maintenance and repair work on a bridge's expansion joints, and especially replacement work, can have a great environmental impact, due, for example, to the use of new materials to replace old ones and the exhaust fumes and fuel wastage that results from traffic congestion.

The formula proposed by NCHRP Report 483 for the life-cycle costs of a bridge can reasonably be considered applicable to the expansion joints within the bridge, in particular considering that an expansion joint is essentially a small bridge at the end of a deck section of a bigger bridge. Adapting the formula for use in relation to expansion joints, and neglecting salvage value, life-cycle cost may be defined as the sum of supply cost, initial installation cost at time of bridge construction, inspection and maintenance cost, periodic direct replacement cost and user cost. It is important that the life-cycle to which reference is made is that of the bridge itself, and not of particular expansion joints which are installed on the bridge at a particular point in time, so that the direct cost of replacement works, and the user costs that accompany those works, will be considered.

The cost of supply and installation of expansion joints on a new bridge may typically be expected to account for only approximately 1% of the total construction cost of the bridge. NCHRP Report 467, for example, records that the total installed cost for two modular expansion joints, each with a movement capacity of 915mm, was US$800,000 or 1.2% of the US$63 million total cost of the Lacey V Murrow floating bridge in Seattle. This is clearly a very small percentage for the parts of a bridge which are arguably subjected to the greatest challenge. The initial cost of supply and installation of the structure's joints is also small in relation to the future costs of maintenance and replacement should the joints perform poorly. Indeed, NCHRP Report 467 goes on to note that the initial cost of supply and installation is 'insignificant' in this context – a view shared by the Transport Road & Research Laboratory in the United Kingdom.

Inspection and maintenance work is an essential part of the proper management of any bridge, and even more so in the case of its expansion joints, which are subjected to greater movements and more dynamic loading than the bridge as a whole. However, NCHRP Synthesis 319 notes that 'some agencies indicated that they tend not to respond to joint problems unless there is a safety hazard or the deck is being rehabilitated or replaced'. A change of mind-set is therefore required of many.

Replacement of expansion joints will almost inevitably be required on any bridge, and the direct cost to the owner or agency can be very significant. With the cost of site mobilisation and traffic management, and the limited progress imposed by the need to keep traffic flowing on the bridge, total cost is likely to be much higher than

the initial supply and installation works. Data from an actual bridge gives an indication of the magnitude of such costs; in 2006, the direct cost to the owner of the replacement of a single nine-gap modular joint on the Anzac Bridge in Sydney, Australia, was conservatively estimated at approximately US$5.3 million. While it is unfair to compare this estimate with the actual cost of initial supply and installation of the somewhat larger joints of the Lacey V Murrow bridge in Seattle, the difference in magnitude between the figures is remarkable. Therefore, in order to minimise the life-cycle costs of expansion joints throughout the lifetime of a bridge, it is necessary to minimise the number of joint replacements required.

The user costs of expansion joints result primarily from the disruption to traffic caused by joint maintenance or replacement works. An indication of their magnitude is also given by data relating to the Anzac Bridge. In addition to the direct costs to the owner, stated above, approximately US$10.6 million of community savings related to traffic disruption, increased travel times, and so on could be realised by avoiding replacement. This emphasises again the importance of minimising the frequency of replacement of its expansion joints.

From the above discussion of the constituent parts of the life-cycle costs of a bridge's expansion joints, it can be concluded that the overall costs can be minimised, and indeed greatly reduced, by the use of suitable joints of high quality and durability, and by appropriate care during installation and attention to inspection and maintenance activities.

To ensure the suitability, durability and quality of the expansion joints selected for use, attention should be paid to a number of issues. Firstly, there is a need for clear specification of the demands which must be satisfied by the joint – such as, for instance, the cumulative movements during the lifetime of the joint (including micro-movements which can occur due to wind or traffic, or the thermal changes that arise when the sun's warmth is temporarily blocked by a cloud). The needs of the preferred joint type must also be evaluated – to ensure, for instance, that the bridge deck is designed to receive the selected joint, with proper access for inspection and maintenance and correctly sized block-outs and bridge gap. The ability of the selected joint, as designed and fabricated by the selected manufacturer, to withstand the loads and movements to which it will be subjected during a long life on a structure, must then be verified. The best verification of this is a strong track record on the part of the expansion joint supplier, with evidence of satisfactory performance of the joint over many years on comparable structures which place similar demands on the joint. Laboratory testing also serves a useful purpose, but the degree to which it can replicate actual service conditions is limited by the need to make testing practical, affordable and possible to complete in a reasonable time frame. Measures which can protect the joint and extend its life, for example the fitting of hydraulic dampers to a bridge deck to reduce fast, erratic movements at its expansion joints, may also be considered, and of course suitable corrosion protection should be ensured.

Recognition of the importance of considering long-term, life-cycle costs must, however, translate into practice in the construction and maintenance of bridges. In spite of the 'insignificant' cost of expansion joint supply in relation to replacement and user costs, supply costs unfortunately still often play a dominant role in the selection process, because a lower-cost, low end product may fulfil short-term needs. It is therefore important that bridge construction contracts are so devised, that the company that chooses the joints and their supplier has a real incentive to ensure their long-term quality and performance.

Life-cycle cost analysis should be considered an imperative for those designing and building bridges, in particular for those who are responsible for the bridge expansion joints ■

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