

Expansion joints for urban bridges – quiet, reliable and low-maintenance

Thomas SPULER

Civil Engineer
Mageba SA
Switzerland
tspuler@mageba.ch

Thomas Spuler, born in 1956, received his civil engineering degree from the Polytechnic of Brugg, Switzerland and is today the General Manager of Mageba. He is a member of the European expert team for Road Bridge Expansion Joints (EOTA), and Vice-President of IABSE's *Working Group 5* on bridge bearings and expansion joints.

Gianni MOOR

Civil Engineer
Mageba SA
Switzerland
gmoor@mageba.ch

Gianni Moor, born in 1968, received his civil engineering degree from the Swiss Institute of Technology in Zurich, Switzerland (ETHZ), and was later awarded an MBA degree by the Business School IESE (Barcelona, Spain). He is currently Deputy General Manager of Mageba SA.

Colm O'SUILLEABHAIN

Civil Engineer
Mageba SA
Switzerland
cosuilleabhain@mageba.ch

Colm O'Suilleabhain, born in 1971, received his civil engineering degree from the University of Dublin, Trinity College in 1993 and qualified as a Chartered Engineer with the Institution of Engineers of Ireland in 2001. He is currently Business Development Manager of Mageba.

Summary

The bridges that a city needs, and in particular its expansion joints, must be designed and fabricated to consider and satisfy a variety of other needs of the city and its inhabitants in addition to providing a simple trafficable route. In an urban setting, issues such as noise, reliability and ease of maintenance take on special significance, due to the increased importance of the structure and sensitivity of adjacent communities to noise, compared with a similar bridge in a rural setting.

Solutions to the challenges facing the suppliers of expansion joints for urban bridges are presented, including descriptions of the various types of "quiet" expansion joint available, and of ways in which existing or new joints can be made quieter. The importance of using high-quality and innovative materials, in particular for sliding components which are particularly susceptible to wear, is discussed. Use of such materials, in expansion joints which have been designed and tested for long life in demanding conditions, will minimise the need for maintenance and replacement work, thus reducing not only the cost of such works but also the effect of traffic disruption on the local population. Other design factors, such as consideration of seismic events, which if neglected could result in a city's lifelines being cut at a time of great need, are also considered.

Keywords: bridges; expansion joints; low-noise; reliable; low-maintenance

1. Introduction

Bridges play a vital role in the life and economy of any city, especially where they create essential links across obstacles such as rivers and canals, as is particularly true in Venice. However they also have potential to impact on the life of the city in negative ways, and therefore must be designed and constructed to minimise such impacts. This is especially true in relation to the expansion joints which facilitate the movements of the bridge while always providing a continuous driving surface, as these components can be the most significant sources of noise from a bridge, and also tend to be more susceptible to damage and wear than the main structure, thus more frequently leading to traffic disruption during repair or replacement works.

2. Expansion joint types which offer particular benefits for urban bridges

The following types of expansion joint are particularly suitable for use on urban bridges, due to their low noise characteristics and high durability:

1. Cantilever finger joints
2. Sliding finger joints
3. Modular expansion joints with noise-reducing surface plates
4. Single gap expansion joints with noise-reducing surface plates

All of these satisfy current requirements relating to durability and noise, with consideration of the relevant and very demanding German and Austrian national standards, and current efforts to develop European Technical Approval Guidelines (ETAG) for bridge expansion joints. These are discussed in sections 2.1 to 2.4 below.

2.1 Cantilever finger joints

The cantilever finger joint, as illustrated in Figures 1 and 2, consists in general of thick steel finger plates which are bolted to steel edge profiles using conventional anchoring. The compact and simple system is assembled from few components and therefore suffers relatively little wear and tear, resulting in minimal maintenance costs.

However traffic forces acting on the cantilever fingers of the joint create relatively high moment loads at the joint's connection points to the main structure. This transfer of forces to the structure requires a strong and well-detailed interface to ensure that damage to the main structure does not result – particularly in the case of joints which allow large longitudinal movements. Furthermore cantilever finger joints permit only limited longitudinal movement capacity relative to other types of joint. Transverse and vertical movements, and rotations, are also very limited.

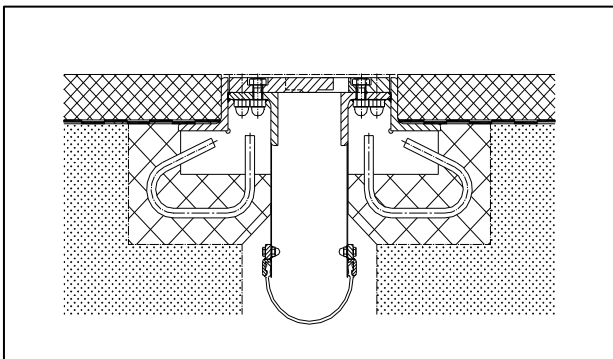


Fig. 1: Cantilever Finger Joint (Tensa[®] Finger Type GF) - cross section



Fig. 2: Cantilever Finger Joint (Tensa[®] Finger Type GF) – as installed

2.2 Sliding finger joints

The sliding finger joint is similar to a cantilever joint, with one key difference: The tips of the fingers which span the bridge gap from one side, receive sliding support from the structure at the other side of the gap. The fingers thus behave statically as simply supported beams rather than cantilevers, allowing them to span greater distances. A sliding finger joint can therefore accommodate much larger longitudinal bridge movements than a cantilever finger joint, and offers the added benefit that the very large moments that arise at the base of a cantilever finger plate do not arise in the case of a sliding finger joint – with correspondingly less potential for damage to the main structure from such forces.

It is important that the free ends of the sliding fingers maintain constant contact with the supporting sliding surface below, to avoid their being subjected to cantilever loading and vibrations, and to ensure that the free ends do not protrude above the driving surface of the road. The finger plates, each approximately 0.5m long, which span the bridge gap are therefore pre-tensioned downwards to ensure that permanent sliding contact is maintained. This pre-tensioning downwards of the finger plates enables the joint to accommodate a certain amount of rotation or vertical movement of one side of the joint relative to the other, for example due to differential settlement or due to movements of the bridge deck which are not parallel to the deck (which may arise, for example, where the bearings beneath a sloped bridge deck are placed horizontally). The flexible and shock-absorbing design of the system also reduces the effect of loading and therefore protects the bridge structure underneath from fatigue-related problems.

In principal, two main kinds of sliding finger joint exist, as described in Sections 2.2.1 and 2.2.2 below.

2.2.1 Sliding finger joint - Steel system

Sliding finger joints, as described above, may be designed in such a way that the pre-tensioning downwards of the sliding fingers is achieved using high-grade stainless steel springs located beneath the cantilever fingers, as illustrated in Figure 3. This variation is particularly flexible, permitting significant vertical movements and rotations about its longitudinal support axis. Furthermore it is very durable due to the almost exclusive use of steel parts. Figure 4 shows an installed example of this “steel system”.

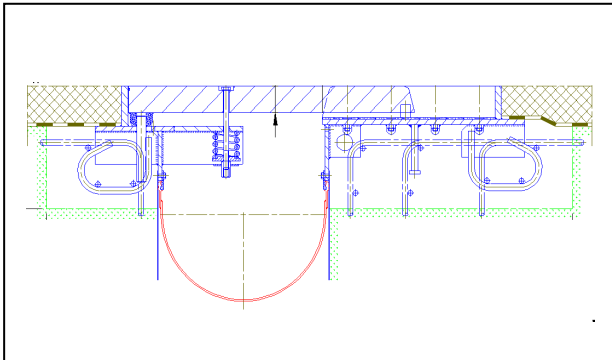
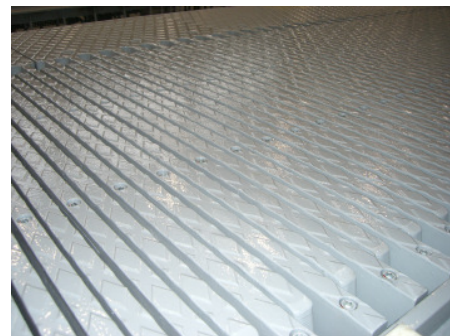


Fig. 3: Sliding finger joint - steel system (Tensa® Finger Type GF) - cross section



Fig. 4: Sliding finger joint - steel system (Tensa® Finger Type GF) - as installed

Case study: John James Audubon Bridge, Louisiana, USA



Sliding finger expansion joints of this type (Tensa® Finger Type GF) believed to be the largest sliding finger joints in the world, have recently been fabricated and delivered for the John James Audubon Bridge over the Mississippi river in Louisiana, which on completion in 2011 will be the longest cable stayed bridge in North America. The expansion joints, designed to accommodate movements of up to 1,240mm, demonstrate that the range of bridge movements for which sliding finger joints can be used is actually somewhat greater than had previously been accepted, opening up new options for bridge designers everywhere. [1]

2.2.2 Sliding finger joint - Metal-elastomeric bonded system

An alternative type of sliding finger joint, the metal-elastomeric bonded system, is illustrated in Figures 5 and 6 below. The pre-tensioning downwards of the sliding fingers results from the elasticity of the composite steel / elastomeric block from which the sliding fingers extend.

A major advantage of this variation is that it is assembled from modular components, allowing easy replacement of sections as required (normally possible in a single night shift). This is a particularly useful feature where only part of an expansion joint may need to be replaced - for example in the lane with heaviest traffic.

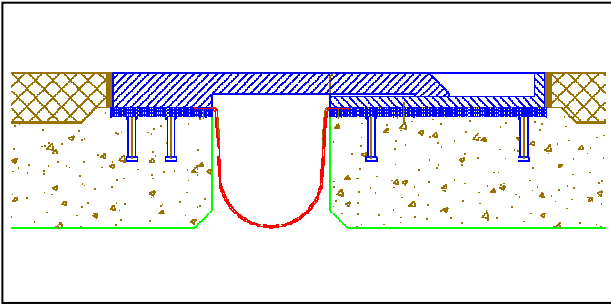


Fig. 5: Sliding finger joint - elastomeric bonded system (Tensa® Flex Type RC)



Fig. 6: Sliding finger joint - elastomeric bonded system (Tensa® Flex Type RC)

Case study: Felsenau Viaduct, Bern, Switzerland



Using an innovative and carefully planned procedure, the existing old modular expansion joints of this very busy highway were replaced with sliding finger joints of the elastomeric bonded type (Tensa® Flex Type RC), with practically no impact on traffic. The modular construction of the joint, with all parts being short and light enough to be lifted into position by two men, enabled the old expansion joint to be removed and the new joint to be placed one traffic lane at a time. Using Mageba's *Mini-Fly-Over* system, which can be installed during the daytime to allow traffic to temporarily pass over the section of joint which has been removed but not yet fully replaced, the joint could be completely installed during a series of night-time and weekend closures of just one lane, even at these quiet times leaving 5 of the highway's 6 lanes open to traffic. [2]

2.3 Modular expansion joints with noise-reducing plates

Modular expansion joints offer many benefits to bridge constructors, especially where large movements or a large degree of flexibility is required to accommodate bridge movements. However, in their standard form, they cannot include "low noise" in the list of advantages they offer over other types of joint. But for instances where noise from an expansion joint would be considered a problem, a solution has been developed which has become increasingly widespread in recent years [3]. Profiled steel plates (so-called "sinus plates" due to their shape) are fixed to the upper surfaces of the expansion joint's lamella and edge beams, creating a driving surface which provides continuous support to the wheels of an over-rolling vehicle. This removes the impact that would normally arise where the wheel has to pass over a gap of up to 80mm. The absence of straight edges perpendicular to the direction of travel further reduces the noise arising at this interface between wheel and expansion joint.

The profiled plates also offer further benefits in addition to reduction of noise. Driver comfort is increased, since impacts when crossing the joint are greatly reduced. The removal of such impacts also serves to minimise fatigue-related problems for the modular joint and the bridge structure from traffic. And due to the bridging effect of the profiled "sinus plates", the gap width between each pair of lamella beams can be increased (from typically 80mm) to 100mm. This means that, for example, a longitudinal movement requirement of 400mm can be facilitated by a joint with 4 gaps of 100mm (fitted with "sinus plates") instead of a joint with 5 gaps of 80mm each. On the other hand, the addition of the sinus plates reduces the joint's flexibility and ability to accommodate certain movements and rotations.

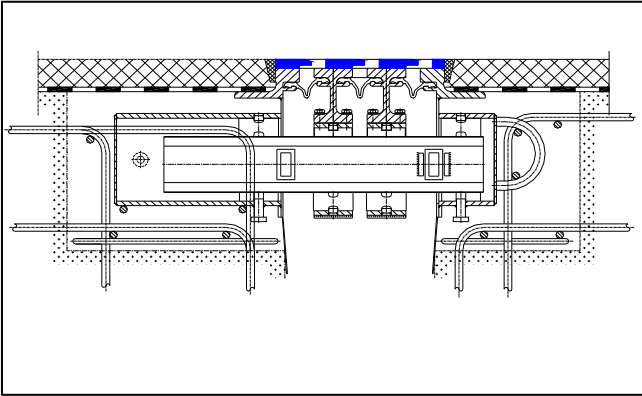


Fig. 7: Modular joint with noise reducing “sinus plates” - cross section

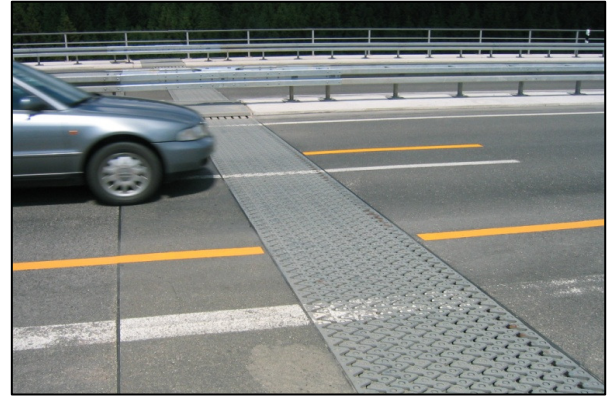


Fig. 8: Modular joint with noise reducing “sinus plates” - in service on a highway

As an option for bridges in seismically active regions, modular expansion joints can be equipped with seismic features to protect the joint and the bridge from serious damage in the event of an earthquake. The *Fuse*[®] *Box* feature ensures that the expansion joint will break free from the structure in a controlled fashion during exceptionally large bridge movements, and can be quickly reconnected. This will enable emergency and evacuation traffic to use the bridge in the immediate aftermath of an earthquake, a vital function if the bridge is a lifeline to an urban area which would otherwise be cut off from the outside world.

Case study: Golden Ears Bridge, British Columbia, Canada



The Golden Ears Bridge, providing an important new transportation link across a major river close to Vancouver, was opened to traffic in Summer 2009, and features *Tensa*[®] *Modular* expansion joints with up to 17 gaps, also featuring *Fuse*[®] *Box* seismic protection. One of these joints is shown in the above picture, during road transportation. The blue and yellow beams above and below the joint constitute a transportation and installation frame, which served on arrival on site to enable the joint to be safely unloaded and installed, with easy adjustment of pre-setting width of the joint to match the actual width of the bridge gap at that time. The pointed *Fuse*[®] *Box* can be seen at the left side of the joint. [4]

2.4 Single gap expansion joints with noise-reducing plates

Single gap joints can also be fitted with noise-reducing “sinus plates” of the type described above, bolted to the top surface of the joint as shown in Figure 9. In addition to greatly reducing noise from traffic, the use of these plates allows the movement capacity of the joint to be increased from 80mm to 100mm, potentially avoiding the need for a costlier alternative. The compact and simple system has no moving parts, therefore suffers little wear and tear, resulting in low maintenance costs.

Such expansion joints can be supplied with various forms of anchorage, which can offer further benefits for their use. One alternative, which uses special quick-drying polymer concrete with excellent strength characteristics, is shown in Figure 10. This version requires much less space and is therefore of particular interest where existing expansion joints are to be replaced with minimal impact on an existing structure and on traffic. Whatever the existing joint type, it is only necessary

to remove the joint to a depth of approximately 60mm (likely to involve no breaking out of concrete and placing of reinforcement) and ensure a clean solid subsurface for the polymer concrete. The polymer concrete cures quickly, allowing the bridge to be re-opened to traffic only 4 to 6 hours after completion of installation and thus reducing impact on traffic to a minimum.



Fig. 9: Single gap expansion joint with noise-reducing “sinus plates”

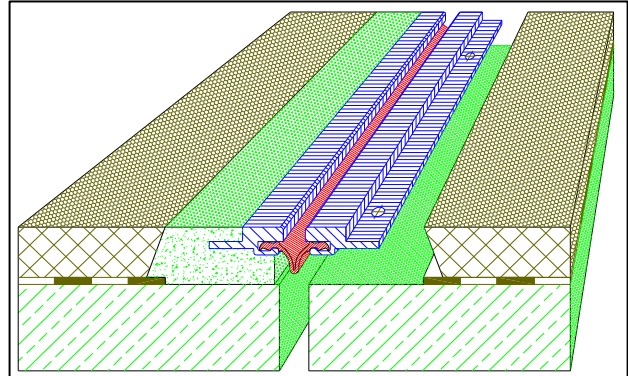


Fig. 10: Single gap joint (Tensa[®] Crete RE-LS) with Robo[®] Flex polymer concrete anchorage (shown here without “sinus plates” for clarity)

3. Additional or alternative noise reduction possibilities

Additional or alternative methods of reducing noise at an expansion joint, which are independent of the joint itself, are also available. Two of these are described below.

3.1 Noise insulating membranes placed below the expansion joint

Noise insulating membranes can be placed directly below an existing or new expansion joint, to absorb the noise energy emitting from the expansion joint under traffic. The system shown in Figure 11 consists of a noise-reducing membrane under the full length of the joint, longitudinal connection rails for this membrane at each side of the bridge gap, and noise-reducing panels at the ends of the joint. This complete system fully encloses the area beneath a joint, in which airborne sound is reflected, damped and absorbed to reduce transmission to the surrounding environment.

3.2 Reinforcement of asphalt

It is possible and recommended to reinforce the asphalt adjacent to an expansion joint, for example by means of reinforcing ribs as shown in Figure 12. These are created by forming vertical cuts at a 45° angle to the edge profile of the joint, and filling these with high strength epoxy mortar. This strengthening reduces the deformation caused by traffic at this interface, thus reducing the noisy impacts that can occur, especially when empty container trucks drive over the joint.



Fig. 11: Robo[®] Silent noise insulation beneath an expansion joint (fully installed)



Fig. 12: Robo[®] Dur reinforcing ribs in asphalt adjacent to an expansion joint

The removal of such local depressions in the carriageway surface brings the added benefit of enhanced driver comfort, and also increases the service life of the expansion joint and the adjoining asphalt.

4. Planning for minimal maintenance works on expansion joints

In order for an expansion joint to be considered truly suitable for use on an urban bridge, it is important that the issue of disruption to traffic during necessary maintenance and replacement works be carefully assessed. Due to its location in the driving surface of the bridge, any such works have the potential to impact significantly on traffic, which results in frustration for commuters and real economic costs to the city it serves. Ideally, of course, an expansion joint should require no maintenance or replacement during the entire life of the bridge, but this can generally not be expected of an expansion joint which is, compared to the main bridge structure, much lighter and less robust, and often a mechanical structure with moving parts which are subject to fatigue and wear.



Fig. 13: Testing of Tensa® Finger Type RSFD cantilever finger joint, with two million load cycles

Cantilever finger joints and single gap joints with noise-reducing “sinus plates” (sections 2.1 and 2.4 above, respectively) have the advantage for long term performance that they have no moving parts, but the range of movements which can be facilitated by such joints is limited and therefore their use may not always be practical. However the long-term performance of even these joint types is strongly dependant on many factors such as detailed design, selection of materials, and fabrication processes, therefore only a joint which has been thoroughly tested, in the laboratory and in service, can realistically be expected to offer reliable and maintenance-free service for many years. The above mentioned joints (*Tensa® Finger Type RSFD* cantilever finger joint, and *Tensa® Grip RS* and *Tensa® Crete RE* single gap joints with noise-reducing “sinus plates”) have each passed

laboratory dynamic fatigue testing with at least 2 million load cycles of minimum 140 KN, as shown in Figure 13 for the case of the cantilever finger joint. Each type has also proven its value over many years on numerous bridges across Europe and further afield.

Careful detailing and selection of materials, finely controlled fabrication processes, and extensive testing are even more important for an expansion joint (such as a modular or sliding finger joint) that contains moving parts and thus acts as a mechanical unit. Typical testing is shown in Figures 14 and 15. Such joint types typically contain sliding surfaces which are particularly susceptible to wear and tear, so the use of a specially developed sliding material may be important for expansion joints which will be subjected to very large or frequent movements. The commonly used PTFE sliding material is adequate for most cases, but a much improved alternative (*Robo® Slide*, a UHMWPE) is now available, offering much greater resistance to wear and much higher bearing resistance than PTFE. This can be used, for example, in the sliding springs and sliding bearings of a modular expansion joint to dramatically increase the life expectancy of these components.

Such selection of the required expansion joint will help minimise the frequency at which maintenance and repair works will be carried out, and perhaps more significantly, how soon the expansion joint will need to be replaced in its entirety. This will therefore play an important role in ensuring that the disruption to traffic resulting from repair and replacement works during the life of the bridge will be kept to a minimum, which is an important consideration for any bridge in an urban environment.



Fig. 14: Laboratory testing of a Tensa® Modular expansion joint – an Opening Movement Vibration (OMV) Test



Fig. 15: Laboratory testing of a Tensa® Flex RC sliding finger expansion joint – with 2 million load cycles of 128 KN each

However it is also important to consider, in the design of the bridge on which the expansion joint will be installed, that the joint will require adequate access at regular intervals during its life for inspections, maintenance, and possibly replacement of wear parts. Wherever possible, permanent access beneath larger expansion joints such as finger and modular joints should be provided, as experience has shown that inadequate access often results in inadequate inspections and maintenance. Experience also shows that minor deficiencies, such as slight damage to corrosion protection or wear of a small number of sliding components, can with time develop into a much greater and costlier problem if not detected and addressed at an early stage in the course of regular inspections.

5. Conclusions

Bridge constructors make a vital contribution to the life of any city, in particular one which is divided or cut off from neighbouring regions by natural features such as rivers, canals, sea inlets or valleys. Attractive as such natural features are, they present a demand for bridges which supplements that from the intersections of the many road and railway routes that criss-cross any urban area.

The careful selection of the components used to build these bridges, and in particular the expansion joints that span the movement gaps at their ends, plays an important role in ensuring that the bridges will always serve their critical function, with interruptions for maintenance and replacement works kept to a minimum. Expansion joint solutions, which have been developed in recent decades to use modern highly advanced materials and extensively tested in laboratories and proven in service, are now available which can enable bridge constructors to discharge their responsibility to the cities they serve better than ever before.

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