Expansion joints with low noise emission

T.Spuler, G.Moor & C.O'Suilleabhain
Mageba SA, Bülach, Switzerland

ABSTRACT: Expansion joints can be a significant source of noise, if not carefully selected and correctly installed. New technologies to address this issue are therefore likely to increase in demand. This paper explores the different types of "quiet" expansion joints available, and new technologies which can transform an otherwise noisy expansion joint into a much quieter one.

1 INTRODUCTION

Noise generated by traffic is becoming an increasingly important consideration in the planning and construction of transportation routes, as populations and cities grow, with more transportation routes required and more housing constructed close to these routes. At the same time, urban populations exhibit ever-decreasing tolerance for noise from these transportation routes. Therefore the demand for "quiet" expansion joints is likely to continue to increase in the coming years.

2 OVERVIEW OF QUIET EXPANSION JOINT TYPES

The following types of expansion joint satisfy current requirements relating to durability and noise, with consideration of the relevant German and Austrian national standards, and current efforts to develop European Technical Approval Guidelines (ETAG) for bridge expansion joints.

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

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 a steel edge profile using conventional anchoring. The compact and simple system is assembled from few components and therefore suffers relatively little wear and tear, resulting in lower initial and maintenance costs.

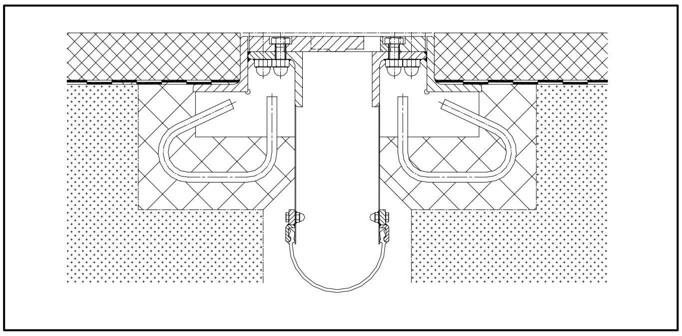

Figure 1: Cantilever finger joint – Cross-section

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.

Figure 2: Cantilever finger joint – As installed

Cantilever finger joints permit only limited longitudinal movement capacity relative to other types of joint which use simply supported rather than cantilever designs. Transverse and vertical movements, and rotations, are also very limited.

	Cantilever finger joints - Main advantages and disadvantages
+	Relatively low initial cost
+	Compact design with few components
+	Reduced wear and tear due to fewer impact interfaces and no moving parts, resulting in low maintenance costs
-	Limited longitudinal movements (300 – 400mm), and limited transverse and vertical movements and rotations
-	Moment loading on the substructure may be significant (depending on the longitudinal movement capacity)

2.2 *Sliding finger joints*

The sliding finger joint is an asymmetric construction consisting of complementary “male” and “female” parts. The female part consists of a steel plate with fingers welded on top, which is fixed at one side of the expansion gap. The male part is an opposing plate with cantilever fingers which is fixed at the other side of the gap. As the bridge deck expands and contracts, the fingers of the male part slide longitudinally between the fingers of the female part, always maintaining contact with (and receiving support from) the base plate of the female part below. Sliding finger joints can therefore facilitate relatively large expansion and contraction movements (in excess of 1,000mm).

The male finger plate of a sliding finger joint is pre-tensioned downwards and its cantilever fingers therefore remain in permanent contact with the opposing sliding surface below. Thus rotation of the joint, for example due to settlement of an abutment, can be facilitated, and the fingers of the joint will not spring up, even under heavy over-rolling traffic. The steel fingers which span the expansion gap act as simply supported beams (in other words, there is no cantilever effect), which enables relatively simple anchoring of the joint. 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.

The problem of cantilevered finger plates protruding above the carriageway surface (for example, due to settlement of the abutment) is greatly reduced with this type of joint, resulting in much reduced risk to traffic from protruding fingers. Furthermore it is possible to install sliding finger joints if the bridge has a longitudinal slope and the sliding bearings of the bridge are installed horizontally. The pre-tensioning of the fingers will ensure that they remain in contact with the structure below and do not protrude above the driving surface, even if the movement of the bridge bearing is horizontal, and therefore not parallel to the surface of the expansion joint.

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 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”.

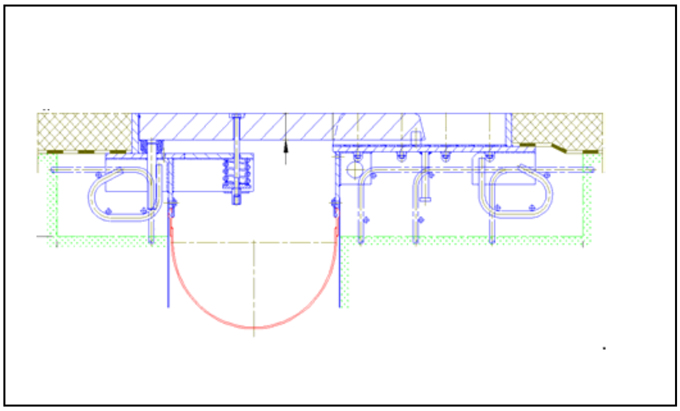

Figure 3: Sliding finger joint (Steel system) – Cross-section

Figure 4: Sliding finger joint (Steel system) – As installed

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.

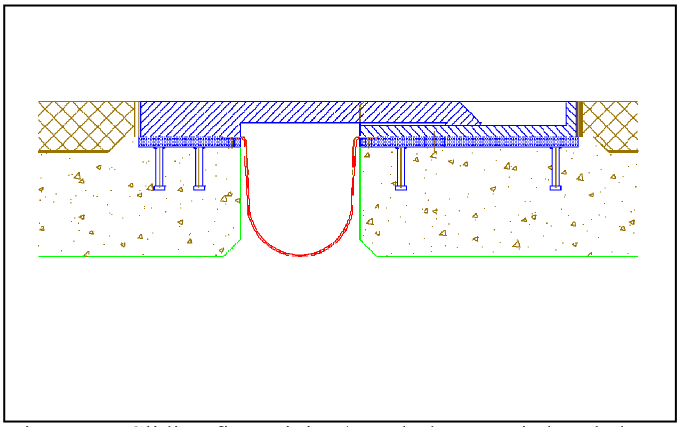

Figure 5: Sliding finger joint (metal-elastomeric bonded system) - Cross-section

Figure 6: Sliding finger joint (metal-elastomeric bonded system) – As installed

Sliding finger joints - Main advantages and disadvantages	
+	Simple, durable, low-maintenance system
+	Simply supported arrangement permits rotational (φ_y) and vertical movements (e_z)
+	Simply supported arrangement also protects the main structure from large moments
+	Easy replacement of finger plates possible, even over night
–	Very limited transverse movement possible
–	Not particularly suited to cycle traffic
–	Initial costs higher than cantilever finger

2.3 *Modular expansion joints with noise reducing plates*

Recent times have seen major developments which allow a normal modular or single gap expansion joint to be transformed into a "quiet" one. A system which is already gaining widespread acceptance is shown in Figures 7 and 8. Profiled steel plates (so-called "sinus plates" due to their shape) are fixed to the upper surfaces of the expansion joint's lamella or edge beams, creating a 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 also reduces the noise arising at this interface between wheel and expansion joint.

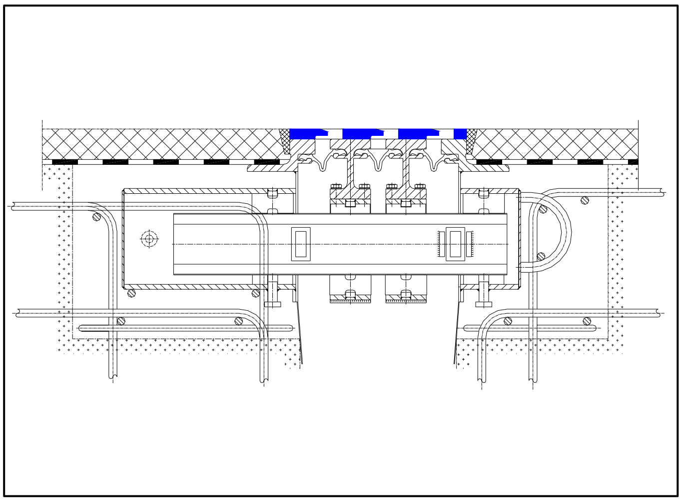

Figure 7: Modular joint with noise reduction – Cross-section

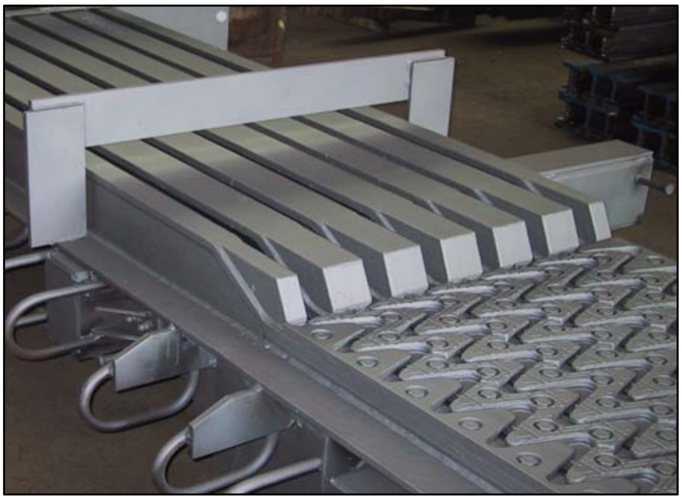

Figure 8: Modular joint with noise reduction – As fabricated

The profiled plates also offer further benefits. Driver comfort is increased, since impacts when crossing the joint are greatly reduced. The removal of such impacts also serves to protect the modular joint and the bridge structure from fatigue-related problems.

The additional costs for the noise reduction of a modular joint are about 40% of the costs of a normal modular joint. However, due to the bridging effect of the profiled “sinus plates”, the gap width between the lamella beams can be increased 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 the “sinus plates”) instead of a joint with 5 gaps of 80mm each. Therefore the cost for a joint with noise reduction may only be about 20% higher than the cost of a conventional modular joint with the same overall movement capacity.

Since the drainage channels of modular expansion joints are at the surface (between the individual lamella beams), they are more easily cleaned than other joints such as finger joints, which have the drainage channel located below the surface.

Existing modular expansion joints can also generally be fitted with noise reducing plates, although this typically requires the adjacent carriageway surface to be raised by about 20mm.

Modular joints with noise reducing plates - Main advantages and disadvantages	
+	Movements and rotations are possible in all directions and about all main axes
+	Very large longitudinal movements possible (in excess of 2,000mm)
+	Very good over-rolling comfort and safety, also for bicycle traffic
−	Relatively high initial costs
−	Complex system, therefore it is necessary to select suppliers that offer a very high standard of technical ability and quality

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 for modular joints. These are bolted to the top surface of the steel edge profiles of the joint as illustrated in Figure 9. The addition of these plates, which bridge over the gap of the joint, allows the movement capacity of the single gap joint to be increased from 80mm to 100mm, potentially avoiding the need for a costlier alternative.

The compact and simple system has few components and no moving parts, therefore suffers little wear and tear, resulting in low maintenance costs. However this system is limited in its ability to facilitate rotations or transverse and vertical movements.

Figure 9: Single gap joint with noise reduction – as fabricated

Single gap joints with noise reducing plates - Main advantages and disadvantages	
+	Very good over-rolling comfort and safety, also for bikes and motor bikes
+	Compact construction with few components, little wear and tear
+	Low initial and maintenance costs
−	Limited transverse movements and rotations possible

3 COMPARISON OF DIFFERENT EXPANSION JOINT TYPES

The graph in Figure 10 shows that for each of the expansion joint types discussed above, the difference in noise level between the roadway and expansion joint is less than about 3 dB, and therefore all are very well suited to reduce the noise emitted from the expansion joint.

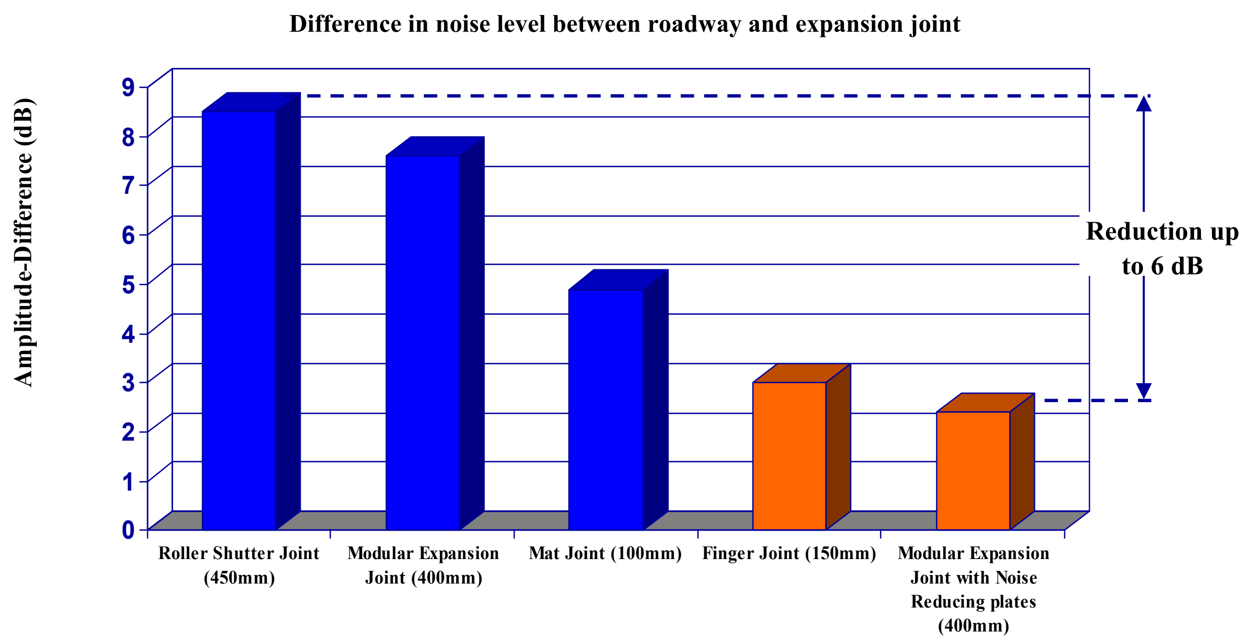

Figure 10: Comparison of noise-reducing capabilities of different types of expansion joint

Table 1 offers a summary of the advantages and disadvantages of the different types of “quiet” expansion joints. Advantages are indicated by “+”, disadvantages by “-“, and the number of each provides emphasis.

Table 1: Comparison of main features of different types of ”quiet” expansion joint

	Cantilever finger joints	Sliding finger joints	Modular expansion joints with noise reduction	Single gap expansion joints with noise reduction
Initial costs	++	+	-	+++
Maintenance costs	++	+	+	+++
Permitted movements and rotations	-	+	+++	-
Possible longitudinal movement	+	++	+++	-
Comfort and safety for vehicles	+++	+++	+++	+++
Comfort and safety for cyclists	-	-	+++	+++
Drainage	-	-	++	++
Number of components	+++	+	-	+++

From this comparison it can be seen that each type of “quiet” expansion joint has its own advantages. Where cost is the main concern, and only limited movements are required, a single gap expansion joint with noise reducing plates may be recommended. Where greater movements and rotations must be facilitated, a modular joint with noise reducing plates may be the solution. Both types of joint with noise reducing plates are suitable for cycle traffic. For longitudinal movements greater than those permitted by a single gap joint, but where only limited rotations and vertical movements must be facilitated, a cantilever finger joint is less costly than a modular expansion joint with noise reducing plates. And where the movements facilitated by a cantilever finger joint are not sufficient, a sliding finger joint may be specified.

4 ADDITIONAL OR ALTERNATIVE FORMS OF NOISE REDUCTION

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

4.1 *Reinforcement of asphalt*

It is possible and also recommended to reinforce the asphalt adjacent to an expansion joint. This can be achieved by means of reinforcing bands of polymer concrete, as illustrated in Figure 11, Alternatively, reinforcing ribs, as illustrated in Figure 12, can be applied, 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.

Both systems strengthen the asphalt next to the joint, reducing the deformation caused by traffic at this interface between asphalt and steel structure. This results in a smoother, leveller surface for traffic to drive on, without the noisy impact caused by local depressions in the surface.

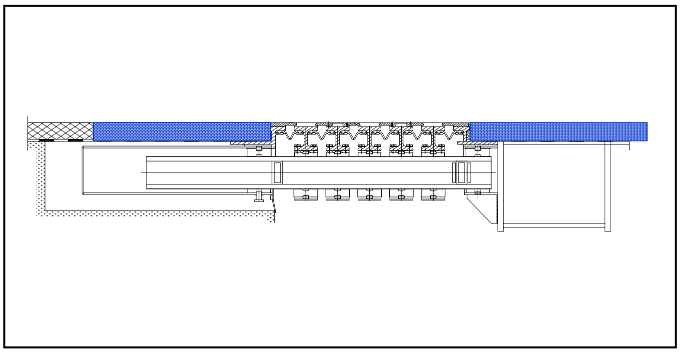

Figure 11: Reinforcing bands in asphalt

Figure 12: Reinforcing ribs in asphalt

4.2 *Noise insulating mats placed below the expansion joint*

Noise absorbing mats can be placed directly below an existing or new expansion joint, to absorb the noise energy emitting from the expansion joint under over-rolling traffic. This is particularly effective if the abutment or the bridge deck resonate to the noise from the joint.

5 PROSPECTS FOR FUTURE USE OF "QUIET" EXPANSION JOINTS

Cantilever finger joints have proven their worth over several decades in many countries, and the market for this type of joint appears to be very stable. The greatest growth in demand currently in many countries is for modular expansion joints with noise reducing plates. In Germany, for example, more and more modular joints are being specified with a requirement for noise reducing plates – currently this applies to about 60% of all bridges on highway routes, and it can be expected that in the near future noise reducing steel plates will be required as a feature on nearly all new expansion joints in Germany. Such systems are also growing in popularity in many other countries, particularly in Europe and Asia.

For single gap expansion joints it is expected that the market will also continue to grow strongly, as a very high percentage of bridges require expansion joints with longitudinal movements of less than 100mm. An increasing number of these bridges will require noise reducing plates to be added to the joint as noise continues to increase in significance in the selection and remediation of expansion joints.

6 CONCLUSIONS

The authors believe that the market for expansion joints with noise reduction will continue to grow strongly in the future. This growth will be fuelled by modern society's requirement for ever more housing adjacent to transportation arteries, and decreasing tolerance of the noise generated by these arteries. It is believed that the growth in the market for modular and single gap expansion joints with noise reducing profiled plates which provide a continuous driving surface will be particularly strong. The benefits of "quiet" expansion types compare well to those offered by alternative solutions of noise reduction such as noise protection walls – the "quiet" expansion joint solutions are relatively inexpensive and offer various additional benefits such as increased driver comfort and protection of the bridge structure. These factors will also serve to ensure that "quiet" expansion joints have a promising future.

7 REFERENCES

1 Bundesanstalt für Strassenwesen, TL/TP FÜ (Version 03/05)

2 Interakustik GmbH, Noise measurement of expansion joint, Viaduct Albrechtsgraben, November 2003

3 Assessment of expansion joint noise, Müller-BBM (independent consultant), February 1999