Single gap expansion joints – an optimal solution for small deck movements

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Summary

Small movement expansion joints are probably the most important type for most road and bridge authorities due to the dominance of short span bridges in their area of responsibility. Considering the key issues of durability and reliability, robust single gap joints have a great deal to offer and should always be considered for use. Variations on the standard, most commonly used version are available to satisfy specific demands – for example, to minimise installation time and disruption to traffic when installed as a replacement for an old joint. They can also be equipped with surface plates if desired to reduce noise and vibrations under traffic. The factors which should be considered in selecting such an expansion joint for use are presented, along with some well-proven solutions. Armed with this knowledge, bridge owners and engineers will be better able to make informed decisions when selecting and using small movement joints in their structures.

Keywords: Bridge, expansion joint, small movement, installation, replacement, durability, low noise

1. Introduction

Every public authority with responsibility for roads and bridges is likely to have a regular need for expansion joints for movements of 100 mm or less. This is due to the simple fact that the majority of bridges have short spans, and their decks therefore do not experience large changes in length due to temperature changes etc. Although small movement joints tend to be less complex than larger ones, their design and selection should not be taken lightly. It is important that the responsible engineers consider the impact of their selection of joint type, and are aware of the different features and benefits offered by various types, as described below.

Fig. 1: Small movement expansion joint (single gap joint with noise-reducing surface plates)

2. Key issues to be considered when selecting joint type

The issues which should be considered when selecting an expansion joint depend on the bridge structure, its location and users, and its owner's practices and preferences in relation to installation, inspection and maintenance. Other factors, such as whether the joint is to be installed in a new structure or as a replacement for an existing one, can also be very significant. The following points should be considered and are important in the majority of cases.

2.1 Ability to accommodate all structural movements

This is the most basic requirement, and typically the first one to consider. The chosen joint type must be able to facilitate all movements (not only longitudinal, but also transverse and vertical) and rotations (about all 3 principal axes). It must do so without allowing constraint forces to arise which could result in damage to the joint or to the main bridge structure.

2.2 Watertightness

The ability of an expansion joint to sustainably prevent leakage of surface water to the structure beneath is another critically important factor. Synthesis 319 [1] of the American National Cooperative Highway Research Program, for example, concludes that "it is important to minimize ... leakage (through expansion joints) to avoid serious damage to the bridge structural support system".

2.3 Strength and durability

A joint's design should maximise durability and reliability, to minimise maintenance and repair effort and to ensure a long service life. An ability to withstand unexpected loading and conditions, and to resist a level of corrosion that would impact on the joint's performance, are also important.

2.4 Simplicity

All else being equal, simpler is generally better and more likely to result in high quality, and for small movement joints there is no need for complication. A simple design will minimise failure mechanisms that may result in danger to traffic, avoid installation problems, and facilitate inspection, maintenance, repair and replacement activities.

2.5 Impacts on traffic and on the structure when installed to replace an existing joint

Being relatively light, mechanical components, a bridge's expansion joints will almost certainly have to be rehabilitated or replaced several times during the course of the bridge's life. The type of joint to be used warrants careful consideration due to the numerous impacts of poor selection. Disruption to traffic on the structure during the works should be minimised, as should the amount of deck structure which must be broken out – to reduce construction effort and time, to optimise use of materials and equipment, and to avoid unnecessary weakening of an otherwise sound structure.

2.6 Noise under traffic and driver comfort

Expansion joints should provide an acceptable riding surface and be reasonably quiet and vibration free. While noise and vibrations may be given only minor consideration in the case of many small movement joints, the importance depends strongly on the bridge's location and users.

2.7 Financial costs

Of course, financial costs to the owner are generally at the forefront of any decision-making process, but care must be taken not to attribute too much weight to this factor. Although costs should in general be minimised, it is important that <u>all</u> costs are considered - initial and long-term, direct and indirect, financial and non-financial. Very often, only the initial financial costs of supply and installation are considered seriously, but these are likely to be far less than future maintenance and replacement costs. In fact, in its 1984 report "Performance in Service of Bridge Deck Expansion Joints" [2], the Transport Road and Research Laboratory (TRRL) in the United Kingdom concluded that initial costs are "insignificant" when compared with the cost of maintenance, especially when user costs resulting from closure are included.

3. An optimal solution for small movements: Single gap joints

For longitudinal deck movements of up to 80 mm (or 100 mm in some cases as described below), the above demands can often be optimally achieved by the use of a single gap joint, such as that shown in Figure 2. An alternative type of small movement joint is shown for comparison in Figure 3. A single gap joint typically consists entirely of robust steel profiles, securely anchored to the bridge at each side of the movement gap, and an elastomeric sealing profile between them. Two types of single gap joint are presented in Sections 3.1 and 3.2 below – each with its own features and benefits which may be of particular interest depending on circumstances. These joints maximise the use of pure steel for strength and durability, without any moving or sliding parts. The strip seal between the steel profiles is more prone to damage but its use is unavoidable, so its suitability must be carefully assessed and its reliability verified – as described in Section 3.3.

Fig. 2: A typical single gap joint, consisting of well-anchored steel edge profiles connected by an elastomeric strip seal

Fig. 3: Alternative types of small movement joint typically offer considerably less strength, durability, reliability and watertightness

3.1 Single gap joints with standard loop anchorages in normal concrete

Where space in the bridge structure is not limited – for example, because the structure is being constructed new and the recesses to receive the joint can be freely dimensioned as desired – standard anchorages and normal concrete can be readily used. The design of a typical well-proven example, for use in asphalted bridge decks, is shown in Figures 4 and 5. The steel edge profiles feature horizontal flanges for the connection of bridge deck waterproofing membranes, as can be seen in Figure 4. For fully concreted bridge decks, without asphalt or waterproofing membrane, a lighter alternative featuring anchor studs instead of anchor loops can be used (see Figure 6).

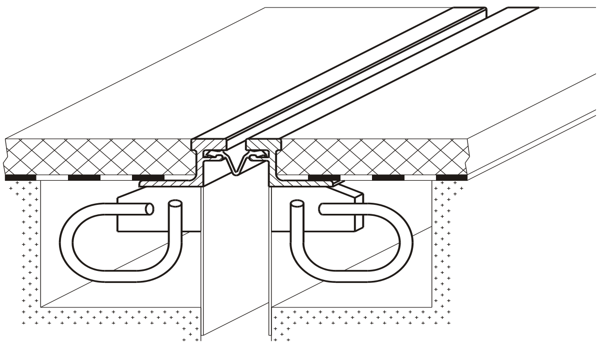

Fig. 4: Single gap joint with standard loop anchorages in normal concrete and asphalted road surface – cross-section

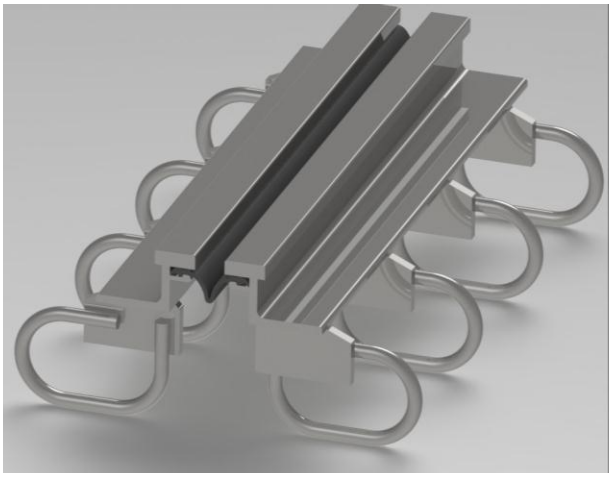

Fig. 5: Single gap joint with standard loop anchorages in normal concrete, for asphalted road surface

These joints can be fitted with various types of elastomeric profile (refer Section 3.3), such as the standard seal in Figure 12 which typically accommodates longitudinal movements of up to 80 mm, or the hump seal in Figure 13 which can allow 100 mm of movement. Alternative versions for special cases can allow up to 200 mm of movement – or simultaneous large longitudinal and transverse movements.

Such joints are well able to fulfil the requirements outlined in Section 2 in the majority of cases for which small movement joints are required: they can facilitate significant transverse and vertical movements; their uncomplicated designs offer excellent strength, durability and watertightness; and they can be fitted with surface plates as described in Section 3.4 to minimise noise under traffic and enhance driver comfort.

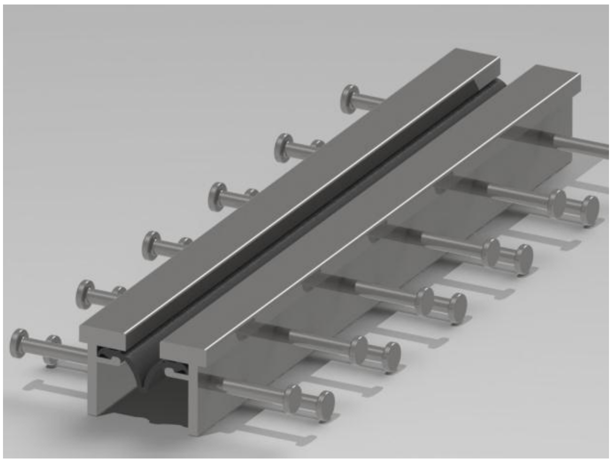

Fig. 6: Single gap joint with stud anchorages in normal concrete, for concreted road surface

3.2 Single gap joints with reduced steel profiles anchored in polymer concrete

An alternative design of single gap joint, which minimises the amount of break-out required when it is installed as a replacement for an old joint, is illustrated in Figure 7. This variety offers benefits which may be of great significance in certain circumstances. The steel edge profiles of the joint are anchored in high-strength polymer concrete, which is strong enough to secure the edge profiles of the joint to a suitably prepared concrete substructure without reinforcement. This enables their dimensions, and in particular their depth, to be greatly reduced – so much so, in fact, that this type of joint can typically be installed within the depth of a bridge’s asphalt surfacing.

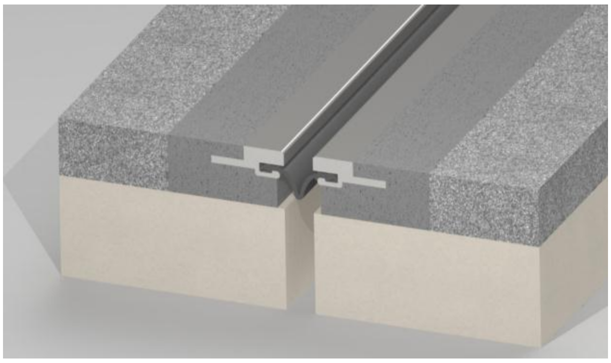

Fig. 7: Single gap joint with anchorage in high-strength polymer concrete

This means that considerably less of the existing structure needs to be broken out, resulting in less construction effort, less wastage of materials and less noise. Indeed, breaking out of more than the surfacing may be highly undesirable or impossible in certain cases, for instance where a girder is in the way or where the steel bars of reinforced concrete would need to be cut, weakening the structure. Whatever the existing joint type, it is only necessary to remove the joint to a depth of approximately 60 - 80mm (likely to involve no breaking out of concrete or placing of reinforcement) and ensure a clean, solid subsurface to which the polymer concrete can bond (see Figure 8).

Fig. 8: The anchorage in polymer concrete minimises break-out – often requiring only removal of the old joint and asphalt surfacing

Fig. 9: Use of a joint requiring anchorage in normal concrete is far less convenient when installed to replace an existing joint

The strength of this type of joint has been proven in laboratory testing – not simply in the basic arrangement shown above, but in the far more demanding arrangement that includes noise-reducing surface plates as described in Section 3.4 below. Fatigue testing of this adapted joint type, which in effect constitutes a cantilever finger joint, is specified by the demanding Austrian standard RVS 15.45 [3]. Having withstood 2 million load cycles at the specified loading level (with downward and upward forces of 31.6 kN and -9.5 kN respectively), the downward forces were increased incrementally to achieve failure; only after a total of 2.44 million load cycles, with the downward force increased to 110.6 kN, or 3.5 times the specified value, was failure finally reached.

In addition to being much stronger than regular concrete, the polymer concrete used also cures very quickly, gaining the strength needed to support traffic loading within a matter of hours (typically 4 to 6 hours, depending on temperature and humidity). As a result of these advantages, the use of this type of joint will not only reduce the construction effort and time requirements, but will also reduce to a minimum the impact on traffic using the structure while the works are carried out.

This joint can be fitted with the same range of sealing profiles as the type described in Section 3.1. And it is equally well able to fulfil the requirements outlined in Section 2 with respect to movements, strength etc, with a simplicity of design that helps ensure high-quality installation. It too can be fitted with surface plates (refer Section 3.4) if desired to reduce noise and enhance driver comfort, and – of particular interest in many cases – it minimises impacts on traffic and on the structure when installed to replace an existing joint. Such expansion joints can thus play an important role in the rehabilitation of many of the countless bridges around the world which require renewal of small movement expansion joints.

Fig. 10: Single gap joints with anchorage in polymer concrete can be installed diagonally and detailed with horizontal or vertical bends

3.3 The elastomeric strip seal – the weakest link in any single gap joint

A typical standard "v-shaped" seal is shown in Figures 4, 7 and 11. The correct performance of the seal results from the precise dimensioning of the extruded elastomer. The secure and watertight connection to the steel edge profiles is ensured by five contact points (see Figure 13), precisely matching the shape of the recesses in the steel profiles. This design, without any mechanical fixings, enables the sealing element to be replaced with relatively little effort should the need ever arise.

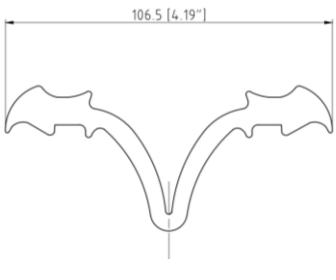

Fig. 11: Cross-section of a typical "v-shaped" strip seal

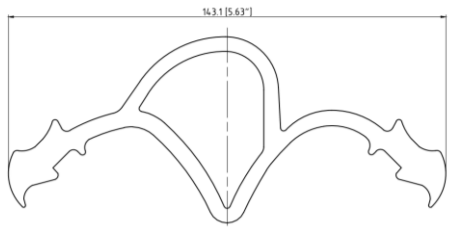

Fig. 12: A "hump seal", similar to the v-shaped seal but featuring an addition hump

A so-called "hump seal", which is the same in most respects but features an additional hump, is shown in Figure 12. The hump is asymmetric and designed to maintain its height as the joint opens and closes, ensuring its effectiveness while never protruding above the driving surface. The hump keeps the joint gap free of dirt and debris, pushing such material up and out each time the joint closes. In addition to providing this self-cleaning service, the hump increases the resistance of the joint to leaks which can result from piercing of the rubber, by providing a second line of defence against such damage. And finally, it fills out the gap, reducing noise under traffic and the difficulties that might be experienced by pedestrians, for example with high heels, as they cross the joint.

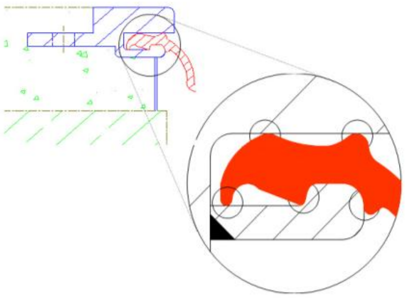

Fig. 13: The end detail of the sealing profile, which ensures a strong, reliable connection and lasting watertightness

Fig. 14: A hump seal fills out the gap, keeping it clean, reducing noise under traffic and increasing pedestrian comfort

As noted above, the elastomeric seal is the part of a single gap joint which is most susceptible to damage or loss of performance (all other parts being solid steel). Two laboratory tests which can be used to verify reliability and performance are described below.

- The *Seal Push-Out (SPO) test* ([4]), in accordance with AASHTO LRFD Bridge Design Specifications [5], subjects the seal to loading which simulates that which might arise under traffic should the seal become packed with dirt and debris. This test is carried out after completion of an *Opening Movement Vibration (OMV) test*, in accordance with the same standard, which simulates the daily thermal opening and closing movements, and the vibrations from traffic, of a 75-year service life – and thus tests the strength of the seal and its connections to the steel profiles in a somewhat "weakened" state.
- The watertightness of sealing profiles, again following deformations which introduce an element of durability to the test, can be verified in accordance with the German standard TL/TP FÜ [6]. This involves testing of watertightness after a period of stressing by 20% more than design movements in both the longitudinal and transverse directions.

Through successful testing in accordance with such standards, it can be shown that the "weakest link" in the single gap joint of any particular manufacturer is anything but weak.

3.4 Optional surface plates

Single gap joints of either type described above can be fitted with surface plates such as the "sinus plates" shown in Figures 1 and 15 – so-called because of their shape which resembles a sinusoidal wave. These consist of profiled steel plates which are connected, by bolting or welding, to the top surface of the joint. Bolted connections offer better fatigue performance, and allow the sinus plates to be easily removed and replaced should the need ever arise - for example, if the elastomeric sealing profile beneath ever needs to be replaced.

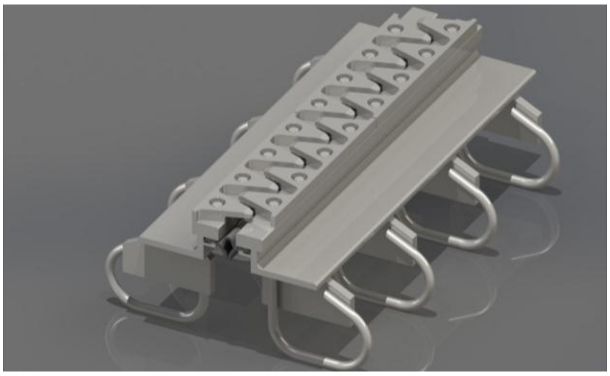

Fig. 15: Single gap joint with surface plates

These plates create a continuous driving surface for a vehicle's wheels, preventing the impacts which would result from crossing an otherwise continuous gap and striking a straight edge. As a result, the fitting of such surface plates offers several advantages, as described by Spuler et al [7]:

- noise from over-passing vehicles is greatly reduced, by up to 80%. This can be very important on a bridge in a residential area, where noise from traffic crossing expansion joints can be a source of considerable disturbance, particularly at night;
- the practical elimination of vibrations protects the expansion joint, the main structure and the vehicles that pass over the joint from fatigue loading and accelerated failure;
- the creation of a smooth driving surface also increases the comfort of all road users, including drivers and other vehicle occupants, cyclists, motorcyclists and pedestrians; and

- due to their bridging effect across the gap, the use of these plates also allows the movement capacity of the joint to be increased from (typically) 80 mm to 100 mm, potentially avoiding the need for a costlier or less convenient alternative for these higher movements.

Retrofitting of surface plates to an installed expansion joint, although possible in some cases, presents challenges. For example, the steel edge profiles of the joint may be weakened (by the drilling of holes or welding) when they would in fact need to be strengthened (to accommodate the new moment loading which will arise). And the driving surface of the bridge would have to be tapered back over a considerable distance at each side, to raise its level by the thickness of the surface plates (approximately 20 mm) without reducing driver comfort. Therefore it is better to carefully consider whether surface plates are likely to be needed, at any time in the future, before the joints are initially fabricated and installed.

Fig. 16: A single gap joint (of type anchored in polymer concrete) featuring sinus plates

However, it should be noted that the equipping of surface plates to an expansion joint can limit the joints flexibility, by reducing its ability to facilitate transverse and vertical movements. The joint's primary function of accommodating specified movements should, of course, not be compromised.

4. Conclusions

Small movement expansion joints are likely to be required by the majority of the bridge structures managed by any authority with responsibility for roads and bridges. Considering all factors which should be taken into account when selecting and detailing a small movement joint, it might be concluded that single gap joints, consisting of robust steel edge profiles and a durable elastomeric strip seal, very often offer an optimal solution. Varieties of the types described in this paper can be designed to satisfy any requirements that are likely to arise, including where an existing joint has to be replaced with minimum impact on the structure and on traffic, and where noise and vibrations from the new joint are to be minimised (see Appendix). Careful consideration of these issues when choosing expansion joints can thus by very beneficial – for the owner, for the environment, and for the bridge users who would be inconvenienced by avoidable repair and replacement activities.

References

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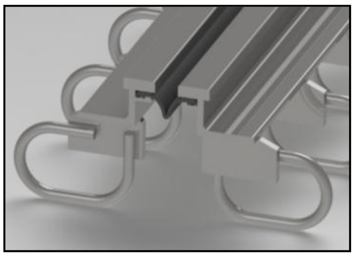
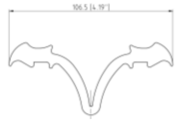
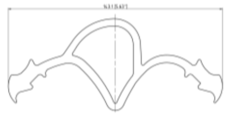
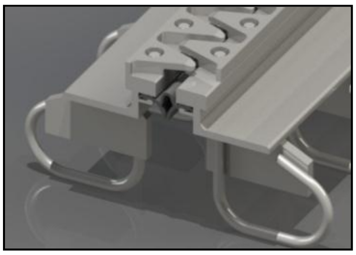
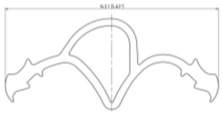
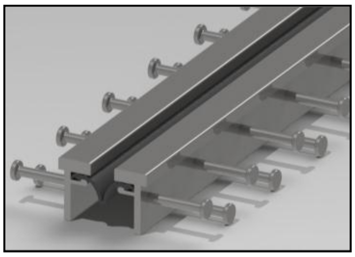
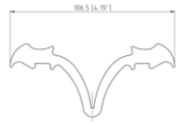
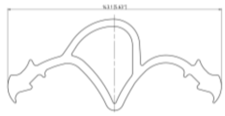
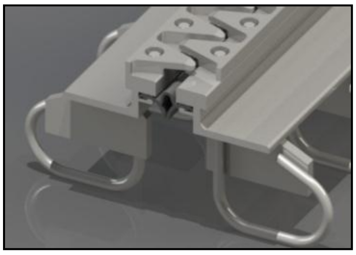
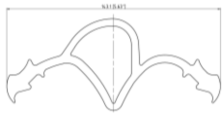
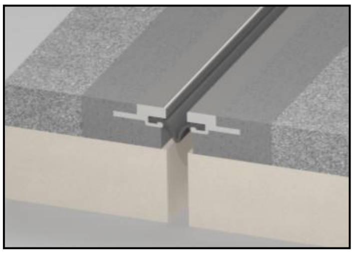
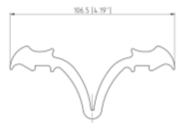
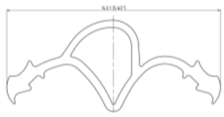
Appendix: Guide to the selection of single gap joints

Type of project	Road surface next to joint	Location and noise/comfort requirements	Joint type	Sealing profile
New build	<u>Asphalt</u> with horizontal connection flange for deck waterproofing membrane to ensure 100% water tightness	Roadway No special requirements		
		Footway (with added cover plate as required)		
		Roadway Noise/vibrations to be reduced (e.g. for benefit of nearby residents and driver comfort)		
	<u>Concrete</u> without connection of waterproofing membrane to the joint	Roadway No special requirements		
		Footway (with added cover plate as required)		
		Roadway Noise/vibrations to be reduced (for benefit of nearby residents and driver comfort)		
Joint replacement	Asphalt or concrete	Roadway No special requirements		
		Footway (with added cover plate as required)		
		Roadway Noise/vibrations to be reduced (for benefit of nearby residents and driver comfort)