A LOW NOISE, LARGE MOVEMENT EXPANSION JOINT SYSTEM FOR CONCRETE BRIDGES

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ABSTRACT

Traffic noise generated by bridge expansion joints appears to be an increasing concern for road authorities in the U.S. and abroad, especially in densely populated areas. In fact, some authorities have banned the use of some expansion joint systems based purely on the excessive noise they generate under traffic.

In addition noise is usually a warning sign that impact forces are not being suitably absorbed, which will then result in future problems with the joint system.

In trying to ascertain the noise generation of various available expansion joint systems, one must ensure that a consistent data-gathering procedure is followed to formulate an unbiased conclusion.

Such an opportunity presented itself recently in Australia. The local road authority, the RTA of New South Wales commissioned the noise testing of a newly installed sealed aluminum finger joint (SAFJ), and a newly installed modular joint, allowing us to compare the noise generated by each system.

The results of these surveys illustrate quantitatively that SAFJ systems do indeed generate a fraction of the noise generated by modular joint systems.

In addition to reviewing the results of this study this paper will also cover the features of this joint system.

Keywords: Finger joint, Modular joint, Molded segmental joint, Thermal movement, Bridges, Expansion joint, Bridge deck

INTRODUCTION

Joint movements that are in excess of 4 inches (100 mm) are typically classified as large movement joints. One of the major problems with large movement joints is dealing with joint openings that are in excess of 4 inches (100 mm). Joint gaps that are larger than this produce high forces due to vehicular impacts as the wheels traverse the joint opening. Large joint gaps will also result in excessive noise which is undesirable in urban areas.

Historically finger or tooth joints have been the most popular method of dealing with large movements[1]. One of the reasons is that they exhibit good performance with regard to noise. However problems with drainage, anchoring and corrosion led to the development of other more state of the art systems.

MOLDED SEGMENTAL JOINTS

In the mid 1960's a molded segmental design was introduced to the bridge market. This system is comprised of steel angles and gap bridging plates which are molded together with rubber to form composite panels (Fig. 1). These panels typically 6 feet in length are then bolted into a joint blockout across the length of the joints providing a moisture barrier. Molded segmental joints became very popular into the 1970's until bolt failures and abrasive wear of the rubber panels eventually led to their demise[2] (Fig. 1a). They also tended to produce more noise than traditional joints due to the slapping effect that is produced as vehicles cross over them.

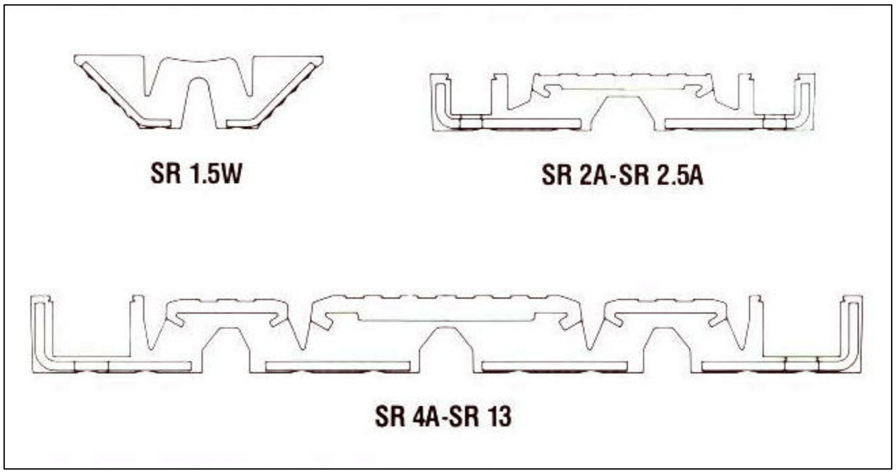


Fig. 1 Molded Segmental Expansion Joint Cross Sections

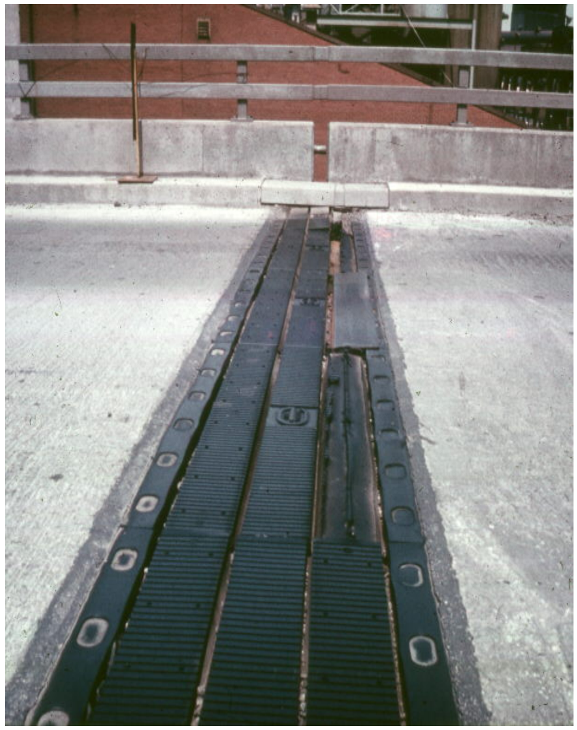


Fig. 1a Molded Segmental Expansion Joint

MODULAR JOINTS

At the same time molded segmental joints were becoming popular, modular joints were evolving into a practical method of accommodating large displacements. Modular joints consist of steel separator beams that break up the joint gap into smaller cells or modules with a maximum opening of 3 inches (75 mm) (Fig. 2). These cells are in turn sealed with a rubber sealing element designed to channel water away from the substructure (Fig. 2a).

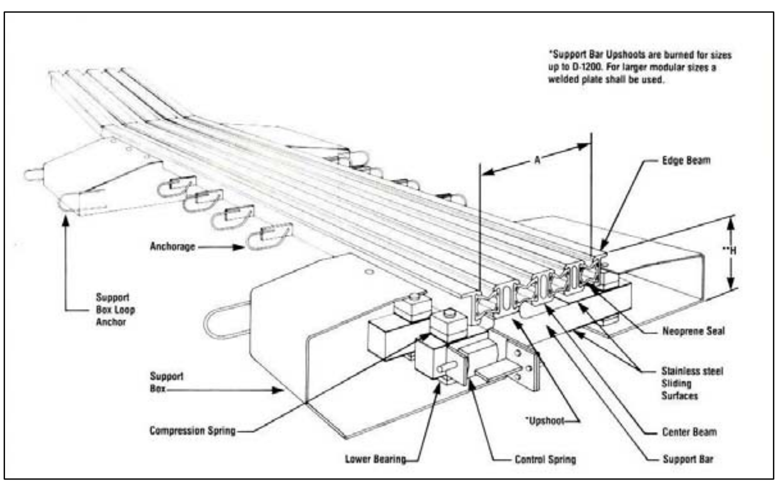


Fig. 2 Modular Expansion Joint Detail

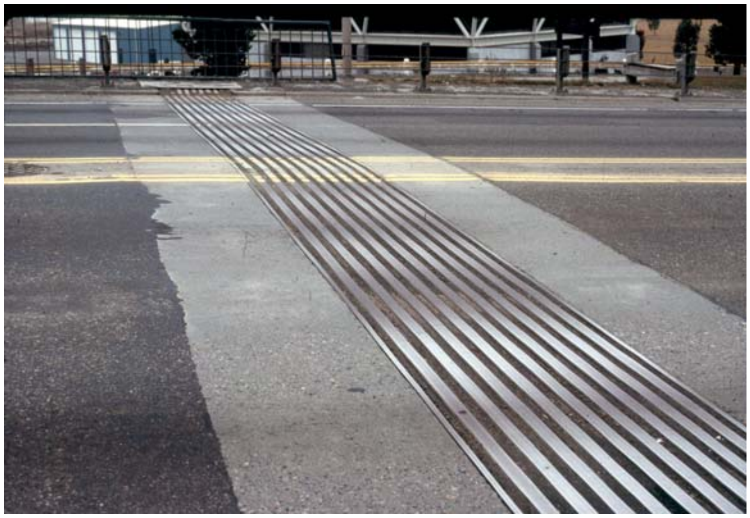


Fig. 2a Modular Expansion Joint

The separator beams are suspended in the joint opening by support bars which span the joint gap. The support bars are then encased by rubber bearings which dampen the impact forces which are transmitted into the joint blockout. Rubber springs are also used to keep the gaps between the separator beams approximately equal.

There are too many different types of modular joints to mention in the scope of this paper. They are still popular today. Many problems have surfaced with the older system's fatigue of the separator beams and support bars and specifically the connections between the two, which has been prolific resulting in modified designs. The support bearings, equidistance springs and the sealing elements have also exhibited signs of wear. Lastly the noise generated by both modular and molded segmental expansion joints (noise typically is associated with impact damage) joints has resulted in bridge owners taking a second look at simpler maintenance free designs.

FINGER JOINTS

One of the reasons that finger joints became so popular was that they are simple in design. With no moving parts coming in contact with one another maintenance issues are minimal. The one major problem with finger joints is drainage. Designed to let water and debris filter through the joint opening, substructural drainage troughs are typically used to keep moisture and debris from compromising the substructure. If they are routinely cleaned out the troughs will provide the intended function. However maintenance of troughs is rare and they inevitably fill up with dirt and debris resulting in incompressibles limiting the free movement of the joint (Fig.3). This in turn creates excessive stresses and cracking to the adjacent concrete in the joint area[3].

Fig. 3 Drainage Trough Filled With Debris

Another problem with finger joints is the loosening of bolts or anchors fastening the finger plates to the joint blockout. Vehicle impact causes this problem which can result in significant liabilities if left unchecked. Corrosion of the steel finger plates has also resulted in field problems with finger joints (Fig. 4).

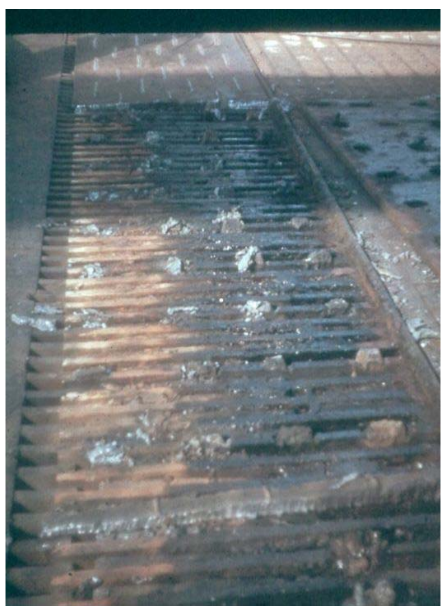


Fig. 4 Finger Plate Corrosion

SEALED ALUMINUM FINGER JOINTS

One finger joint type that seems to address all of the aforementioned problems is the sealed aluminum finger joint system (SAFJ) (Fig. 5). SAFJ are comprised of standard length saw tooth aluminum panels that are designed to accommodate vehicular traffic across the joint with a minimal amount of impact force. Being manufactured out of aluminum the corrosion issues with conventional steel finger plates is drastically reduced. In addition the saw tooth finger design reduces impact forces. However the unique feature of the SAFJ is the use of a rubber sealing element which is mechanically locked into the finger plate just below the deck level (Fig. 6). This sealing element is designed to channel away moisture and debris and keep it from compromising the substructure. The aluminum finger plate panels are post-tensioned into the deck alleviating the problem of anchor bolts loosening which has been prevalent with some finger joint systems. In addition the aluminum fingers are designed to eject debris from the top of the sealing element as they close.

Fig. 5 Sealed Aluminum Finger Joint

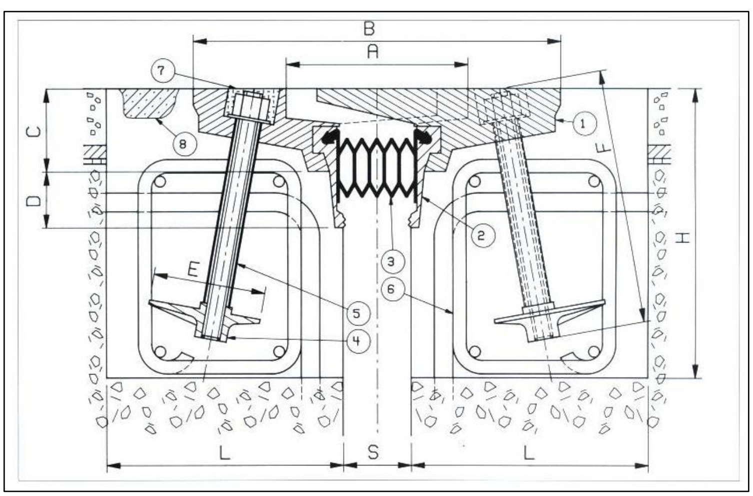


Fig. 6 SAFJ With Sealing Element

When comparing large movement bridge expansion joint systems, it has long been accepted that the SAFJ joint design generates the least noise, when compared to the modular or molded segmental systems especially. This quality, along with other substantial advantages has made the SAFJ popular in the last few decades in many countries around the world. Of particular interest are environments where traffic noise is politically or environmentally unacceptable. High population density urban areas such as in Hong Kong, where expansion joints may be very close to dwellings or natural environments and where noise impact must be minimized are common places where SAFJ systems are now being utilized.

Until now however, although intuitive, the low-noise quality of the SAFJ was somewhat subjective. Recently, an interesting set of circumstances arose, which put some numbers to this issue. In June 2006 the Road and Transportation Authority (RTA) of New South Wales in Australia commissioned an independent survey to measure the noise levels generated by a newly installed SAFJ system on the Wallamba River Bridge near Nabiac[4]. By comparing the noise levels generated by a modular joint system under similar traffic conditions, utilizing the same test method and equipment, the RTA was able to quantifiably derive the potential noise reduction achieved by an SAFJ system over a modular joint[5].

The noise surveys were conducted by an independent consultant on both the Nabiac 6.3" in. (160 mm) movement SAFJ and a recently installed 8 seal large movement Modular joint.

The noise survey method was largely guided by the RTA Specification B316 and AS 2702-1984 "*Acoustics – Method for measurement of road traffic Noise*" and the DEC's "*Environmental Criteria for road traffic noise (ECRTN)*" Traffic counts were performed as per AS 2702 in 15 minutes noise survey intervals.

For the SAFJ , one Bruel & Kjaer 2260 Sound analyzer was placed 328 ft. (100 m) away from the joint to measure "background" or "control" traffic noise, and another analyzer was simultaneously positioned 13.1 ft. (4 m) from the centre of bridge, adjacent to the expansion joint (Fig. 7).

Fig. 7 Sound Analyzer

For the Modular joint , one Bruel & Kjaer 2260 Sound analyzer was placed 656 ft. (200 m) away from the joint to measure “background” or “control” traffic noise, and another analyzer was simultaneously positioned 49.2 ft. (15 m) away from the joint and 13.1 ft (4 m) from the centre of bridge, due to a steep embankment preventing any closer positioning.

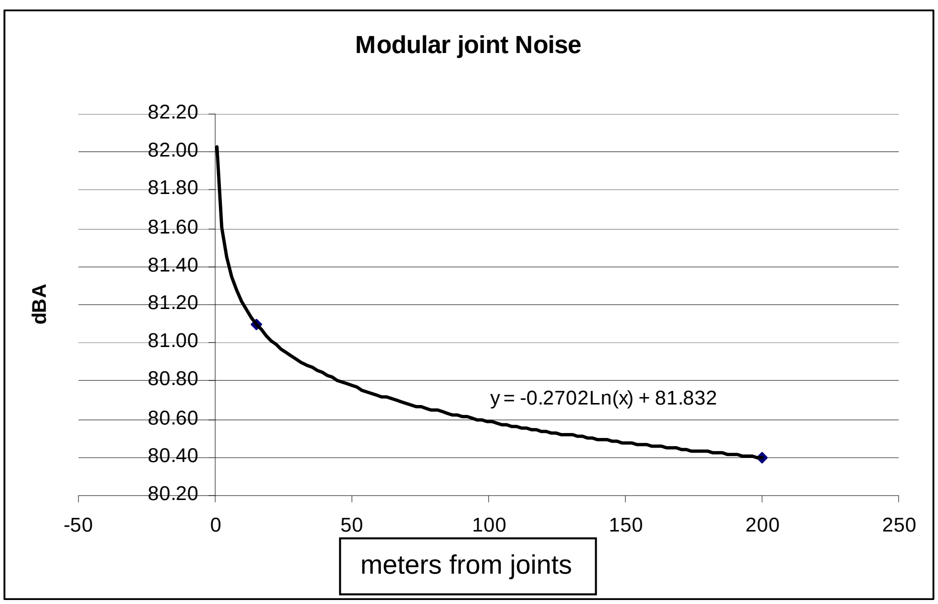
The average hourly results of the noise surveys were as follows:

Joint type	Location from joint (m)	Laeq (dBA re 20 uPa)	LA1	LA10	LA50	LA90
Finger	100	74.00	84.75	76.50	66.50	56.50
	0	74.50	85.30	77.00	67.00	57.00
differential		0.50	0.55	0.50	0.50	0.50
Modular	200	80.40	93.50	84.00	64.30	55.00
	15	81.10	93.80	84.80	65.30	56.30
differential		0.70	0.30	0.80	1.00	1.30
trend	*0*	*81.83*	***y = 81.832 - 0.2702 Ln(x)***			
corrected differential		*1.43*				

Table 1 Noise Levels of Joint Systems

Because noise intensity in decibels is logarithmic based, if we assume that the control noise level equates to “zero” joint noise, when a logarithmic best fit trend line is fitted to the modular joint data at 49.2 ft (15 m) and 656 ft. (200) and extrapolated back to 0 ft/m (adjacent to the joint), we can estimate the noise level at the same position as measured at the finger joint. This is shown as “trend” in the table above. The resultant corrected differential noise adjacent to the modular joint can thereby be estimated to be approximately 1.43 dBA. (Because any logarithmic function has a singularity at x = 0, the fact that we fit a natural logarithm trend to decibels that are normally expressed as a base 10 log does not matter.)

See Below Graph:



We can also argue that the differential noise level only is comparable for 2 different test locations. This is because background or "base" noise is a function of asphalt texture, the geometry of the site and lots of other factors. But because this noise is a baseline only, it does not affect the differential noise contributed by the expansion joint.

Given the above, one can put forward the argument that the modular joint, in this instance, is 1.43 / 0.5 = 2.86 times noisier than the SAFJ system.
Whilst this argument may be simplistic, it is nonetheless an interesting observation in an attempt to use numerical methods to compare the noise impact of different types of expansion joint systems.

CONCLUSIONS

The trend towards finger joints is a result of simplicity in design and low maintenance. The historic problem of drainage is addressed by the SAFJ with an innovative sealing element (Fig. 8). In addition the SAFJ has a lower installed cost than comparable modular joint designs. The post tensioned anchor design coupled with the low noise features makes the SAFJ a practical solution for expansion joints on concrete bridges in a variety of different environments.

Fig. 8 SAFJ Installed on Bridge

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