JKR EXPERIENCE IN BRIDGE DECK EXPANSION JOINTS

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ABSTRACT

A high percentage of bridges in Malaysia are of simple spans construction with expansion joints over the supports. Introduction of joints to a multi-span bridge system simplifies the analysis for load effects. This, however, has also led to many maintenance problems caused by faulty joints. Expansion joint on bridge deck is a relatively cheap component in a bridge yet it is often not given sufficient attention by bridge designers. The designer would often select a standard joint type from the supplier's catalogues and leave the quality of installation to the contractor. There is growing popularity of jointless bridges that do away with bridge deck expansion joints. Nonetheless, there remain joint problems associated with existing bridges and attention of bridge engineers on the right selection and installation of joints to replace them is needed.

INTRODUCTION

The PWD Malaysia (JKR) owns and manages over 2,084 federal bridges (not including culverts) and about 87 percent of these bridges are of simple span construction. Simple span bridges are easy to design and construct. Introduction of joints or hinges at bridge deck over the supports (rather than continuous over the supports) reduces the degree of statical indeterminacy of the structural system and thus simplify the structural analysis. With the availability of many computer programs in structural analysis these days this advantage is no longer significant. There is a trend now towards the design of jointless bridges where the decking span continuously over the piers and/or cast integrally with the abutments.

Nevertheless, there remain joint problems associated with existing bridges for Maintenance Engineers to solve. The authors, in performing their duties in JKR, have often been expected to propose the 'best' type of bridge joint to replace old ones. This has not been an easy task because most proprietary joints available in the market are good joints in terms of design. The fact is: the performance of a deck joint depends largely on the workmanship in installation and the selection of the right type of joint based on many factors.

This paper begins by discussing common types of deck joints used by JKR and their problems. From these discussions the features of an ideal type of bridge joint can be identified. The opinions expressed herein are based on the experience of the authors in addressing bridge joint problems for JKR bridges; particularly those found along Kuantan-Segamat Highway, East-west Highway and the Middle Ring Road 2 (MRR2).

COMMON TYPES OF BRIDGE JOINTS

Technical document from UK MOT, BD 33/94 (DTp 1994) and its advice notes BA 26/94 (DTp 1994) have classified expansion joints as follows:

i. Buried joint
ii. Asphaltic plug joint
iii. Nosing joint with poured sealant
iv. Nosing joint with preformed compression seal
v. Elastomeric joint
vi. Elastomeric elements in metal runners
vii. Cantilever comb or tooth joint

Schematic details of these joints are given in the Advice Notes BA 26/94. Essentially, an expansion joint, regardless of its type, has a component to provide the running surface while accommodating the deck movement, a fixing system to hold the running surface to the deck, a water stop and optionally, a subsurface drainage system. An asphaltic plug joint, for example, consists of a layer of rubberized bituminous material over the gap that is stable enough to provide the running surface while flexible enough to accommodate the expected deck movement. The specially formulated premix pavement is held in position by adhesion with the concrete substrate. Sealant and a Tee plate over the joint gap together act as a water stop to prevent dirt and water from leaking through the gap. In some design, a subsurface drainage system is also provided to drain the water from the adjacent road pavement.

Performance in service of common types of bridge joints has been studied and presented in TRRL Reports (Price 1984, Cuninghame, 1995). Factors that are considered important in influencing the performance of bridge joints are:

- Structural movement at the joints
- Traffic over the joint
- Joint design
- Material used
- Bond and anchorage
- Conditions of the substrate
- Detritus, foreign matter and corrosion
- Weather and temperature
- Site preparation and workmanship
- Performance of the bearings

The investigations concluded that it is generally a complex combination of these factors that influence the joint performance and that these factors vary with and within joint types (Price 1984).

A great number of proprietary products are available in Malaysia and JKR has, over the years, used each of these types of joints above except the elastomeric joint elements in metal runners. The experience and observation of each of these joint types are now discussed.

Buried joint

A product known as Rigiflex Lubrithene/A was popular in the early 80s. The schematic detail of the joint is presented in Figure 1.

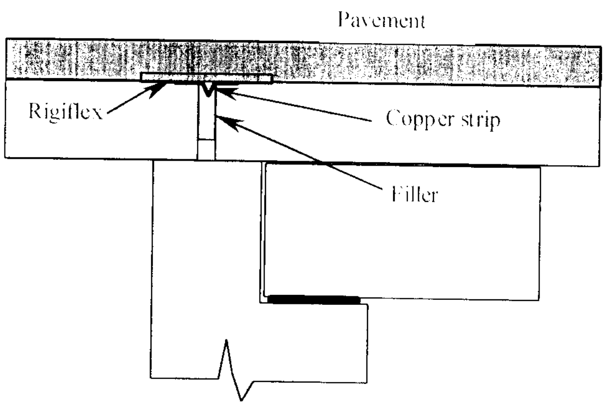

Figure 1 Rigiflex joint

The component laid beneath normal premix surfacing serves as a lubricating flashing to accommodate the movement and distribute any potential crack over the gap by the formation of many fine cracks on the premix surfacing. The copper strip, either fastened over the gap or cast into the deck slab, provides the bridging over the joint gap. The filler, perhaps with a little help from the copper strip, serves as a water stop. This type of joint had been the most common joint used by JKR for small movement in the early 80s, only to be replaced by asphaltic plug joint. The rigiflex, however, may not perform as designed and random lines of sizeable crack would appear on the premix surfacing (see Figure 2).

Figure 2 Typical failure of buried joint

Asphaltic Plug Joint

Asphaltic plug joint is an in-situ joint comprising a band of specially formulated flexible material supported over the deck joint gap by thin metal plates. This type of joint is an improvement to the buried joint and is also meant more for small movement.

JKR first used asphaltic plug joint at Sultan Ismail Bridge in Muar and Kota Bridge in Klang around 1986. The performance of the joint at either site was considered not satisfactory because the rubberized bituminous material cracked, flowed or rutted under wheel load like that shown in Figures 3 & 4.

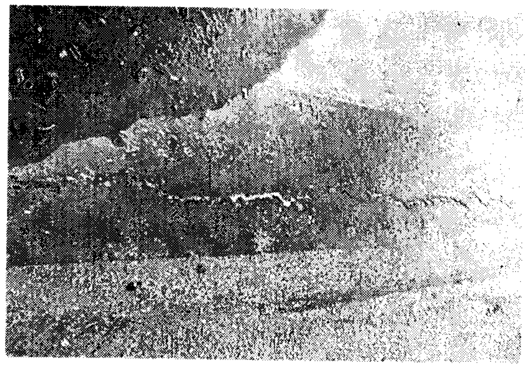

Figure 3 Cracking on asphaltic plug joint

Figure 4 Flowing in asphaltic plug joint

The supplier of the joint had attributed the unsatisfactory performance to the hot climate in Malaysia, the steep gradient of the bridge deck and presence of stationary and queuing traffic. It was later reported in a seminar that four factors would need to be considered in the choice of asphaltic plug joint (Huges 1989):

- Climate
- Bridge design
- Traffic
- Movements

It was specifically mentioned that asphaltic plug joint should not be used on bridges in the proximity of traffic lights and junction. More discussion on asphaltic plug joint will be made later.

Nosing Joint with Poured Sealant

Nosing is an in-situ material or fabricated components used to protect the adjacent edges of the surfacing at the expansion joint. It may be made up of epoxy mortar or armored steel angles anchored to the bridge deck.

Typical pattern of failure for nosing joint with poured sealant is shown in Figure 5. In this case, cracking is happening on the nosing. There is also separation of the nosing from adjacent premix surfacing.

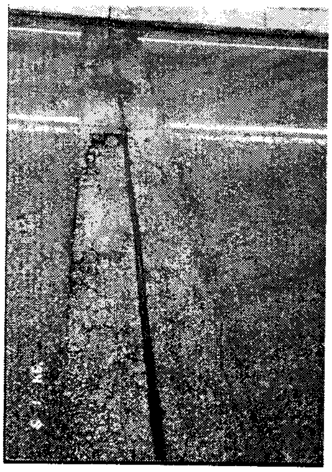

Figure 5 Typical failure of Nosing joint with poured sealant

Nosing Joint with Preformed Compression Seal

A few types of proprietary products using epoxy mortar nosing and preformed rubber compression seal have been used by JKR for larger joint gap exceeding 25mm. Common problems associated with this type of joint are cracking, debonding and detachment of the nosing as well as displacement of the compression seal (see Figures 6 and 7).

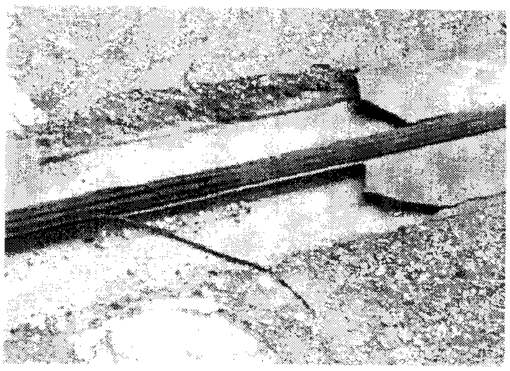

Figure 6 Detachment of nosing

It makes sense to reinforce the epoxy mortar nosing with Fiber Reinforced Plastic fabrics (FRP); as one product has in its design. In normal cases, to hold the compression seal in place would rely on the pressure exerted by the seal under compression. It may be preferable to use adhesive to hold the seal in place. Some products have specially designed ribs on the sidewalls of the preformed seal to improve the bonding. Others make use of some inflation technique to apply air into the preformed compression seal, which in turn exerts pressure on the nosing edges.

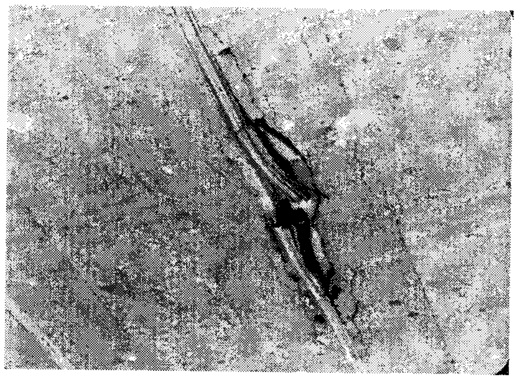

Figure 7 Displacement of compression seal

What is most important, however, is still the selection of the right size of compression seal for the joint opening. When there is a misfit, whatever means to make the seal stay in place would be difficult.

Elastomeric Joint

This joint consists of prefabricated rubber (reinforced) or metal running plates with flexible strip seal to accommodate deck movement. The running plates bridge over the joint gap and are fixed to the bridge decks by an elaborate anchorage system, either by holding down bolts or anchor bars. Bituminous or resinous material (usually epoxy mortar) called *transition strip* is used to fill the space between the prefabricated joint and the cut edge of the surfacing to form a smooth continuous running surface.

Many products, from abroad or locally manufactured, are available in the Malaysian market. JKR calls this joint the "Load-bearing elastomeric joint" and often specifies it when the deck movement is large. JKR has seen a number of successful use as well as premature failure in this type of joint.

Practically every part of the joint is susceptible to damage. First is the running plate. Rubber joint of poor quality may tear under repetitive traffic load. This, however, is not common. What is common is cracking, debonding and/or detachment of the transition strip causing the joint to finally unfastened (Figures 8).

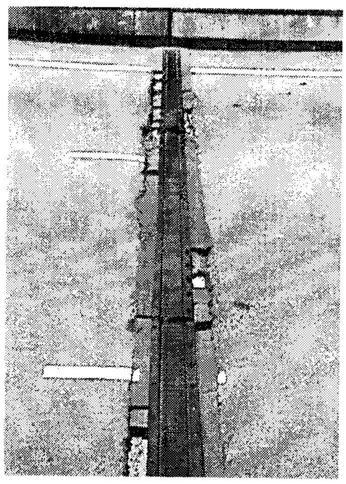

Figure 8 Failure of transition strip

The interface between the transition strip and the adjacent pavement has often been the point of entry for deck water. There are many cases where the joint appears to be in good condition while indeed there is leakage that is betrayed by the water stain at the underside of the decking (See Figures 9 & 10).

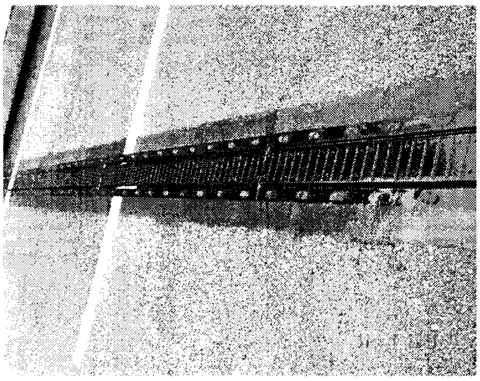

Figure 9 Elastomeric joint appears to be in good condition but see Figure 10

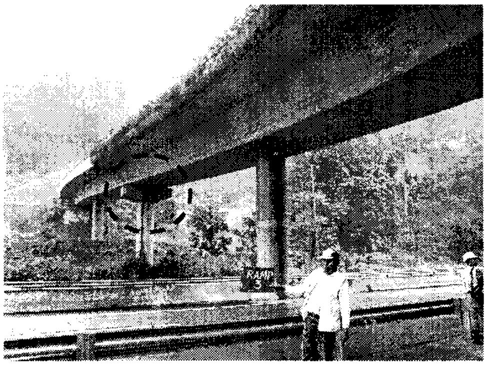

Figure 10 Water stain at the pier indicates leakage at joint

The anchorage system is also a major source of problem. The caps covering the holding down bolts almost always are displaced. The holding down bolts when exposed may pose as a hazard to vehicles (Figure 11).

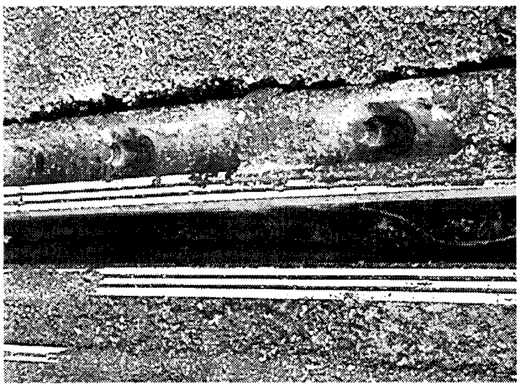

Figure 11 Protruding bolts pose as traffic hazard

It is not uncommon to find the bolts being sheared off in service. This affirms the need for proper tests to be carried out to check the suitability of the bolts. Also, a tight supervision from the Client is necessary to ensure that only approved holding down bolts are installed on sites.

A type of joint common in the US that can be classified under elastomeric joint uses the strip seals in place of compression seals. The metallic armors to hold replaceable strip seal are fixed with an anchorage system comprising sinusoidal steel mechanism or bolts going sideway into a nosing. This nosing consists of a special aggregate reinforced elastomeric mixture. JKR has keen interest in this type of anchorage system because it does away with the holding down bolts. JKR has experienced successful and unsuccessful use of the joint. A typical pattern of failure involves breakage of the nosing (Figure 12).

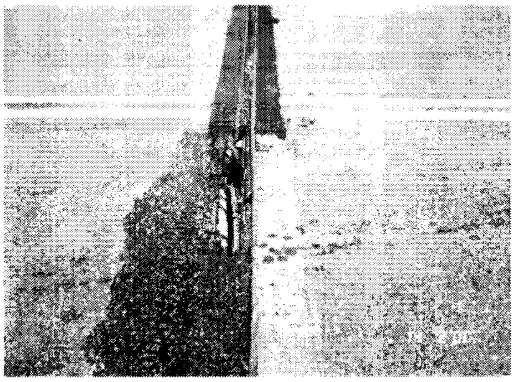

Figure 12 Typical failure of strip seal joint

Another common problem with elastomeric joints is the failure of deck surfacing at location adjacent to the transition strip (see Figure 13). This may be caused by the impact onto the pavement due to transition strip being laid higher than the adjacent pavement or by the weakening of the pavement due to presence of water dammed up by the raised transition strip.

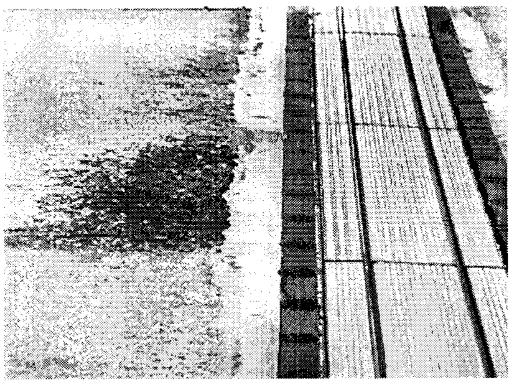

Figure 13 Failure at deck surfacing

Comb Joint

Comb joint or tooth joint (or finger joint) is not common among JKR bridges. The only installation of the joint known to the authors is in Sultan Ahmad Shah Bridge at Temerloh (Figure 14). The performance of this joint has been good except that the steel trough drainage system under the joint needs to be cleared regularly of grits and dirt.

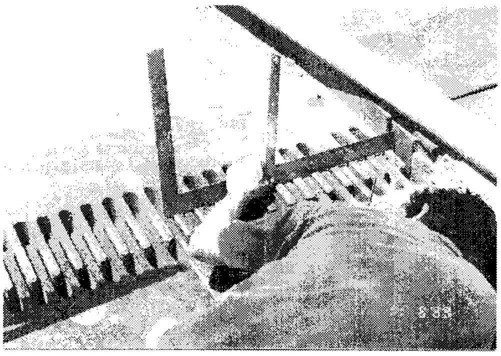

Figure 14 Comb joint as used in Ahmad Shah Bridge in Temerloh

IDEAL JOINT TYPES

Is there an ideal joint type that can be recommended? It is much to be desired. All the proprietary joints in the market have been well researched and designed and as long as they are properly manufactured they are good joints. What the authors have observed through inspecting many JKR bridges with joint problems is that to achieve good performance two areas deserve more attention. One involves the right selection of the joint type for the site; which we will discuss herebelow under the heading of "design of joints". Another is the quality control during joint installation. This is in view of the fact that workmanship is a very important element in getting a good joint performance.

Design of Joints

What is meant in the heading is not the design of joint details as a joint manufacturer would want to pay attention to. Rather, it refers to the selection of a suitable joint for the site; a task a bridge designer is traditionally responsible for. The selection shall be made based on the following factors:

Type and configuration of the bridge
The amount of movement
The traffic
Durability requirement
Cost

It is pertinent that the bridge engineer makes an effort to choose among the suppliers' catalogues the right type of joint suitable for the site based on the above considerations. The authors have observed that in many cases the gaps have been over provided.

In order to specify a suitable joint there is the need to first understand what is meant by a good joint. In this connection, the functional requirements as given in Technical Memorandum BE 3/72 are good reference and are reproduced herebelow:

i. It shall withstand traffic loads and accommodate movements of the bridge due to temperature, creep, shrinkage and loading, and shall not give rise to unacceptable stresses in the joint or other parts of the structure.
ii. It shall have good riding quality and shall not cause inconvenience to any class of road user. (Including cyclists, pedestrians and animals where they have access).
iii. When a joint would present a large smooth metal area at the road surface it shall not cause a skidding hazard.
iv. The joint shall not generate excessive noise or vibration during the passage of traffic.
v. Parts liable to wear shall be easily replaceable.
vi. It shall either be sealed, or have provision for carrying away water, silt, grit and salt.
vii. It shall be easy to inspect and maintain.

BD 33/94, in updating BE 3/72, has reworded item ii to say that "... shall not cause a hazard to any class of road user, ...". Indeed, this should be understood as including the way the joint would typically fail, for example, the protruding bolts of a failed elastomeric joint.

Quality Control of Joint Installation

It is well recognized that the installation quality plays a major role in the performance of the joint. In this country, suppliers are mainly agents to a propriety product (Abrahams 1989). Installation of the joint is mainly carried out by a general contractor. The owners are essentially without protection in terms of the quality of joint material and installation at sites. JKR has hitherto relied on very strict warranty requirement but this has not been effective in ensuring good joint performance.

There requires much quality control during installation of the joint, especially those in-situ joints like asphaltic plug joint. In the case of asphaltic plug joint the formulation of the mix is not to be disclosed. What are being specified in the product brochures and subject to quality control tests are the binder and the aggregates. It is, however, the properties of the mix that are critical in ensuring the quality of the product.

There was an effort by Bridge Unit, JKR to use Marshall test as the quality control test for the special mix used in an asphaltic plug joint. A product (identified herein as Product X) was tested in a local lab by its supplier. The properties of the mix are tabulated in column two of Table 1. Bridge Unit had earlier used a specially designed asphaltic concrete mix as an alternative to the proprietary product for Tunggak Bridge in Kuantan. The service performance of the joint was monitored for one year and was found to be good. Marshall properties of the mix used are tabulated in column three of Table 1. The proportion and grading of aggregates and cement used are presented in Table 2.

It is intuitive to suggest that for the asphaltic plug joint to work it requires that the mix be stiff enough not to deform under the wheel load yet flexible enough to deform and accommodate the movement. The two requirements are contradictory and a tradeoff must be achieved in the design. These two criteria are best represented by Marshall properties: the stability and flow. Interested reader is referred to BS 594 (1973) for the discussion on Marshall tests.

From Table 1, it is seen that the flow values for the two mixes are close while the Marshall stability of the JKR designed mix almost doubles that in the asphaltic plug joint mix. The JKR design mix from asphaltic concrete seems to suggest some desirable properties for the joint. The high stability is necessary to prevent rutting or settlement of the mix under wheel load. By having a high Void in total mix would prevent bleeding of the bitumen. However, the efforts by Bridge Unit in identifying the right quality control test for asphaltic plug joint is not complete and further study needs to continue.

Table 1 Marshall properties of asphaltic plug joint

Test Properties	Product X	JKR design
Marshall stability (kg)	614	1248
Unit weight (kg/m3)	2152	2330
Flow (mm)	4.73	4.57
Bitumen content (%)	25	6.9
Void in total mix (%)	0.51	2.05
Voids filled with binder (%)	98.71	88.0

Table 2 Grading used in JKR designed mix as an asphaltic plug joint

Aggregate Type	% Used			B.S.	Sieve Size					
		¾"	½"	3/8"	3/16"	No. 7	No. 25	No. 52	No. 100	NO. 200
1	18		14.6	2.5	0.1					
2	15			13.7	0.1					
3	17			17.0	15.3	5.4	0.2	0.1	0.1	0.03
4	48			48.0	47.5	44.2	22.1	14.5	8.5	6.1
Cement	2			2.0	2.0	2.0	2.0	2.0	2.0	1.84
Design	Grading	100	96.6	83.2	65	51.6	24.3	16.6	10.6	7.97
uired	Grading	100	78-100	68-90	52.72	38-58	20-36	12-25	7-16	4-8

CONCLUSIONS

The service performance of bridge deck joints discussed in this paper have been based on the observations made by the authors in their duties in inspecting bridges and investigating bridge problems for the last 16 years. Although no systematic research procedure had been followed, some conclusions are evident from what have been observed:

i. Practically every type of joint ever used in JKR bridges has experienced some forms of failure. The exception is the comb joint; but then there is only one case where comb joint is used.

ii. It is important that bridge designer pays more attention to selecting and specifying the right type of joint based on the considerations discussed in this paper.

iii. Workmanship in installing the joint is most important in further ensuring the good performance of the joint

iv. There is a need for a specification for workmanship. In the case of asphaltic plug joint, an effort by Bridge Unit to use Marshall properties as a criterion for quality control is heading in the right direction. However, further study needs to continue.

ACKNOWLEDGMENT

The authors wish to acknowledge with thanks the kind permission of the Director General of JKR, Dato' Ir. Zaini bin Omar, Director of Roads Branch, Ir. Mohamad Razali bin Othman and Senior Superintendent Engineer of Bridge Unit, Ir. Chin Wei Choong, for their permissions to publish and present this paper.

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