TABLE OF CONTENTS ~ EXPANSION JOINTS

5.8.3 Expansion joints

5.8.3.1 General

5.8.3.1.1 Policy overview

Although the Bureau prefers jointless construction, some designs require deck expansion joints because of bridge length, bridge skew, use of stub abutments, use of expansion bearings, or other factors. Where expansion joints are necessary it is important that they be sealed and drained in order to protect both superstructure and substructure components from deterioration caused by runoff and deicers.

In general, expansion joint types are selected based on the amount of movement to be accommodated. Compression seals are rated for movements to 2 or 3 inches, strip seals are rated for movements to 4 or 5 inches, and finger joints are rated for movements to 10 inches or more.

As the Bureau has extended the policy limits for use of integral abutments there has been less need for expansion joints that accommodate small movements. Therefore, for new bridges the Bureau has eliminated use of compression seals in favor of strip seals. At skews above 30 degrees, strip seals lose movement capacity and may not be practical. For movements larger than strip seals can accommodate the Bureau designs and specifies finger joints. Except in unusual cases, strip seals or finger joints are adequate for expansion joints in Iowa bridges. Expansion joints other than strip seals or finger joints require approval of the supervising Unit Leader.

During rehabilitation of existing bridges the Bureau currently replaces compression seals with strip seals. If sliding plate joints are in good condition the Bureau rehabilitates and modifies the joints to remain in service. Sliding plate joints in poor condition are replaced with strip seals.

Typical strip seal details and notes, including watertight integrity testing, are given on standard sheets [BSB SS 1026s1 and 1026s2]. Approved manufacturers and products are given in an Construction and Materials Bureau Instructional Memorandum [CMB IM 436.02, Appendix A].

Currently there are no standard sheets or standard specifications for finger joints.

To improve the performance of portland cement concrete (PCC) approach pavement and expansion joints at integral abutments, the Bureau has developed a BE joint filled with tire buffings. The joint is shown on Design Bureau plans [DB SRP BR series] that are included with bridge plans. The BE tire buffing joint replaced CF tire buffing joints for projects in the October 2024 letting [CF joint details can still be found in DB SRP PV-101]. The CF tire buffing joints previously replaced foam plastic blocks that were difficult to maintain.

5.8.3.1.2 Design information [AASHTO-LRFD 3.12.2]

Performance of expansion joints will depend on annual temperature cycles during the service life of the bridge and concrete shrinkage during the initial period of service. In lieu of Procedures A and B for temperature ranges in the AASHTO LRFD Specifications [AASHTO-LRFD 3.12.2] the designer shall use the ranges in Table 5.8.3.1.2. The table also includes appropriate thermal and shrinkage coefficients.

Table 5.8.3.1.2. Design temperature ranges, thermal coefficients, and shrinkage coefficients for expansion joints

Type of Superstructure	Design Temperature Range	Thermal Coefficient	Shrinkage Coefficient
Steel	75°F each way from 50°F, 150°F temperature range	0.0000065 /°F	--- (1)
Concrete	50° each way from 50°F, 100°F temperature range	0.0000060 /°F	0.0002 in/in (2)

Table notes:

(1) Although the concrete deck will shrink after placement, the typical shear stud attachment of the deck to the steel superstructure will cause the shrinkage to dissipate in small cracks throughout the expansion length rather than accumulating at the end. Therefore, shrinkage need not be considered for steel superstructures.

(2) Actual shrinkage (and creep) will vary depending on the type of concrete superstructure and scheduling of superstructure construction. The overall combination of temperature range, thermal coefficient, and shrinkage coefficient approximates the behavior of the deck in most situations.

With use of the information above and joint settings of 90, 50, and 10 degrees Fahrenheit as required in articles below [BDM 5.8.3.2 and 5.8.3.3], the designer need not apply a setting factor or an AASHTO LRFD load factor in design of strip seal and finger joints. Experience has shown that joints are correctly sized without application of modifying factors.

5.8.3.1.3 Definitions

Unit Leader is the supervisor of the Bridges and Structures Bureau Preliminary Bridge Design Unit, Final Design Unit, or Consultant Coordination Unit.

5.8.3.1.4 Abbreviations and notation

N, the number of teeth per wheel width
P, the finger load per tooth, k
PCC, portland cement concrete
W, the wheel load with impact, k
Wabo, Watson Bowman Acme Corporation

5.8.3.1.5 References

Bashore, F.J., A.W. Price, and D.E. Branch. *Determination of Allowable Movement Ratings for Various Proprietary Bridge Deck Expansion Joint Devices at Various Skew Angles, Final Report*. Lansing: Michigan Department of Transportation, 1980.

Bolluyt, J.E., V.B. Kau, and L.F. Greimann. *Final Report, Performance of Strip Seals in Iowa Bridges, Pilot Study, TR-437*. Ames: Iowa Department of Transportation and College of Engineering, Iowa State University, 2001. (Available on the Internet at: http://www.iowadot.gov/operationsresearch/reports/reports_pdf/hr_and_tr/reports/tr437.pdf)

Michigan Department of Transportation (MDOT). "Special Provision for Expansion Joint Device." Lansing: MDOT, 2004. (The Frequently Used Special Provision is available on the MDOT web site, http://mdotwas1.mdot.state.mi.us/public/dessssp, under Special Provisions – Frequently Used (2003) from 03SP706A link.)

Phares, B.P. and C. Duffy. *Evaluation of D.S. Brown Steelflex® Strip Seal Expansion Joint Systems at Skew*, Bridge Engineering Center, Iowa State University, Final Report, June 2019.

Purvis, Ron. *Bridge Deck Joint Performance, NCHRP Synthesis 319*. Washington: Transportation Research Board, 2003.

5.8.3.2 Strip seals

5.8.3.2.1 Analysis and design

Because of consolidation in the strip seal industry, only two manufacturers provide approved products [CMB IM 436.02, Appendix A]:

- D.S. Brown Company, and
- Watson Bowman Acme Corp. (Wabo).

Feasibility of approved strip seals for steel and concrete superstructures may be determined from the maximum allowable expansion lengths in Table 5.8.3.2.1-1. Considering the recent increases in allowable bridge lengths for use of integral abutments [BDM Tables 6.5.1.1.1-1 and 6.5.1.1.1-2], strip seals will have more limited use than in the past.

Table 5.8.3.2.1-1. Approximate maximum allowable expansion lengths for approved strip seals

Seal type, steel (S) or concrete (C) super-structure	Max. gland installation temp. F (2)	Min. install width, inches	Approximate maximum allowable expansion length in feet for skew in degrees						
			0	10	20	30	40	50	60
Wabo SE-300, S	60	1.5	225	220	225	260	260	145	---
Wabo SE-300, C	60	1.5	220	215	220	255	255	140	---
Wabo SE-400 (1), S	70	1.5	335	340	355	345	235	45	---
Wabo SE-400 (1), C	60	1.5	370	375	395	380	255	50	---
Wabo SE-500, S	65	2.0	425	--- (3)	--- (3)	--- (3)	--- (3)	--- (3)	--- (3)
Wabo SE-500, C	60	2.0	445	--- (3)	--- (3)	--- (3)	--- (3)	--- (3)	--- (3)
D.S. Brown A2R-400 (1), S	60	2.0	295	300	265	160	115	55	---
D.S. Brown A2R-400 (1), C	60	2.0	295	300	260	160	115	55	---

Table notes:

(1) Joint settings and maximum gland installation temperature will need to be specified separately for each product, if both the Wabo and D.S. Brown products are adequate for the joint. See Example 2 in the commentary for this article.
(2) Allowable expansion length will be less than the table value if maximum gland installation temperature is above this temperature.
(3) No data on movement capacity is available for this gland.

Joint design shall be based on the thermal and shrinkage values given in Table 5.8.3.1.2 and the strip seal data in Table 5.8.3.2.1-2. There are four conditions that need to be considered during design:

- Long-term movement capacity parallel with centerline of roadway including shrinkage if applicable,
- Long-term maximum opening at minimum deck temperature after shrinkage,
- Short-term minimum opening at maximum deck temperature before shrinkage, and
- Manufacturer's minimum installation width, which will determine the maximum gland installation temperature.

The long-term joint movement considering both temperature and shrinkage shall meet the allowable long-term movement capacities given in Table 5.8.3.2.1-2. If possible, the designer should choose a strip seal from each approved manufacturer so that there is competition during the bidding process.

Table 5.8.3.2.1-2. Allowable movement capacity, minimum installation width, and minimum opening width for approved strip seals

Seal type/steel extrusion type	Minimum installation width, inches (1)	Minimum opening width, inches (1)	Allowable movement capacity parallel with centerline of roadway in inches (2) for skew angle in degrees						
			0	10	20	30	40	50	60
Wabo SE-300/A	1.5	0	3.0	3.0	3.1	3.5	3.7	3.3	2.8
Wabo SE-400/A	1.5	0	4.0	4.1	4.3	4.3	3.7	2.7	2.6
Wabo SE-500/A	2.0	0	5.0	--- (3)	--- (3)	--- (3)	--- (3)	--- (3)	--- (3)
D.S. Brown A2R-400/ SSA2	2.0	0.5	4.0	4.1	3.9	3.4	3.4	3.5	3.3

Table notes:

(1) This dimension is measured perpendicular to the joint.
(2) In 1980 the Michigan DOT determined allowable capacities and published them in *Determination of Allowable Movement Ratings for Various Proprietary Bridge Deck Expansion Joint Devices at Various Skew Angles, Final Report* [BDM 5.8.3.1.5]. Recently the Michigan DOT has updated the capacities in Special Provision – Frequently Used 03SP706(A), "Special Provision for Expansion Joint Device," 06-24-04.
(3) No data is available.

AASHTO-LRFD 14.5.3.2 limits the maximum single gap opening in the roadway surface to 4.0-inches in the direction of travel. Strip seal designs may be designed based on the limits given in Table 5.8.3.2.1-2 even though some designs may exceed the 4.0-inch limit given in AASHTO. Approval of the supervising Unit Leader is required for strip seals designed for longitudinal bridge deck movements greater than those given in Table 5.8.3.2.1-2.

The designer shall select a maximum installation temperature in the range of 60 to 90 degrees Fahrenheit at which to provide the minimum installation width listed in Table 5.8.3.2.1-2 for each acceptable strip seal. A higher temperature will allow more construction flexibility, but a lower temperature will allow a greater expansion length. With the addition of the bid item “Neoprene Gland Installation and Testing” the contractor has a reasonable option to return to the otherwise completed bridge during cooler temperatures, install the gland, and test the installation for leaks.

Based on the maximum installation temperature and minimum installation width for each acceptable strip seal it will be possible to determine the long-term maximum opening and the short-term minimum opening. The designer shall check the computed openings with the appropriate allowable values in Table 5.8.3.2.1-2.

The designer shall determine and specify the joint settings at 90, 50, and 10 degrees Fahrenheit for each acceptable strip seal [BSB SS 1026s1].

The overall design process for strip seals is shown in two examples in the commentary for this article.

5.8.3.2.2 Detailing

Two standard sheets provide typical details [BSB SS 1026s1] and notes [BSB SS 1026s2] for strip seal installations. The designer should note that the installation requires the following:

- Rails recessed below the surface of the deck,
- A rail anchorage system at 18 inches, maximum,
- Upturned strip seal rails at barrier rails,
- Removable cover plates at barrier rails, detailed so that traffic passes the attached ends first and in passing cannot snag the sliding ends, and
- Watertight integrity testing.

The designer needs to provide the following on the plans:
- Joint settings at 90, 50, and 10 degrees Fahrenheit for each acceptable strip seal, and
- Maximum deck temperature at which the strip seal gland may be installed.

By default, the bid item estimate reference note for steel extrusions explicitly excludes D.S. Brown from consideration. Including this default language is intended to ensure contractors do not consider D.S. Brown as an approved equal when the designer specifically excludes D.S. Brown from the table of approved expansion devices on BSB SS 1026a1. Designers must remove this portion of the estimate reference note if they include D.S. Brown as an option in the table of approved expansion devices on BSB SS 1026a1.

5.8.3.3 Finger joints

Finger joints generally are used for expansion joints larger than those that can be accommodated by strip seals. Approval of the supervising Unit Leader is required for finger joints designed for longitudinal bridge deck movements greater than 10 inches.

5.8.3.3.1 Analysis and design [AASHTO-LRFD 3.4.1, 3.6.1.2.5, 3.6.2.1, 14.5.3.2]

Align the teeth with respect to the direction of movement. Typically, the alignment will be in the longitudinal direction of the bridge, unless the structure is on a horizontally curved alignment.

As noted in Figure 5.8.3.3.1, for either option the minimum joint opening (at maximum design temperature) in the longitudinal direction is 1.0 inch for steel superstructures [AASHTO-LRFD 14.5.3.2]. For concrete superstructures the minimum joint opening may be less to account for creep and shrinkage, but not less than 0.5 inches.

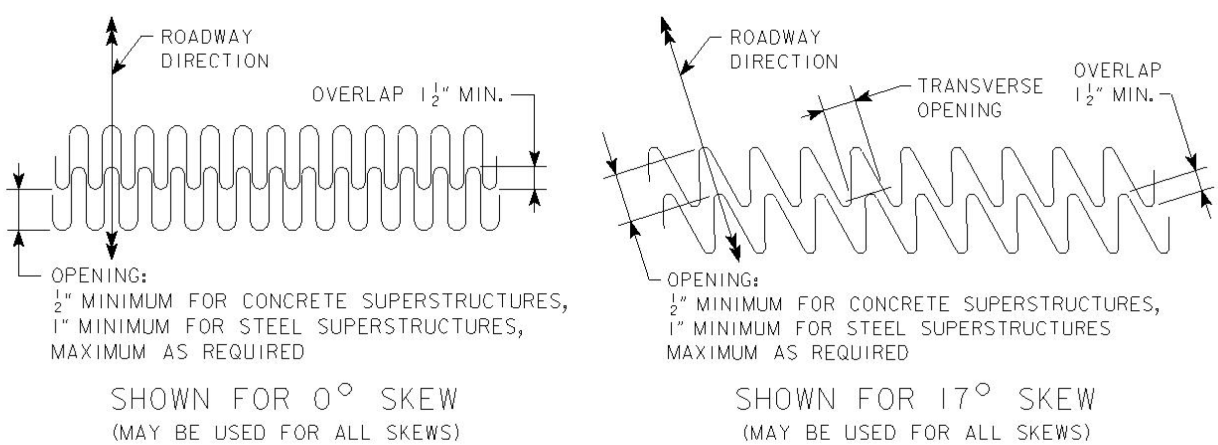

Figure 5.8.3.3.1. Finger joint opening limits

As noted in Figure 5.8.3.3.1, for either option there shall be at least 1.5 inches of tooth overlap in the longitudinal direction at maximum joint opening (at minimum design temperature) in the strength limit state [AASHTO-LRFD 14.5.3.2].

Limit finger joint surface openings to permit safe operation of motorcycles. When the maximum longitudinal opening in the direction of traffic exceeds 8 inches, the transverse opening shall not exceed 2 inches. For longitudinal openings 8 inches or less, the transverse opening may be increased to 3 inches [AASHTO-LRFD 14.5.3.2].

The top of the expansion device is to be parallel to profile grade, and the end of each tooth is to be beveled at a 1 vertical to 12 horizontal slope over the end 3 inches. Maintain at least a 0.25-inch gap between adjacent fingers.

A finger joint tooth shall be designed as a cantilever beam for the larger factored stress resulting from the load per tooth, P, applied as follows:

- P at 3 inches from the end of the tooth, or
- P/2 at 1.5 inches from the end of the tooth.

$$P = \frac{W}{N}$$

Where:

P = the load per tooth, k

W = the wheel load with dynamic load allowance = (16 kips)*(1.75) = 28.0 kips [AASHTO-LRFD 3.6.2.1]

N = the number of teeth per wheel width
Note: Take wheel width as 20 inches [AASHTO-LRFD 3.6.1.2.5].
Count teeth on only one side of the joint.

At the Strength I limit state, a load factor of 1.75 shall be applied to the tooth load [AASHTO-LRFD 3.4.1]. The designer then shall check the factored maximum cantilever tooth stress against the factored tooth yield stress.

Tooth thickness shall not exceed 3 inches. If necessary the designer may either use stiffeners to support the fingers (as for the Saylorville Reservoir Bridge on Iowa Highway 415) or let the fingers bear on a support beam (as for the Iowa-Illinois Memorial Bridge on I-74 over the Mississippi River). For example details consult the plans for the appropriate bridge.

To accommodate bicycle traffic, use special floor plates in the shoulder area [AASHTO-LRFD 14.5.3.2].

The designer shall determine and specify the joint settings at 90, 50, and 10 degrees Fahrenheit for each finger joint assembly.

Because finger joints are open joints, elastomeric drainage troughs are required to prevent deicing chemicals and debris from spilling onto the ends of the beams, bearings, and substructure components. Locations of drainage outlets need to meet criteria for deck drains.

5.8.3.3.2 Detailing [AASHTO-LRFD 14.5.3.5]

All finger joint parts except trough hardware shall be galvanized.

Curb plates and barrier plate boxes at ends of finger joints shall not be shop welded to the finger joint assembly but shall be kept separate. After the deck is finished the plates and boxes shall be field welded in place and the galvanizing repaired by an approved method [CMB IM 410].

Give special attention to details of the finger joint anchorage system. For steel superstructures the joints should be rigidly connected to the stringers or girders.

The finger joint assembly should contain a galvanized shim plate pack to allow for field adjustment of the top of the finger joint at connections to all girders. The shim plate pack should be comprised of ¼-inch and 1/8-inch plates that allow for a minimum adjustment range of +/- ½-inch. The allowable adjustment range should be coordinated with the allowable haunch adjustments shown in the beam line haunch details.

Finger plate armor should be pierced with ¾ inch diameter vertical vent holes spaced not more than 18 inches on center in order to expel entrapped air. In lieu of hand packing of concrete under the armor per AASHTO-LRFD C14.5.3.5, the plans shall include CADD Note E910 which states that concrete shall be forced under and around the finger plate hardware. The note also requires localized internal vibration to consolidate the concrete.

For elastomeric drainage troughs, three aspects are of primary concern: sheet type, elastomer, and trough details. Sheet types should be low durometer (50 to 60) and synthetic fabric reinforced. Minimum thickness of the side curtains and the reinforced neoprene trough should be 1/4" [CMB IM 494].

To specify the elastomer, place the following standard note on the plans [CMB IM 494]:

> The elastomer compound for trough and curtains shall be in accordance with Table 4195.02-2 of Article 4195.02 of the Standard Specifications, except the tensile strength shall be 1500 psi minimum or it shall be Ethylene Propylene Diene Monomer (EPDM) (ASTM D 2000, Line call outs 3BA, 515, A14, B13, F17, C12, and K21).

Generally, the elastomeric drainage trough should be detailed as in Figure 5.8.3.3.2.

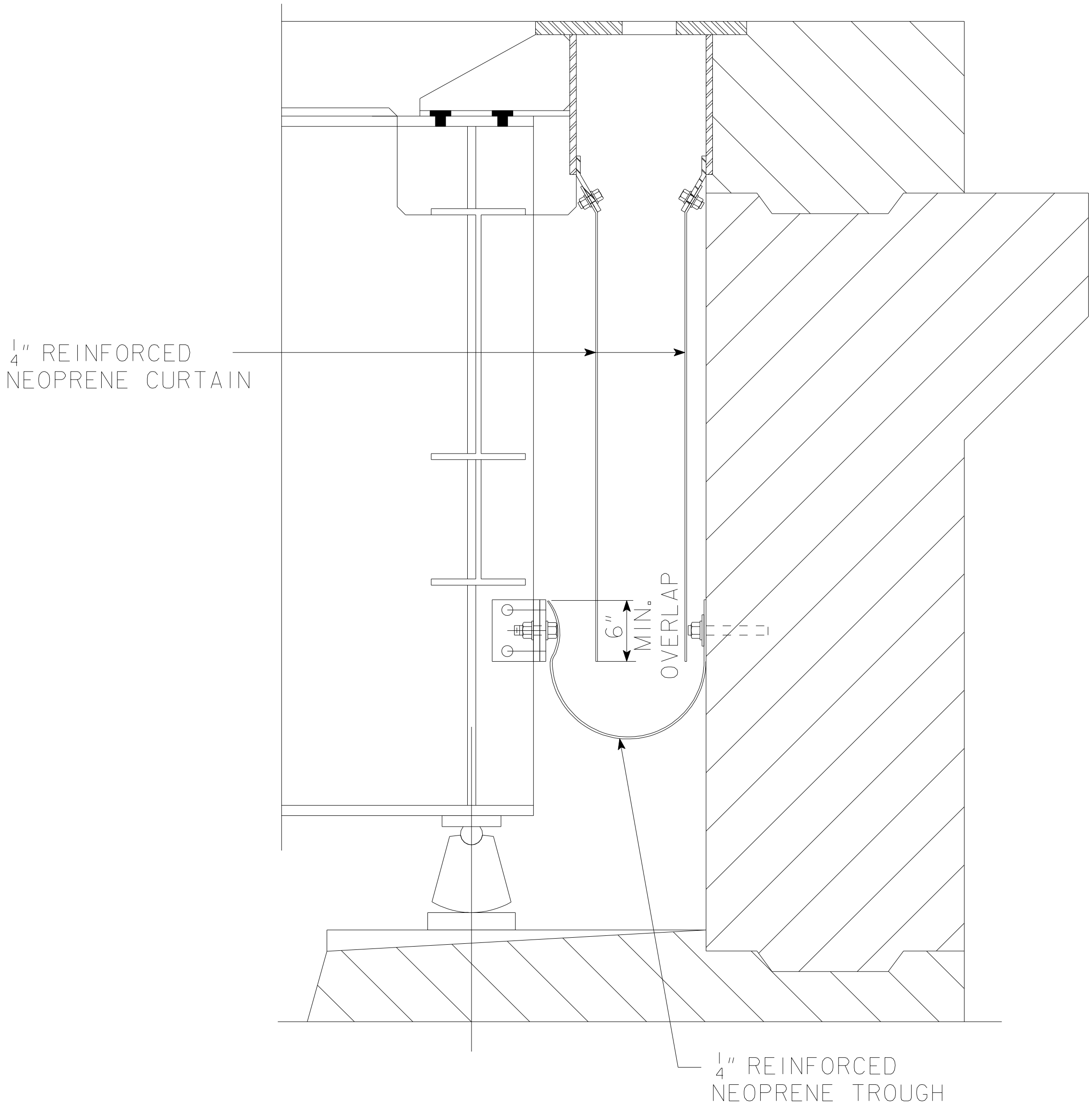

Figure notes:

- The toothed plates should be recessed ¼ inch below the deck surface as noted below.
- Although no shims are shown, a shim plate pack typically will be provided to adjust the elevation of the finger joint assembly with respect to the top flanges of the girders.

Figure 5.8.3.3.2. Finger joint with elastomeric drainage trough

To limit the possibility of debris accumulation, a minimum slope of 8% is required for the drainage trough. Drainage outlets should be at the gutter lines. Drainage troughs should be continuous full width of the bridge including curb and parapet area when the joint is over a pier or at an abutment and elsewhere where a closed drainage system is required. Keep the drainage trough continuous the full width of the bridge, where possible. If not, check with the supervising Unit Leader. If splicing of the elastomeric sheet side curtains is necessary, a minimum splice length (overlap) of 2 feet is recommended, overlap of the upstream sheet shall be on the inside relative to the downstream sheet.

The finished joint should be recessed ¼ inch to avoid damage by traffic or snow removal equipment.

All hardware, including bolts, studs, washers and concrete anchors, used to attach the trough shall be stainless steel. The trough should be attached in a secure manner with a minimum of 5/8 inch diameter bolts at 18 inch centers.

5.8.3.4 Tire buffing joints

5.8.3.4.1 Analysis and design

Typical integral abutments designed by the Bureau are intended to move with respect to the approach pavement. Consequently, there is need for an expansion joint between an integral abutment and portland cement concrete (PCC) approach pavement. The BE expansion joint used at an integral abutment [DB SRP BR series] includes a fill of tire buffings capped with a backer rod and a poured sealer. The list of approved sealers is included on the BR sheets. The BE joint size is 2 inches perpendicular to the abutment for setting temperatures between 40° and 80°F. The BE joint size and setting temperature applies to all integral abutment bridges meeting the requirements found in BDM 6.5.1.1.1. See BDM C5.8.3.4.1 for supporting calculations.

Reinforced approach slabs with the BE tire buffing joints should be included with all integral abutment bridge projects. In some cases, the first panel of the reinforced approach slab is tied to the abutment paving notch with stainless steel dowels [DB SRP BR-205 for CCS bridges]. As such, the approach slab moves with the bridge and the BE expansion joint is placed between the far end of the approach slab and a stationary sleeper slab. New bridges with semi-integral abutments often use tied approach slabs as well.

5.8.3.4.2 Detailing

See the Design Bureau plan for details of the tire buffing joint [DB SRP BR series].

5.8.3.5 Other joints

Reserved