Chapter 19

EXPANSION JOINTS

NDOT STRUCTURES MANUAL

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Chapter 19
EXPANSION JOINTS

LRFD Article 14.4 discusses bridge joint movements and loads, and LRFD Article 14.5 provides requirements for joints and considerations for specific joint types. This Chapter presents NDOT criteria for the design and selection of expansion joints in bridges.

19.1 GENERAL

19.1.1 Overview

Reference: LRFD Articles 14.4 and 14.5

The tributary expansion length equals the distance from the expansion joint to the point of assumed zero movement, which is the point along the bridge that is assumed to remain stationary when expansion or contraction of the bridge occurs. The location of the point of zero movement is a function of the longitudinal stiffness of the substructure elements.

Expansion joints in bridges are necessary to accommodate the expansion and contraction of bridges due to temperature variations. The following general criteria apply to all expansion joints in bridges:

1. General NDOT Practice. Bridges shall be designed to minimize the number of expansion joints because of their inherent operational and maintenance problems. Abutment seats tend to deteriorate due to leaky joints, to collect debris and to provide locations for animal and human habitation. The use of continuous structures minimizes the number of joints. As a consideration, when conditions permit, the designer may be able to eliminate the expansion joints and tie the approach slab into the superstructure, as suggested in Section 11.4.4. However, joints are always provided at the roadway end of approach slabs with an anchor or sleeper slab.

2. Consistency. Whenever possible, the bridge designer shall use the same type of joint and construction details used at the ends of bridges for locations of expansion at interior supports and in-span hinges.

3. Maintenance Problems. Many of the maintenance problems on bridges are the result of failed joints. Therefore, when joints are required, the selection, design and detailing of expansion joints are of critical importance. The potential for joint seal failure can be minimized by regular cleaning and timely maintenance.

4. Temperature Range. The bridge designer shall use Procedure A of LRFD Article 3.12.2.1 to determine the appropriate design thermal range. The minimum and maximum temperatures specified in Figure 19.1-A shall be taken as $T_{MinDesign}$ and $T_{MaxDesign}$, respectively, in LRFD Equation 3.12.2.3-1.

5. Recess Detail. Embedded steel elements, such as approach slab protection angles and strip seal expansion joint restrainers, shall be recessed ¼ in from finished grade. This recess provides protection from snow plow blades and accommodates milling of the concrete adjacent to the joints.

Region	Steel Bridges	Concrete Bridges
Outside of Clark County	-20°F to 105°F	0°F to 80°F
Clark County	20°F to 120°F	30°F to 100°F

LRFD PROCEDURE "A" TEMPERATURE CHANGES

Figure 19.1-A

6. Effects of Skew. The thermal movements of skewed bridges are such that asymmetrical movements ("racking") can occur along the length of the expansion joints. The movement is not solely in the longitudinal direction. The acute corners of a bridge with parallel skewed supports tend to expand and contract more than the obtuse corners, causing the joint to rack.

7. Other Geometric Considerations. Horizontally curved bridges and bridges with other special geometric elements, such as splayed girders, do not necessarily expand and contract in the longitudinal direction of the girders. Refined analysis of the entire bridge including superstructure and substructure elements may be necessary to characterize the thermal movement of complex bridges. The effect of thermal movements on the bearings of complex bridges could be more pronounced compared to bridges with simple geometrics. Refined analysis of horizontally curved, steel-girder bridges is recommended to estimate thermal effects because even slight curvature may develop large radial forces at bearings.

8. Blockouts. Provide blockouts in decks and approach slabs at expansion joints to allow for placement of the joint. The expansion joint assembly will be installed and the block-out concrete placed after profile grinding has been completed.

9. Cover Plates Over Expansion Joints. Cover plates shall be used over expansion joints at sidewalks. Where bicycles are anticipated in the roadway, the use of cover plates in the shoulder area shall be considered.

19.1.2 Estimation of General Design Thermal Movement, Δ_T

Reference: LRFD Article 3.12.2.3

The design thermal movement in inches shall be estimated by the following equation:

$$\Delta_T = \alpha L \left(T_{MaxDesign} - T_{MinDesign}\right) \quad \text{(LRFD Equation 3.12.2.3-1)}$$

where:

α = coefficient of thermal expansion, 6 x 10^{-6} for concrete bridges and 6.5 x 10^{-6} for steel girder bridges, in/in/°F

L = tributary expansion length, in

$T_{MaxDesign}$ = maximum design temperature from Figure 19.1-A.

$T_{MinDesign}$ = minimum design temperature from Figure 19.1-A.

19.1.3 Estimation of Design Movement

In addition to the thermal movement determined in Section 19.1.2, the effects of creep (CR) and shrinkage (SH) should be included in the total movement for prestressed concrete bridges.

For steel girder structures, creep and shrinkage effects are minimal and can be neglected in expansion joint design.

19.1.4 Setting Temperature

The designer shall determine gap widths at setting temperatures of 40°, 55°, 70°, 85° and 100°, consistent with the minimum and maximum temperatures at the bridge site. The gap widths should consider minimum gap widths and, for cast-in-place post-tensioned boxes, elastic shortening when appropriate. See the Design Examples in Section 19.3 for illustrations of typical calculations.

19.2 EXPANSION JOINT SELECTION AND DESIGN

19.2.1 General

Figure 19.2-A presents the typical application for several types of expansion joints used by NDOT. This Figure also provides the maximum joint movement and recommended usage.

The bridge designer determines the type of expansion joint and its required movement rating based on the expansion and racking demands, skew, gap widths and whether the joint is new or a retrofit. Gap width is the perpendicular distance between the faces of the joint at the road surface. Gap width does not directly apply to asphaltic plug joints. The minimum gap shall not be less than 1 in for steel bridges, as suggested in LRFD Article 14.5.3, but may be less for concrete bridges where creep and shrinkage must be considered. The maximum gap width should be 4½ in for strip seals and 3 in for individual components of modular joints.

Racking is the movement along the joint itself due to skew affects. It should be limited to 20% of the rated movement of the joint.

19.2.2 Strip Seal Joint

Reference: LRFD Article 14.5.6.7

A strip seal consists of a neoprene membrane (gland) rigidly attached to a steel restrainer on both sides of the joint. The material is premolded into a “V” shape that opens as the joint width increases and closes as the joint width decreases.

The strip seal expansion joint is NDOT’s preferred deck expansion joint system for new bridges with estimated total design thermal movements ranging from 1 in to 5 in. The contractor will select a strip seal joint from the Qualified Products List (QPL) that provides the estimated total design thermal movement for each joint.

Strip seal joints are watertight when properly installed. Under the best conditions, the life of a strip seal tends to be longer than that of other joint seals. However, these seals are difficult to replace, and splices in the membrane should be avoided. They can be damaged by snowplows, especially if the skew is 20° or greater.

Joint Type	Total Joint Movement (in)	Typical Usage
Strip Seal	≤ 5	New and Retrofit
Modular Expansion	> 5	Where large movements are anticipated
Preformed Filler	≤ 2	Typically only used for Retrofits
Asphaltic Plug	≤ 1	Typically only Used for Retrofits
Pourable Seals	≤ 1	Typically used for Retrofits and Longitudinal Joints

EXPANSION JOINT SELECTION

Figure 19.2-A

Where practical and where additional protection for bearing assemblies and hinges is warranted, a secondary sealing system may be provided below the expansion joint assembly.

19.2.3 Modular Expansion Joint

Reference: LRFD Article 14.5.6.9

Modular joints are expensive and may require significant maintenance. Therefore, in the selection of modular joint systems, use only those that have been designed to facilitate the repair and replacement of components and that have been verified by long-term in-service performance. It is critical that the contract documents include a detailed description of the requirements for a modular joint system.

NDOT only uses modular expansion joints where large movements are anticipated. The following will apply to the design of modular-type expansion joints:

1. Expansion Movement. Modular joints should only be considered where the anticipated total expansion movement exceeds 5 in.
2. Joint Support. The blockouts and supports needed for modular joint systems are large and require special attention when detailing. For modular joints supported from the top of the girder, a detail of the supporting device shall be shown in the contract documents.
3. Splices. Where practical, modular joints should be full length with no field splices across the roadway width. If a field splice is required for staged construction on a slab-on-girder bridge, the support girders should be spaced at a maximum of 2 ft from the splice location, which should be outside of the wheel path. The splice will be designed according to the manufacturer's recommendations.
4. Neoprene Seal. The neoprene seal, which is a strip seal gland in a modular joint, will be one piece across the roadway width, regardless of construction staging considerations.

19.2.4 Preformed Joint Filler

Reference: LRFD Article 14.5.6.6

NDOT practice is to use preformed joint fillers where anticipated movements are small. The movement capacity of this type of joint is dictated by the joint width at the time of installation. Preformed joint fillers are relatively easy to maintain because local joint failures can be repaired. This system can be bonded to concrete or steel surfaces.

Preformed joint fillers are available in a variety of materials including elastomeric compression seals and expansion foam. The contractor will select a preformed joint filler from the QPL that provides the estimated total design thermal movement for the joint. If a specific type of joint filler is required for a design, then it should be clearly defined in the contract documents. Movements up to 2 in can be accommodated with this type of joint. Some preformed joint fillers do not perform well due to racking; therefore, preformed joint fillers should not be used where racking exceeds 15% of the specified movement rating of the joint.

19.2.5 Asphaltic Plug Joint

Reference: LRFD Article 14.5.6.5

NDOT typically only uses an asphaltic plug for retrofit applications for total movements of up to 1 in. This joint system is a smooth, durable, load-bearing surface that uses a combination of polymer-modified asphaltic binder and selected aggregate. Its advantages include the elimination of any mechanical anchorage system, ease of placement, low maintenance and rideability. Its disadvantages include its non-flexibility in cold temperatures and its tendency to rut under heavy traffic and turning movements in hot weather.

19.2.6 Pourable Seals

Reference: LRFD Article 14.5.6.5

Traditionally, pourable seals are used on shorter spans and longitudinal joints where the movement is ½ in or less.

Currently available systems typically include pourable silicone sealer and polyethylene foam backer rod as joint filler. The silicone is a self-leveling, rapid-curing, two-component polymer material. The backer rod is squeezed into the joint opening to prevent the sealant from spilling through the joint and to form the shape of the sealer. The silicone sealant is poured into the opening on top of the backer rod. It is important that the joint edges be clean and sound so that the silicone bonds tightly. The thickness of the silicone at the center should be no more than half the width of the joint. The bottom of the silicone must not bond to the material below. Pourable seals perform best if the seal is poured when the ambient temperature (which must be above 40°F) is at the middle of the historical range or the joint opening is at the midpoint.

There are certain advantages to this type of seal. Unlike many premolded seals, the performance of pourable seals is generally unaffected by joint walls that are not perfectly parallel or perfectly vertical. It is also relatively easy to repair. If a short portion of the seal fails, it is easy to remove the seal, clean the walls and quickly refill the joint. This activity minimizes traffic disruption and work zone hazards.

19.3 EXAMPLE PROBLEMS

The following presents two example problems for the design of expansion joints.

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Example 19.3-1 — Cast-in-Place, Post-Tensioned Concrete Box-Girder Bridge

Given: Cast-in-place, post-tensioned concrete box-girder bridge (not in Clark County)
L = expansion length = 240 ft
θ = skew angle = 0°

CR + SH = 1.00 in

Portion of total creep and shrinkage occurring after joint setting.

Problem: Determine expansion joint movement requirements.

Solution: Estimated design thermal movement:

$$\Delta_T = \alpha L \left(T_{MaxDesign} - T_{MinDesign}\right) \quad \text{(LRFD Equation 3.12.2.3-1)}$$

For a concrete superstructure:

α = 6.0×10^{-6} in/in/°F
$T_{MaxDesign}$ = 80°F based upon the bridge location and Figure 19.1-A
$T_{MinDesign}$ = 0°F based upon the bridge location and Figure 19.1-A
Δ_T = (6.0×10^{-6} in/in/°F) (240 ft) (12 in/ft) (80° – 0°)
Δ_T = 1.4 in
Δ_{total} = Δ_T + CR + SH = 1.4 + 1.00 = 2.40 in (See Section 19.1.3)

A strip seal joint is acceptable because the estimated total design movement is within the range for strip seals.

Movements from setting temperature of 70°F:

1.4 in/(80°F – 0°F) = 0.0175 in/°F
Contraction (from 70°F to 0°F) = 1.23 in
Expansion (from 70°F to 80°F) = 0.18 in

Check the joint performance for both initial (without CR and SH) and final (with CR and SH) conditions:

<u>Initial Condition:</u>

Minimum joint opening @ 80°F = 1.50 in (least gap opening)
Joint opening at time of installation @ 70°F = 1.50 + 0.18 = 1.68 in

Final Condition:

Joint Opening @ 80°F = 1.50 + (CR + SH) = 1.50 + 1.00 = 2.50 in
Joint Opening @ 70°F = 2.50 + 0.18 = 2.68 in
Joint Opening @ 0°F = 2.68 + 1.23 = 3.91 in

Conclusion:

The gap width will vary from 1.5 in at 80° to 3.91 in at 0°. The strip seal must have a 4-in movement rating. The gap width at installation is 1.68 in, assuming 70°.

Using this Example, a table of installation gap widths can be developed to account for varying field temperatures during installation:

Setting Temperature	Gap Width
40°	2-3/16 in
55°	1-15/16 in
70°	1-11/16 in
80°	1½ in

Example 19.3-2 — Steel Girder Bridge with Concrete Deck

Given: Steel plate girders supporting a reinforced concrete bridge deck in Clark County
L = expansion length = 250 ft
θ = skew angle = 30°

Problem: Determine expansion joint movement requirements.

Solution: Estimated design thermal movement:

$$\Delta_T = \alpha L \left(T_{MaxDesign} - T_{MinDesign}\right)$$ (LRFD Equation 3.12.2.3-1)

For a steel superstructure:

$\alpha = 6.5 \times 10^{-6}$ in/in/°F
$T_{MaxDesign}$ = 120°F based upon the bridge location and Figure 19.1-A
$T_{MinDesign}$ = 20°F based upon the bridge location and Figure 19.1-A
Δ_T = (6.5 x 10^{-6} in/in/°F) (250 ft) (12 in/ft) (120° – 20°)
Δ_T = 2.0 in

A strip seal joint is acceptable because the estimated design thermal movement times the cosine of the skew angle (2.0 in (cos 30°) = 1.7 in) is within the range for strip seals.

Movements for setting temperature of 70°F:

2.0 in/(120°F – 20°F) = 0.02 in/°F
Contraction (from 70°F to 20°F) = 1.0 in
Expansion (from 70°F to 120°F) = 1.0 in

Joint openings (normal to the joint) @120°F = 1.5 in (assumed minimum gap):

@ 70°F = 1.5 in + (0.02 in/°F)(120°F – 70°F)(cos 30°) = 2.37 in

@ 20°F = 1.5 in (assumed minimum gap) + 2.0 in (estimated design thermal movement) x (cos 30°) = 3.23 in

Minimum nominal seal width to accommodate racking:

Using a 4-in strip seal, the amount of racking that can be accommodated:

Maximum allowed racking normal to seal = 4.0 x 0.20 = 0.80 in
Corresponding movement parallel to joint = 0.80/sin 30° = 1.6 in
Corresponding temperature range = 100° x (1.6/2.0) = 80°
Minimum installation temperature = 120° – 80° = 40°
Maximum installation temperature = 20° + 80° = 100°

Conclusion:

The gap width of the seal varies from 1.5 in to 3.2 in. A 4-in strip seal would be required for longitudinal movement. Racking requires limiting the installation temperature to between 40° and 100°. The gap width at 70° installation is 2.37 (2⅜) in.

Using this Example, a table of installation gap widths can be developed to account for varying field temperatures during installation:

Setting Temperature	Gap Width
40°	2⅞ in
55°	2⅝ in
70°	2⅜ in
85°	2⅛ in
100°	1⅞ in

Do not install joints outside of this temperature range.