SECTION 14
JOINTS AND BEARINGS

14.1 GENERAL REQUIREMENTS

Joint and bearing systems shall be designed to accommodate all calculated movements and loading expected throughout the life of the bridge. Joints and bearings shall also be designed to accommodate regular maintenance activities that will prolong the life of these devices.

14.2 CODE REQUIREMENTS

Unless otherwise noted, the design of joints and bearings shall be in accordance with the latest AASHTO, as supplemented by the *AASHTO Guide Specifications for LRFD Seismic Bridge Design,* where applicable.

Long-term concrete properties, including creep and shrinkage strains, shall be determined in accordance with AASHTO. ***AASHTO 5.4.2.3.1***

14.3 UNIFORM TEMPERATURE MOVEMENT

Bridges are subject to heat transfer from the ambient air temperature and radiant heat from direct sunlight. Bridges of different structure types react at different rates, with concrete structures reacting more slowly due to a larger thermal mass than that of steel structures, making them less susceptible to large temperature swings over a short amount of time.

Variations in the average temperature of the bridge superstructure result in thermal expansion and contraction. Maximum and minimum anticipated temperatures over the life of the structure shall be used for design.

Temperature ranges for either Procedure A or B (preferred) may be used for structures designed in accordance with AASHTO 3.12.2, along with the appropriate load factors provided in AASHTO Table 3.4.1-1. Temperature gradient may be considered where appropriate in accordance with AASHTO 3.12.3.

14.4 EXPANSION JOINTS

14.4.1 General

Bridges shall be capable of accommodating movements, rotations, and deformations imposed on the structure through temperature changes, concrete creep and shrinkage, and shortening due to applied loading. Expansion joints shall also accommodate both bridge skew and curvature and have adequate maintenance access.

Other possible sources of joint movement and rotation include, but are not limited to, live load (such as braking), wind, seismic loads, and settlement. Movements from these force effects vary based on code requirements, bridge configuration, and the complexity of the bridge and shall be considered as appropriate.

Expansion joint devices shall prevent water, deicing chemicals, and debris infiltration to the substructure elements below. Expansion joints shall also provide a relatively smooth riding surface between approach pavements and the structure, or adjacent structural elements.

The Designer is responsible for giving adequate thought to the type, size, and performance of the selected expansion joint system to ensure that the appropriate system is used on the structure.

When the skew angle is greater than or equal to 30^o, the Designer shall consider placing the expansion joint normal to the roadway alignment to prevent snowplow damage.

Due to maintenance concerns with expansion joints, it is preferred to implement jointless construction wherever possible. Jointless construction uses integral or semi-integral abutments and piers to eliminate expansion joints on the bridge superstructure. A joint at the end of the approach slab shall be used to accommodate movement and to prevent damage to the roadway pavement as defined in 14.4.2.

Refer to BDM Section 11.3 for additional information on integral abutments and approach slab requirements.

14.4.2 Design Guidelines and Selection

The need for an expansion joint will be determined based on the amount of bridge movement (determined from design) and roadway approach type. Bridges with total temperature movement (expansion plus contraction) of ¾ in. (which typically corresponds to a bridge length of about 150 ft.) or less are not required to have expansion joints at substructure locations or at the ends of approach slabs, unless the roadway approach is concrete pavement. When the roadway approach is concrete pavement, an expansion device shall be required between the end of the approach slab and the roadway approach despite the amount of bridge movement in order to deal with the concrete pavement growth, unless approved by Unit Leader in coordination with the Expansion Joint SMEs. In lieu of a strip seal joint, a silicone seal joint or compression seal joint may be used between the end of the approach slab and the roadway.

For non-complex straight bridges with no skew, the total movement shall be determined by using AASHTO 3.12.2 and 14.5.3.2. For complex bridges, movement calculation shall include consideration for superstructure type, contributing length, structure curvature, construction phasing, fixity condition between superstructure and substructure, superstructure rotations, and substructure stiffness. Skews, horizontal and vertical alignment, grade, and cross slopes shall be considered when selecting and designing a joint system. This can be accomplished by finite element analysis, modeling soil as springs, calculating depth of fixity based on soil/structure interaction analysis, etc.

Wherever practical, expansion devices shall be installed in preformed concrete block-outs after completion of the bridge deck. The installed expansion gap shall correspond to the ambient temperature at the time headers are placed. The plan sheets shall include installation gaps sizes and corresponding temperatures for the range recommended by the manufacturer.

14.4.3 Small Movement Joints

Small movement joints are not recommended when total movement is greater than 2 in. The total movement shall be determined in accordance with AASHTO 14.5.3.2. These joint systems shall not be used for new construction on Interstate Highways or State Highways without Unit Leader in coordination with Expansion Joint SMEs approval.

14.4.3.1 Asphaltic Plug

Asphaltic plug joints consist of modified asphalt installed in a preformed block-out over a steel plate and backer bar. These joints provide a smooth riding surface that is built to match the adjacent roadway.

Due to observed creep and poor expansion performance of these joints, CDOT does not recommend asphaltic plug joints on Interstate Highways, State Highways with high traffic counts, or roadways with heavy trucks. Therefore, use of asphaltic plug joints requires approval from Unit Leader in coordination with Expansion Joint SMEs approval.

14.4.3.2 Silicone Seals

Silicone seals are flexible, poured sealants designed to provide a watertight expansion joint seal in both new and rehabilitation projects. Silicone sealants allow good elastic performance over a range of temperatures; provide self-leveling installations; can be installed against non-parallel surfaces; and bond without the use of additional adhesives.

Silicone seals shall be considered for rehabilitation projects where long-term closures are not acceptable or where rehabilitation on the joint header is not possible, thereby eliminating compression seals as a viable option.

Silicone seals shall be installed such that the maximum tension movement is no more than 100 percent of the install width and the compression movement does not exceed 50 percent of the install width. Silicone seals shall be installed a minimum of ¼ in. below the pavement surface to minimize contact with crossing tires.

Installation gaps shall not be less than 1 in. at 60° F.

Figure 14-1: Silicone Seal

14.4.3.3 Compression Seals – Elastomeric or Foam

Compression seals are continuous manufactured elastomeric or foam elements, typically extruded with an internal grid system. These joints shall be installed against prepared concrete or steel faces with adhesive material and may or may not be armored.

Foam elements shall be comprise of a precompressed, silicone and foam hybrid system. Generally, foam joint systems come in stick lengths between 6 and 7 feet and are installed into field-applied epoxy adhesive on the joint faces. The sticks are easily joined in the field with silicone to accommodate the total gap length. Additional silicone sealant bands are applied to the joint faces and are tooled to a cove-bead to provide a watertight seal.

Elastomeric compression seals shall be furnished and installed as a single continuous piece across the full width of the bridge deck. Field splices are not allowed. Termination in median barriers is recommended on wide bridges.

The maximum gap shall not exceed 2 in. at -30° F to prevent damage from debris and wheel loads.

Compression seals are not allowed on bridges with skew angles exceeding 15°. This is due to past performance and improper joint sizing to accommodate the transverse movement component.

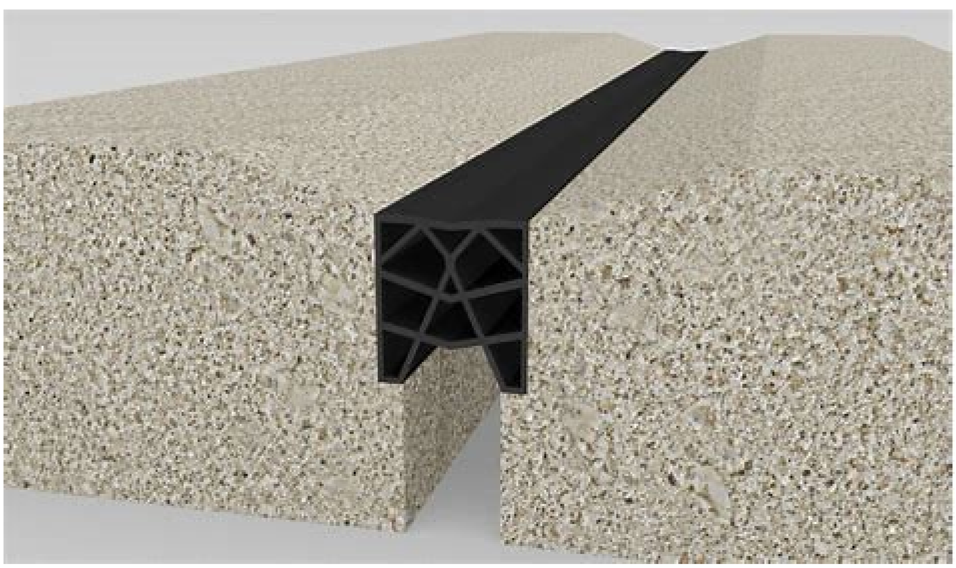

Figure 14-2: Compression Seal - Elastomeric

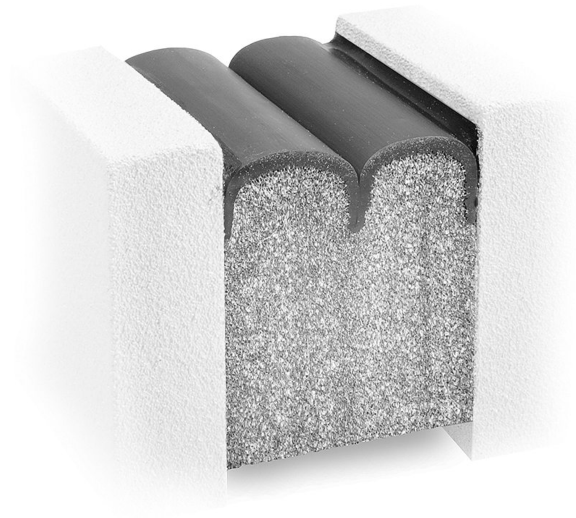

Figure 14-3: Compression Seal - Foam

14.4.3.4 Saw-Seal Joint

A saw-seal joint shall be placed in the top of asphalt and polyester polymer concrete (PPC) overlays when expansion joints are not used at the following locations:

- Interface between the bridge deck and approach slab
- Interface between the approach slab and roadway approach pavement

Saw-seal joints control cracking in the overlays and reduce potholes, which increase the likelihood of water intrusion in the deck.

14.4.4 Strip Seals

Strip seal systems consist of a preformed neoprene gland mechanically locked into steel edge rails embedded into concrete on both sides of an expansion gap. Strip seal joints provide a cost-effective joint system that allows easy neoprene gland replacement when needed.

The use of epoxy bonded strip seal joint systems is not allowed on new construction.

Strip seal steel rail components shall be installed as one continuous length where possible due to maintenance concerns. It is preferred to have the steel rail component of the strip seal be supplied in as long of pieces as possible based on phasing and slope changes to minimize the number of field splices. Horizontal angle changes in the expansion joint exceeding 35° shall be avoided so that the factory requirement of vulcanizing the strip seal corners is not necessary.

Strip seal neoprene glands shall be installed as one continuous length to provide a watertight joint sealing system.

Strip seals are the preferred joint alternative for bridge lengths greater than 250 ft. because they have proven to provide the best long-term performance. Strip seals shall be used for all new construction where the total joint movements are expected to be 4 in. or less and the skew is less than or equal to 25°. For joints between ¾ to 2” of movement, small movement joints may be used with Unit Leader’s approval in coordination with Expansion joint SMEs. If the skew is greater than 25°, oversized glands shall be considered subject to the conditions below.

Unit Leader in coordination with Expansion Joint SMEs will approve the use of oversized glands, but oversized glands may be considered under the following conditions:

- Total factored joint movement does not exceed 5 in.
- Factored cyclical (Thermal) joint movement does not exceed 3.5 in.
- Modular joints are not practical due to joint lead time during construction.
- Use of oversized glands allows the bridge to require joints at the ends of approach slabs only.

Due to life-cycle maintenance costs with oversized glands in comparison to modular joints, the use of oversized glands shall not be made based solely on initial construction cost alone but also consider the durability of the joints. Evaluate on a case-by-case basis.

Appendix A contains a design example for a strip seal expansion.

14.4.5 Modular Joints

Modular joints are complex structural assemblies that consist of multiple pre-molded neoprene strip seals held into place by separate extruded steel beams. These joints are designed for movements greater than 4 in. The use of modular joints should be avoided by designing multiple strip seals if possible. For new bridges, use of modular joints needs Unit Leader approval. Modular joints shall not be placed at either end of approach slabs due to maintenance and inspection concerns.

Modular joints shall be designed by the manufacturer to the latest AASHTO requirements for fatigue and fracture. The Contractor shall submit to the Engineer of Record calculations signed and sealed by a Colorado Professional Engineer, along with the shop drawing, for review and acceptance I prior to fabrication. The Designer shall be responsible for ensuring this requirement is in the project specifications.

Modular joints shall be specified in 3 in. increments, with 6 in. being the minimum. In addition to thermal movements determining the size of joints, manufacturers have gap requirements that may increase the size of the required joint. For example, a 0 in. to 9 in. joint may be required where movement indicates that a 0 in. to 6 in. joint is feasible. The Designer shall check manufacturer's requirements before final sizing.

Modular expansion joints shall be installed as one continuous unit due to maintenance and manufacturer concerns. Field splicing of modular joints is not allowed without Unit Leader in coordination with Expansion Joint SMEs approval. Where field splicing is required, all splices shall be fully welded or hybrid welded/bolted splices. Fully bolted splices are not allowed.

14.4.6 Finger Joints

Finger joints can be used to accommodate moderate to high movement ranges. Finger joints can also accommodate minor rotations and vertical displacements across the joint. Finger joints are fabricated from steel plate, with the fingers sized to maintain minimum spacing and to minimize live load deflections. Fabricated sections shall be less than or equal to 6 ft. to allow maintenance access. A taper shall be fabricated on each finger to ease the transition between plates and to minimize the potential for snowplow damage.

To provide a watertight seal, finger joints require the installation of an elastomeric or metal trough to capture water and convey it away from the substructure. Without proper and routine maintenance, these trough systems clog and lead to water damage to the joint and substructure below. For this reason, finger joints shall be limited to replacement of existing finger joint expansion devices only.

14.4.7 Cover Plates

14.4.7.1 Sidewalk Cover Plates

Expansion joints shall be extended across all sidewalks and into the bridge rail. Accessible sidewalks shall have expansion joints covered with Americans with Disabilities Act (ADA) compliant cover plates. Cover plates may be fabricated or proprietary but shall comply with the latest ADA requirements. ADA compliant expansion joints installed at the top of the sidewalk shall not have cover plates.

Cover plates shall not protrude above the walking surface by more than ½ in. and shall be installed flush with the walking surface whenever possible. Where cover plates protrude more than ¼ in. above the walking surface, a 2:1 edge taper shall be provided.

Cover plates shall have an anti-slip surface treatment such as treads and roughened surfaces. These surfaces shall be galvanized.

14.4.7.2 Bridge Rail Cover Plates

Bridge Rail and bridge rail curbs shall have removable steel cover plates to provide continuity of the bridge rail over the expansion joint and to protect the expansion joint embedded in the bridge rail. See the CDOT Staff Bridge Structural Worksheets for bridge rail for cover plate details.

14.4.8 Joint Headers

Expansion joint headers shall be the same material as the bridge deck or better products approved by the Unit Leader in coordination with the Expansion Joint SMEs. They shall be installed ¼ in. above the top of the expansion system and even with the final roadway surface.

When using modular joints or replacing finger joints, the Engineer of Record shall be responsible for ensuring that the provided block-out can accommodate the specified joint system, regardless of manufacturer.

The use of accelerated mix designs and bagged mixes is allowed per the requirements of Concrete Class DR.

14.4.9 Expansion Joint Details

CDOT Staff Bridge provides Structural Worksheets for 0 to 4 in. expansion joints, modular expansion joints, and asphaltic plug joints.

14.5 BEARINGS

14.5.1 General

Bridge bearings transfer permanent and transient loads from the bridge superstructure to the substructure. These loads can be vertical (e.g., dead load or live load) and horizontal (e.g., wind, braking, or seismic). Bearings shall also accommodate anticipated movements (e.g., thermal/creep/shrinkage) and rotations. When bearings and expansion joints are collocated, movements allowed by bearings shall be accommodated by adjacent expansion joint systems, which requires that bearings and expansion joints be designed interdependently and in conjunction with the anticipated behavior of the overall structure.

Several bearing types are available that can achieve the above requirements, including elastomeric bearings (plain and reinforced); polytetrafluoroethylene (PTFE) sliding bearings; and High-Load Multi-Rotational (HLMR) bearings (pot, spherical, and disc bearings). Each bearing type differs in regard to vertical and horizontal load carrying capacity, displacement capacity, and rotational capacity. Understanding the properties of each bearing system is critical for economical selection of bearing systems or the elimination of bearings in favor of integral connections of the superstructure to the substructure.

14.5.2 Design Guidelines and Selection

Where bearings are required, the following bearings shall be used unless otherwise approved by Unit Leader in coordination with the Bearing SMEs through the Structure Selection Report process:

- CDOT Type I (plain or steel reinforced elastomeric bearing pads)
- CDOT Type II (PTFE sliding elastomeric bearings)
- CDOT Type III (pot or disc bearings)
- CDOT Type IV (rocker plate with elastomeric pad)
- CDOT Type V (rocker plate with PTFE)

All bearings shall be the same size and type at each substructure unit. This is due to potential damage from differing deflection and rotational characteristics. Bridge superstructure units (e.g., superstructure limits between expansion joints) requiring Type III bearings shall use Type III bearings for the entire superstructure unit except where the superstructure is integrally connected to the substructure (e.g., integral abutments and fixed piers with integral pier diaphragms).

14.5.3 Thermal Movement

All bridges with bearings shall be designed for a thermal movement range determined in accordance with AASHTO 3.12.2 and factored using AASHTO Table 3.4.1-1, plus the effects of creep, shrinkage, and post-tensioning, if applicable. When designing the elastomer for Type I and Type II bearings, the 65 percent reduction of the design thermal movement range shall not be used. This allows the bridge to be constructed on the hottest day of the year without having to reset the bearings after construction is complete.

When the erection temperature of the bridge is known or if a special provision to verify/adjust the position of the bearings after the completion of the bridge is included in the construction specifications, the application of the 65 percent reduction in the design thermal movement may be used.

AASHTO 14.7.5.3.2

14.5.4 Additional Rotation Requirements

CDOT follows the AASHTO requirement that adds a tolerance of 0.005 rad. to the calculated rotations of the structure to account for uncertainties in the fabrication and placement of the bearings. Section 512.11 of CDOT's Standard Specifications for Road and Bridge Construction provides a flatness tolerance for the bearing seat location, which is included in this tolerance.

AASHTO 14.4.2

14.5.5 Design Coefficient of Friction Requirements

PTFE sliding surfaces can be effective in reducing the friction coefficient between the bearing and the sliding surface. When the temperature is cold, the coefficient of friction can increase dramatically. CDOT uses a range of friction values in the design of bridges to cover the variations in the coefficient of friction that the structure may see during its life. A minimum coefficient of friction shall be 0.02, and the maximum coefficient of friction shall be taken from AASHTO. The maximum coefficient of friction shall be based on the Dead Load only case for determining the compressive stress on the PTFE.

AASHTO Table 14.7.2.5-1

14.5.6 Bearing Inspection and Removal

All bridges shall be designed such that the bearings can be inspected, and if necessary, the bearings can be removed without special tools. Normal girder construction typically provides access to the bearings from both the front and the sides of the bearings. These access locations shall be kept clear whenever possible. Cast-in-place concrete box girder bridges are the hardest to inspect and replace the bearings. Pedestals for bearings shall be used whenever practical.

The bridge plans shall provide all structural elements necessary to jack and support the bridge for bearing replacement. This may consist of a block-out in the superstructure diaphragm, corbels, or steel jacking brackets bolted to the substructure. The design of the jacking system shall be based on using either 50-ton or 100-ton jacks, which are commonly used in Colorado. The minimum size of 50-ton jacks is 6 in. high by 8 in. in diameter. The minimum size of 100-ton jacks is 8 in. high by 10 in. in diameter. Designing for these sizes ensures that most jacks that differ from these sizes will still fit the designed structural element supporting the jack. Only one size of jack shall be used at each substructure location. If multiple jacks are required or a jacking block-out in the diaphragm is used, an additional 3 in. horizontally shall be provided for the hydraulic jack hoses. Bearings shall be designed to be removed with a jacking height of ¼ in. or less. Other commonly used and available jacks with reduced height requirements may be used with Unit Leader in coordination with the Fabrication/Construction Unit approval.

Jacking the bridge under live load is not permitted without Unit Leader in coordination with the State Bridge Engineer and Fabrication/Construction Unit approval. Live load may be placed on the bridge provided that temporary blocking is in place or the jacks are securely locked out. The substructure plans shall state this policy and show the Service Loads for Dead Load, Live Load, and Live Load plus Dynamic Load Allowance.

14.5.7 Leveling Pads

Leveling pads are plain elastomeric pads used for locked-in-girders at integral substructures and shall be thick enough to prevent girder-to-support contact due to anticipated girder rotations up through and including the deck pour. Leveling pads shall be designed for dead loads only using AASHTO Design Method A. Rotation restrictions other than preventing girder-to-support contact shall not be considered. Compressive stress and stability during construction shall be checked in accordance with BDM Section 5.5.1.2. A Shore A durometer hardness of 60 shall be used in the design. Normally these pads are ½ in. thick and may be up to 1 in. thick.

AASHTO 14.7.6

Appendix A includes a leveling pad design example.

14.5.8 Type I Bearings

Type I bearings that are plain pads may be designed using AASHTO Design Method A. The minimum Shore A hardness shall be 60 durometer.

Type I bearings that are steel reinforced elastomeric pads shall be designed using AASHTO Design Method B. If approved by Unit Leader in coordination with the Bearing SMEs, AASHTO Design Method A may be used for light to moderately loaded steel reinforced elastomeric bearings if determined to be more economical based on eliminating the testing and quality control costs required for AASHTO Design Method B. The minimum low-temperature grade of elastomer shall be Grade 3.

AASHTO 14.7.5

The minimum bearing height shall be 2 in. to facilitate inspection and removal of the bearing. The bearing height shall be limited to 6 in. based on constructability and cost-effectiveness.

Appendix A includes reinforced Type I Bearing design examples.

14.5.9 Type II Bearings

A Type II bearing is a Type I bearing with a bonded PTFE surface with a stainless steel mating surface to provide the necessary horizontal displacement capacity for the bridge. The elastomeric portion of the bearing shall meet the requirements of a Type I bearing. The sliding surfaces shall meet AASHTO requirements.

AASHTO 14.7.2

The Structural Design Engineer shall verify that the stiffness of the elastomeric pad is sufficient to enable the sliding surface to engage without excessive pad deflection.

AASHTO 14.7.5.3.2

Appendix A includes a Type II bearing design example.

14.5.10 Type III Bearings

Type III bearings shall consist of HLMR bearings and are a special design for each bridge. These bearings shall follow the AASHTO specifications for pot bearings and disc bearings. Disc bearings are preferred to pot bearings.

AASHTO 14.7.4 & 14.7.8

The minimum bearing height shall accommodate minimum jacking spacing required for the readily available jacks. This requirement is applicable to any other bearing type that is desired to be replaceable or reparable.

14.5.11 Type IV & V Bearings

Type IV and V Bearings consist of rocker plates on top of elastomeric pads with and without sliding surfaces. These bearings are not typically used but may be an option.

14.5.12 Bearing Details

CDOT Staff Bridge provides Structural Worksheets for Type I, II, III, IV, and V bearings.

All bearings shall be installed on a level concrete surface. In the direction of movement, the minimum length of the concrete surface (beam seat) shall be the maximum of the following:

- The dimension of the bearing in the direction of consideration, plus 50 percent of the maximum horizontal displacement (Δ_o) on each side, or 50 percent of the minimum longitudinal plan dimension of the bearing, whichever is greater
- The minimum support length for the seismic design requirements of AASHTO 4.7.4.4

The size of the level concrete surface is to provide the ability to adjust the position of the bearing in the future and to provide adequate beam seat width for seismic displacement. Unit Leader shall review all deviations from the aforementioned seat width requirements, such as a narrower beam seat with a recessed bearing.

The plans shall clearly show the orientation of guided bearings along the bent line.

Sole plates and masonry plates shall be a minimum of ¾ in. thick at the edges of the plate.

Sole plates and bearing top plates shall be oversized 2 in. longitudinally (1 in. in each direction) to accommodate construction tolerances.

Because Type III bearings are dependent on the manufacturer of the bearing, they are generally shown schematically on design drawings. The Structural Design Engineer shall be responsible for coordinating with bearing suppliers and/or manufacturers when Type III bearings are required.

If slotted holes are needed in bearing top plates for anchor bolts in the direction of structure movement, they shall be sized for the maximum horizontal displacement (Δ_o). Slots shall be oversized a minimum of 1 in. (½ in. in each direction) or 1 anchor bolt diameter, whichever is greater.

Anchor bolts in sole plates may be omitted if an alternate transverse restraint is provided. Sole plates without anchor bolts shall be a minimum of 2 in. wider than the bearing device or the girder to accommodate construction tolerances.

14.6 SHOP DRAWINGS

The Structural Design Engineer shall review shop drawings for all fabricated bearing and joint elements. Particular attention shall be paid to Type II and Type III bearings and modular expansion joints. The Contractor performing the work shall submit modular joint calculations. Working drawings for 0 in. to 4 in. expansion joints shall be reviewed as time allows to avoid possible construction issues. In addition, compatibility between the bearings and the joint elements shall be checked. The Structural Design Engineer shall be responsible for reviewing calculations submitted with the shop drawings. The review verifies that calculations, shop drawings, and design drawings are compatible and in compliance with AASHTO and the BDM.