3.14 Expansion Joints and Bridge Bearings

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Typographic Conventions:

The typographical convention for this manual is as follows:

Non italic references refer to locations within the KDOT Bridge Design Manuals (either the LRFD or LFD), or Hyper links shown in red, as examples:

- Section 3.2.9.12 Transportation
- Table 3.9.2-1 Deck Protection

Italic references and text refer to locations within the AASHTO LRFD Design Manual, for example:

- *Article 5.7.3.4*

Italic references with a LFD label and text refer to locations within the AASHTO LFD Standard Specifications, for example:

- *LFD Article 3.5.1*

3.14 Expansion Joints and Bridge Bearings

3.14.1 General

Expansion joints and bearings provide mechanisms to accommodate movements of bridges without generating excessive internal forces. This section provides guidance on joint and bearing selection and the movement and loads that must be used in their designs. See Section 3.3.4.4 for Thermal Force Considerations.

To determine movements for bearings and joints, the point of fixity must be established for the bridge or bridge unit. The point of fixity is the neutral point on the bridge that does not move horizontally as the bridge experiences temperature changes. Use the following guidance in determining bridge fixity:

- For single span structures, fix the bearings at the low end of the bridge by using an integral abutment or as conditions allow use a integral abutment on both ends of the bridge.
- For two span structures, fix the bearings at the pier and use integral abutments if possible.
- For multi span structures on steep grades, use an integral abutment, if possible, on the low end. Also consider fixing the first pier from the low end to anchor the structure.
- Structures with three or more spans need to be examined with respect to the longitudinal stiffness of the bridge. The longitudinal stiffness is a function of the interaction between pier stiffness, bearing types and joint locations. See Appendix 3.14.A Longitudinal Temperature Forces and Movements for an example.

The number and location of expansion joints is determined based on a maximum joint opening of 6 in. in the bridge.

- Each bridge or bridge unit shall have fixed bearings at a minimum of one pier to provide increased resistance to longitudinal movements.
- Consider providing fixed bearings at tall pier locations. Some tall or flexible piers may deflect prior to mobilizing the translational capacity of the bearing.
- A combination of fixed, expansion and limited expansion bearings can be provided at the piers to accommodate the movements for the bridge or bridge units.

When joint openings exceed 6 in., three options are available:

1. The preferred option is to provide additional joints at the piers splitting the superstructure into units.
2. A 'shelf type' hinge may be placed at the dead load inflection point of an interior span.
3. On very rare occasions, and with prior approval, provide modular expansion joints at bridge ends only.

Mechanical Expansion Device

Predicting joint movement is an inexact science. It is essential that the joint movement be provided for in the design. Bridges are not constructed under conditions where close tolerances can be maintained. In addition to movements caused by thermal effects, such factors as creep, shrinkage, moisture content, abutment rotation, and live load rotations can affect the resulting movements. Therefore, to select an expansion device with a movement capacity too close to the thermal effects only, would not be conservative. For finger, sliding plate, or modular devices, provide a movement equal to the value calculated for thermal requirements plus at least 1 inch. This extra allowance is a seating tolerance for field installations. Base movements due to variation in temperature shall be based upon the requirements of *Article 3.12.1* for cold climate using Procedure A. Provide a joint setting schedule for mechanical expansion devices. Show joint openings for a temperature range from 45^{o}F to 90^{o}F in 15^{o}F increments. Use a reference temperature of 60° F.

3.14.2 Expansion Joints Types and Usage

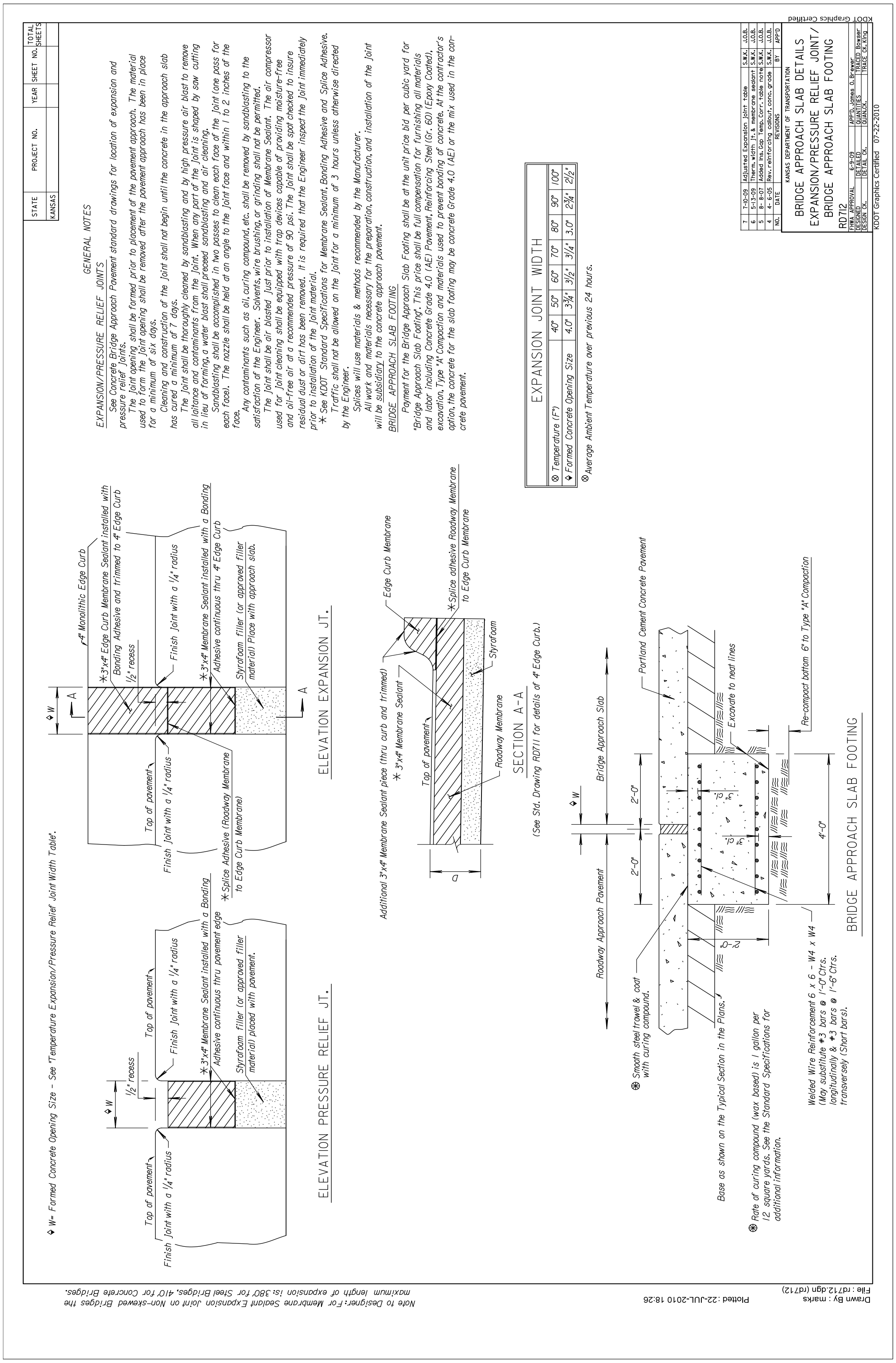
The use of an expansion device on a bridge can result in a maintenance problems in the future. It is KDOT policy to use integral or semi-integral abutments and locate the expansion joint on the approach pavement instead. Approach pavement joints are to be used for steel bridges with length of expansion up to 380 ft., and for concrete bridges with length of expansion up to 410 ft. in length.

Where conditions require an expansion device on the bridge, at a unit break in the structure, or when the approach slab joint has been exceeded, use an armored strip seal, finger plate, or sliding plate with a trough. Modular expansion joints are difficult to install and maintain and have been less than reliable. Prior approval by the State Bridge Office is required for modular joints. All expansion joints on bridge decks shall be watertight and prevent deck drainage through the deck onto the substructure elements.

3.14.2.1 Membrane Sealant

For movements resulting in openings up to 4 inches the use of a “Membrane Sealant” type expansion device is preferred, see Figure 3.14.2.1-1 Membrane Sealant for details. Install the expansion joint “Membrane Sealants” in the approach slab without armoring whenever possible. Where expansion joints are located on the bridge deck, use armoring to protect the bridge deck from spalling. “Membrane Sealant” expansion joints are placed in units which are five foot in length. This will accommodate large roadway widths or staged construction. When using membrane sealant-type joints in integral or semi-integral abutments use the gap vs. temperature table on Road Standard RD712 along with the standard size joint detailed on the standard.

Figure 3.14.2.1-1 Membrane Sealant



3.14.2.2 Finger Plate/ Sliding Plate

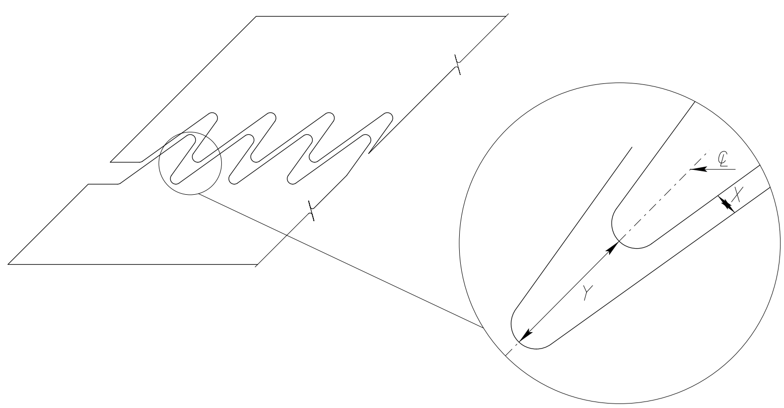
For larger movements, 4 inch opening and larger , use steel finger plate see Figure 3.14.2.2-2 Finger Plate Expansion Device or steel sliding plate-type expansion devices see Figure 3.14.2.2-3 Sliding Plate Expansion Device. For skewed structures, a sliding plate expansion device is recommended.

Sliding plate type joints have alignment and durability advantages over other more complex joints and should be used when ever possible. Bevel the ends of the sliding plates which make up the sliding plate assembly to reduce the impact and provide a smooth transition. The bevel also acts as a self-cleaning mechanism.

As an aid to designers, finger plate expansion joint geometry equations can be found at Appendix 3.14.B Finger Joint Geometry . Use the maximum gap shown below in accordance with *Article 14.5.3.2*.

Finger plate and sliding plate devices are used with a fabric trough to collect drainage. On the plans, do not specify a material thickness for the fabric trough material. The Special Provision covers the material thickness of the fabric trough. The fabric trough should be sloped as steep as possible to drain, as a minimum will be 1.0 in./ft. per *Article 14.5.6.3*. Where possible use large open ended fabric trough drains. Where the trough can come into contact with the structure, bond additional fabric material to resist abrading. At the exit end of the drain bond an additional strip on the outside of the trough to stiffen the fabric.

Figure 3.14.2.2-1 Maximum Finger Plate Gap



Article 14.5.3.2

Partial Plan of Finger Joint

Showing Maximum Gaps

Maximum Opening *

$X \leq 2''$ when $Y > 8''$

or

$X \leq 3''$ when $Y < 8''$

Figure 3.14.2.2-2 Finger Plate Expansion Device

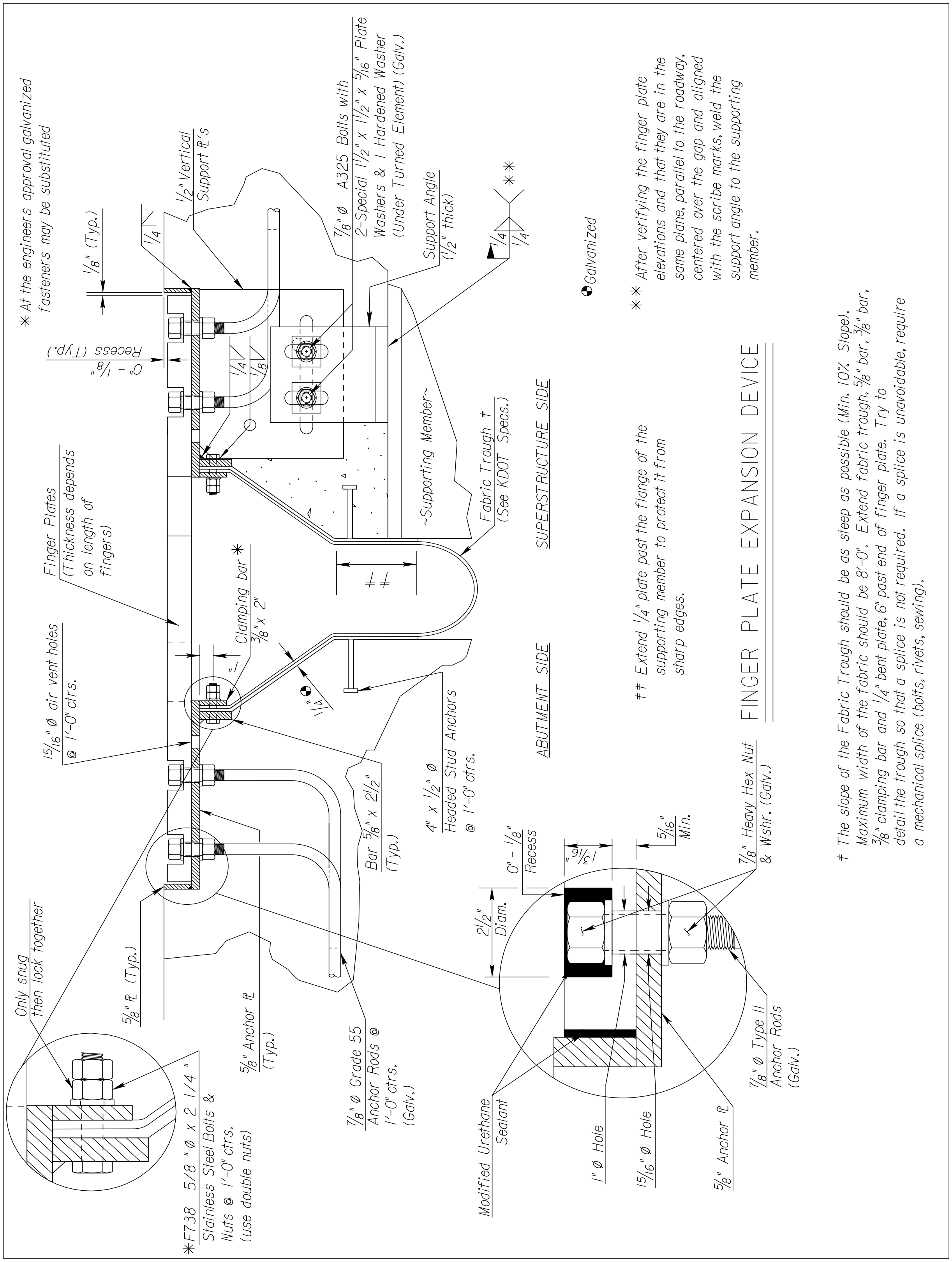


Figure 3.14.2.2-3 Sliding Plate Expansion Device

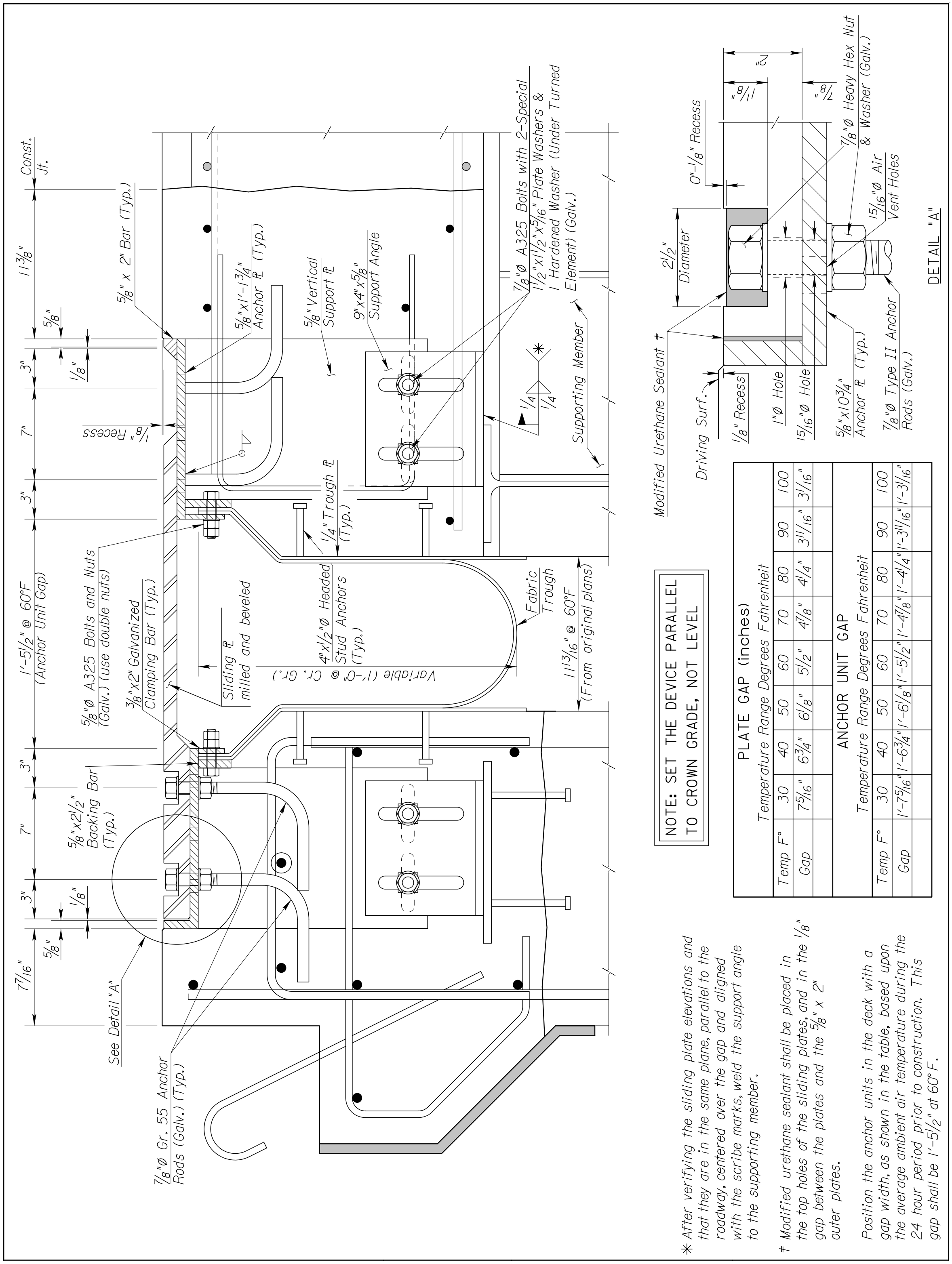


PLATE GAP (inches)

Temperature Range Degrees Fahrenheit								
Temp F°	30	40	50	60	70	80	90	100
Gap	7 5/16"	6 3/4"	6 1/8"	5 1/2"	4 7/8"	4 1/4"	3 11/16"	3 1/16"

ANCHOR UNIT GAP

Temperature Range Degrees Fahrenheit								
Temp F°	30	40	50	60	70	80	90	100
Gap	1'-7 5/16"	1'-6 3/4"	1'-6 1/8"	1'-5 1/2"	1'-4 7/8"	1'-4 1/4"	1'-3 11/16"	1'-3 1/16"

* After verifying the sliding plate elevations and that they are in the same plane, parallel to the roadway, centered over the gap and aligned with the scribe marks, weld the support angle to the supporting member.

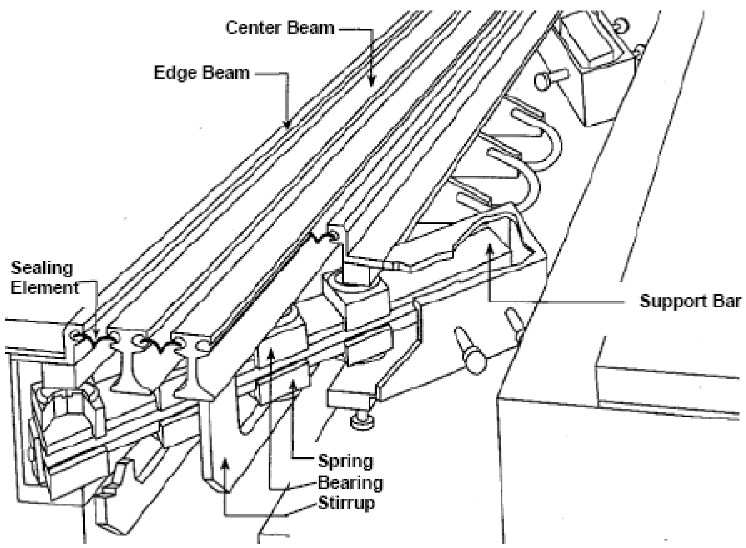
‡ Modified urethane sealant shall be placed in the top holes of the sliding plates, and in the 1/8" gap between the plates and the 5/8" x 2" outer plates.

Position the anchor units in the deck with a gap width, as shown in the table, based upon the average ambient air temperature during the 24 hour period prior to construction. This gap shall be 1'-5 1/2" at 60°F.

3.14.2.3 Modular Joint

Modular expansion joints shall be used when dividing the bridge into units will not reduce the joint expansion to less than 6 in. Provide joint setting schedules with modular joints. Conventional modular joints are one-directional units. Bridges with skews or horizontal curvature may require the use of "swivel" modular joints. Swivel modular jointsThese accommodate lateral movement as well as longitudinal movements. Modular joints have additional requirements, defined by *Article 14.5.6.9,* that do not apply to other joint types. Adhere to this criteria when designing this type of expansion joint. Modular joints must be approved for use by KDOT Bridge Office, prior to final plan submittal.

Figure 3.14.2.3-1 Modular Expansion Device

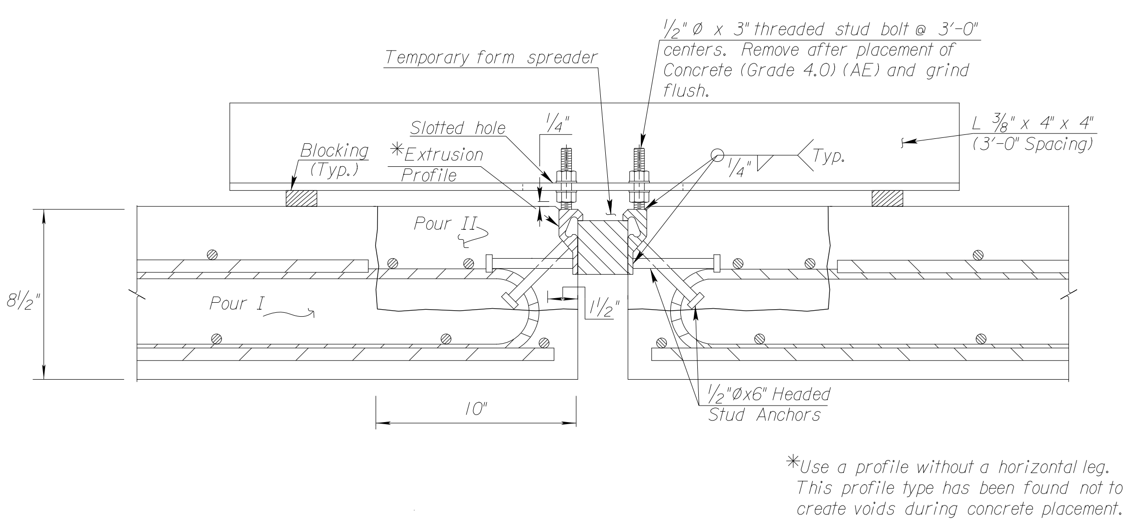


3.14.2.4 Strip Seal Assembly

For new structures, strip seal assemblies are used by KDOT primarily when other bridge expansion layouts using integral or semi-integral abutments cannot accommodate the required movements. The maximum joint opening strip seal is 4 inches without a skew. For skewed bridges reduce the allowable joint size as a percent of the skew angle. When used, details similar to Figure 3.14.2.4-1 Strip Seal Expansion Device (Preferred Details) should be incorporated into the plans. Use armored strip seal assemblies with headed stud anchors welded to the armoring. Do not use elastomeric concrete for new construction. Recent issues have limited its use to repairs only. When detailing strip seal joint types, use extrusion without a horizontal leg on the armoring angles. Armoring angles required pressure epoxy to be used after the joint is constructed. Failures of strip seal joint is almost exclusively due to lack of consolidation of the concrete (air voids) under or behind the armoring angle or shrinkage of the grout. In either case, premature failure of strip seal assemblies is likely. Strip seals used on skewed structures must be designed by considering the "skew effects" when sizing the joint. The extrusion and anchorages will be blasted and prime-coated with inorganic zinc everywhere except in the gland cavity. Paint in the gland cavity prevents the adhesive from bonding.

As seen in the Figure 3.14.2.4-1, two concrete pours with a block out is required. These two pours contain the same grade of concrete. This will facilitate the use of an erection angle supported by the previously cured (Pour I) concrete. The reinforcement details shown below tie the block-out second pour (Pour II) to the bridge deck concrete.

Figure 3.14.2.4-1 Strip Seal Expansion Device (Preferred Details)



3.14.3 Expansion Joints Structural Design

In Kansas, it is likely that at some time a strip seal, sliding, finger plate or modular joint will be struck by a snow plow. Recess the joint 3/8 in. to minimize the impact effects for modular, sliding plate and strip seal. Finger Joint fingers we ground were the joint crosses the roadway crown. According to *Article 14.5.1.2*, for structures with bridge skew angles greater than 20^{o} degrees, the engineer will, as a minimum, design the joint to resist 0.120 kip/in for a total length of 10 ft. the snow plow impact load, is applied perpendicular to the edge beam or anchorage. For joint skew angles between 30^{o} and 35^{o} apply the requirements of *C14.5.3.3* or increase the loading, as this is the range for most snow plowing operations in Kansas.

Barrier rails shall be plated when the maximum expected gap exceeds 4 inches. Corral rails shall be plated when the maximum expected gap exceeds 3 inches. At discontinuities in the bridge railing, reduce the confinement reinforcement spacing to 4 inches maximum on either side of the joint, for a distance equal to the height of the rail on either side of the joint.

For finger plate expansion devices the minimum overlap for the fingers is 1.5 inches at the Strength Limit State per *Article 14.5.3.2*.

Where there is a sidewalk on the structure with an expansion device passing through it, plate over the opening in compliance with the Americans with Disabilities Act Accessibility Guidelines.

The dynamic allowance for finger or sliding plate assemblies is 75% per *Article 3.6.2.1-1.*

3.14.3.1 Expansion Joint Details

- Galvanize all parts.
- The rails and armoring for expansion devices should be fabricated from Grade 36 or Grade 50 steel and be supported vertically to serve as an end form for the deck concrete. <u>Weathering steel and aluminum extrusions will not be used.</u>
- The horizontal anchorage lugs should be located at least 3 in. below the deck surface.
- Air vents, according to *Article 14.5.3.5,* will be provided in all the flat surfaces of the device to prevent voids from forming during concrete placement. The plans will require sounding anchorages for voids, drilling the anchorages (every 18”) and pressure epoxy the voids when found.
- All seals should be continuous across the width of the bridge with watertight joints and be sloped per *Article 14.5.6.3*.

• Finger Joints and Sliding Plates:

a) Hold-down bolts: Use Gr. 36,55,105 AASHTO M314 as specified in the Standard Specifications (Subsection 1615).
b) Minimum bend diameter of Anchor Bolts: For 3/4" bolts, the minimum distance from the bottom of the threads to the PC of the bend is 1 in. Likewise, for the 7/8 in. bolt, the minimum distance is 1¾ in. Select the largest pin diameter which will provide the required "thread to PC tangent distance" and concrete cover. Specify the pin diameter in increments of 1/4" with an absolute minimum of 2 in. for Gr. 55 (type II) material.
c) Use Gr. 36 or 50 material in finger plates assemblies, except as noted in d).
d) For all fingers and sliding plates specify Charpy testing: M270(T3) Steel.
e) Use 5/8" diameter (ASTM F-1554)Gr. 36 bolts for attaching the fabric trough to the device. Double nut (jam nut) the connection through the fabric and trough. Do not use Stainless Steel the threads which gall creating installation problems.
f) If the fabric trough requires a splice, lap and bond downhill or at center line. Add an additional layer of fabric (in strips) to the outside of the trough at girder locations were rubbing can occur. Also, add an additional strip on the outside near the discharge end to stiffen and maintain its shape.
g) Provide as much slope as possible in the trough for drainage and cleaning. For wide bridges have the high point at the centerline and drain to both sides.

h)At abutments use anchor details similar to Figures 3.14.2.2-1 and -2.

• Expansion devices shall be bid by the linear foot. Clearly define on the details the limits of pay length for all expansion devices. Out to out of bridge deck is suggested practice.

• Erection angles <u>are required</u> for all strip seal, sliding plate, finger plans and modular devices and are to be shown on the plans. These construction temporary support angles are <u>Subsidiary</u> to the device and remain property of the contractor.

3.14.4 Bearing Device General

Bearing devices are designed to transmit the loads from the superstructure to the substructure and to provide for expansion and rotation of the superstructure. The device must be able to accept the loadings which may occur simultaneously from several directions. The bearings must also resist and transmit to the substructure the force effects from live loads, braking forces, temperature change, centrifugal force, wind force and in certain cases a percentage of the dead and live load for seismic considerations. The bearing design should be easy to maintain or require minimum maintenance. Consideration should also be given to the future need to jack girders to repair or maintain bearing devices. Per *Article 14.6.1* include the design load magnitude and direction for each device on the plans; identify and use Service I Limit State for this purpose.

Rockers movements, and tendency to tip under seismic actions shall be considered in the design. For seismic restrain, when a portion of the dead and live load is to be resisted by the bearing devices, bearings that can tip or slide for thermal translation offer little resistance in that direction. Avoid relying on one pier to resist all of the seismic forces. Anchoring the structure at an integral abutment is the preferred method. Consider a cable or tie rod external longitudinal restraint only when other options have been investigated and will not be practical. Consider tying bridge units together at hinge locations.

For structures that are horizontally curved, the thermal expansion will cause a translation movement along a chord from the fixed bearing location to the bearing in consideration. The degree of horizontal curvature and the type of device being used are the key factors to determine this effect. Investigate the need for bearing alignment to be other than orthogonal. Provide a table for the layout and alignment of the bearing devices if required. Check the resultant rotation of the conventional type elastomeric device for horizontally curved bridges. If the translation and rotation are inadequate, a multi-rotation type bearing like a pot bearing, should be used.

KDOT's preference for bearing devices is conventional reinforced elastomeric type devices or elastomeric PTFE slider type devices. Past performance indicates a properly designed and installed device of this type performs better than other bearings.

The bearings shall be designed in accordance with AASHTO LRFD Specifications unless otherwise noted. Provision for temperature change and rotation of the supports due to deflection of the span should be made for all simple spans having a clear length greater than 50 feet. For continuous bridges, provision should be made in the design to resist thermal induced changes. If not practical, the bearing must accommodate movement caused by temperature changes. Expansion or contraction movement may be provided by hinged or flexible columns, steel rollers or rockers, sliding bearing plates, plain or laminated elastomeric pads, or prefabricated disc or pot bearings.

Bearing devices utilizing steel masonry plates will have a lead, elastomeric or cotton duck mat placed between the concrete and the masonry plate. Bevel the sole plate for grades > 1.0%.

Bearing devices are to be designed with the distribution factor for shear using the interior or exterior beam, whichever controls. The impact factor to be used for joints and bearings is 1.75 as per *Article 3.62*. Elastomeric devices need not consider live load impact. The phi factor for all bearing devices is taken as 1.0 per *Article 14.6.1*.

3.14.5 Material

Steel:

Do not use weathering steel in rocker bearing, pot bearing, bolster devices, or backing plates bonded to Teflon or welded to stainless steel. Painted ASTM A709 Gr. 36 or Gr. 50 is generally used.

Gr. 70 is not available in non-weathering steel and Gr. 100 is difficult to get in small quantities. If a high strength material is required (higher than Gr. 50), ASTM A514 is a suitable non-weathering material that comes in Gr. 90 and Gr. 100, and is available in small quantities. Sole plates may be made of weathering steel when used with elastomeric expansion devices.

When specifying stainless steels for use in bearing devices, use the following designations (both designations may be required on the plans):

- ASTM A240 Type 304 for plates.
- ASTM A276 Type 304 for bars and shapes.

When specifying mild steel for pins used in the construction of steel bearings, specify ASTM A108 Gr. 1018 for pins 4 in. or less in diameter.

For pins greater than 4 in., *Article 6.4.2* of the AASHTO specifies steel forgings as per ASTM A668. Steel forgings are not guaranteed to be weldable, therefore only use the ASTM A668 specification for pins which are not to be welded.

For pins greater than 4 in. which are to be welded, specify ASTM A572 Gr. 42 (max 6 in. plates) or Gr. 50 (max 4 in. plates). Two plates can be welded together in the shop and machined into two half pins. Therefore, two 6 in. plates can produce two half pins with a maximum diameter of 12 in. Likewise, two 4 in. plates can produce two half pins with a maximum diameter of 8 in..

Corrosion Protection: For mechanical bearing devices use stainless steel for the half-pin, shoe and cradle. When the limit of practicality is reached for stainless steel use mild steel. Prime the entire device with inorganic zinc and top coat all surfaces except the contact surfaces. The bearing surfaces receive a dry film lubricant (graphite) to reduce the friction.

Bearing Seat Mats:

A lead mat, cotton duck, or neoprene pad is required between the steel masonry plate and the concrete surface to provide uniform distribution of load.

Sliding Surfaces:

Use dimpled non-lubricated virgin unfilled teflon.

Anchor Bolts:

Type I and Type II anchor bolts are now designated as AASHTO M314 Grades 36, 55 or 105 when Grade 36 is specified a weldable Grade 55 is an acceptable replacement.
Old Type I = Gr. 36
Type II = Gr. 55
= Gr. 105
Use ASTM A563 nuts and ASTM F436 washers.

All anchor bolts, nuts and washer will be galvanized. Anchor bolts are swagged according to KDOT Standard Specification 1615.

Guides:

Use ASTM A 709 painted or galvanized materials for guides.

3.14.7 Sliding Bearings

When the thermal expansion exceeds 3 inches, a polytetrafluoroethylene (PTFE) Teflon/Stainless Sliding bearing device or commonly called a PTFE slider bearing should be used if possible. PTFE bearings with elastomeric devices are common and have performed well when installed correctly. See Figure 3.14-8 Example- TFE Elastomeric Bearing Device for details.

The PTFE mating surface is polished stainless steel sheet material with a minimum of ¼ inch thick. The stainless steel sheet and the PTFE are attached to backing surfaces. See Figure 3.14-8 Example- TFE Elastomeric Bearing Device for details.

Recess the surface of the PTFE into its steel substrate one-half of the PTFE thickness. This will eliminate excessive creep or plastic flow in the TFE which could lead to separation or bond failure. In addition, confining the PTFE permits the use of a higher contact stress.

The PTFE material shall be a minimum of 1/4 in. thick and recessed into the base plate 1/8 in. Do not bond the TFE to the recessed area. Dimple the TFE with 5/16 in. diameter holes 1/16 in. in depth.

Paint the masonry plate, sole plate and the TFE backing plate with organic zinc primer and, top coat with water bourne acrylic. Add a note on the plans indicating that the entire device will be masked off prior to blasting, priming or painting the girders in the field.

Sliding steel plates, other than TFE sliding bearings, are not used because of the probability they will corrode, freeze, and become maintenance problems. For short span bridges, a satisfactory detail can be made by providing a steel bearing plate and rounded steel plate for rotation. Other sliding bearings include self-lubricating bronze, copper-alloy or teflon-coated plates. Teflon-coated bearings should be chamfered at the ends and held securely in place by being inset into the metal of the pedestals or sole plates. Provisions shall be made against accumulation of dirt which will interfere with free movement of the span.

3.14.8 Roller, Rocker, and Pedestal Bearings

Do not use rocker type bearing in areas where the seismic restraint is required or where a plastic hinge is detailed due to seismic design category per Section 3.3.4.8 of KDOT's LRFD Bridge Design Manual.

KDOT does not use rollers for expansion on new structures at the present time. Both the pedestal (bolsters) and rocker will have a pin attached to the bottom of the beam or girder to compensate for the rotation due to deflection. For rockers, a pintel, either internal or external, is required as part of the design to force the device to tip rather than slide on the masonry plate. Per *Article 14.8.2*, beveled sole plates should be used to uniformly distribute the load to the bearing plate when in the final permanent position the angle between the sole plate and masonry plate is equal to or greater than 1 degree.

The overhang section of the bearing plate should be designed as a cantilever and stresses kept within the factored resistance limits. Per *Article 5.7.5* at the Strength Limit State the concrete stress under masonry plates shall be limited by *Equation 5.7.5-2*. It has been KDOT policy to require a 3 in. minimum edge clearance between the masonry plate and the outside face of the concrete.

Rockers should have a diameter as large as practical with a minimum of 6 in. The contact stresses, at the service limit state, should be computed by *Article 14.7.1.4*. The designer must check the movement on rockers to be sure when the rocker translates horizontally it does not bind the pin plate and cradle or tip the rocker past the limit of stability. The rocker must be free to move within the factored limits without binding. Beyond the required limits, "failure" is to occur in this order:

- first the pintle contact,
- second the pin plate to cradle contact
- and last the excessive tipping of the shoe on the masonry plate.

Check vertical distance between top of rocker and flange when at maximum movement. See Figure 3.14-6 Rocker Clearance(See 3.14.E Rocker Clearance Calculator) for procedure and See example 3.14.E Rocker Clearance Calculator also download Rocker Clearance Calculator Program with section 3.14.

For computation of friction force in bearings, see Figure 3.14-13 Expansion Bearing Friction.

The bearing surfaces of pins, rockers, and base plates shall be finished according to *Table 18.1.4.2-1 of the AASHTO Bridge Construction Manual*.

Use Bridge Notes NOT6630 and NOT6640 for instruction to the field on painting and lubrication/ protection of the bearing device during installation.

3.14.9 Elastomeric Bearing Devices

An elastomeric bridge bearing device is constructed partially or wholly of elastomer for the purpose of transmitting loads and accommodating movements between a bridge and its supports. The reinforced elastomeric bearing device is considered appropriate for many types of bridges and can accommodate a wide range of span lengths. These devices should be limited to thermal movements of 3 in. Because these devices can not be corrected for the temperature the entire temperature range should be used. KDOT does not use reduction factors for elastomeric devices use the full temperature range without any reductions. Use AASHTO's method A for all elastomeric bearing designs, and limit the height of the device to 6 in. if possible. Use method B only if method A will not work or if the device is larger than 6 in. in height. Designs of elastomeric bearings include plain pads, reinforced bearings (consisting of layers of elastomer restrained at their interfaces by integrally bonded steel plates), bearings of external steel load plates bonded to the upper or lower elastomer layers, spherical dome bearings and pot or floating bearings.

Plain Pads:

Plain elastomer pads should be used only where small horizontal movements are expected. Plain pads used primarily as leveling pads for locked-in girders need only be thick enough so the bottom of the girder does not come in contact with the edge of the concrete. The minimum thickness of these pads shall be ¾" and the durometer (D) equal to 60. When computing the allowable compressive stress ($G \cdot S/\beta$) of thin, plain leveling pads, use $\beta = 1$. The allowable compressive stress need not be taken less than 500 psi. Beveled plain pads may be used up to 4.0 percent slope. See Section 3.5.2.11 in the KDOT LRFD Bridge Design Manual for additional discussion on the use of plain pads on prestressed girder bridges.

Elastomeric Bearing Devices:

Reinforced Elastomeric Bearing devices consist of internal steel plates which are bonded to the rubber during the molding process. The plates develop tensile stress when the bearing is subjected to compressive load and they restrain the bulging of the rubber. This provides greater compressive and rotational stiffness and controls the vertical deflection and rotation of the bearing. Horizontal movement is permitted by shearing deformation of the rubber, and for a given total rubber thickness, it is unaffected by the presence of reinforcement. Because there is no adjustment in the field, the designer will size both the slotted hole, and the device for the full temperature range.

Elastomeric bearing devices are designed for compression, deflection, rotation, shear, and stability. The maximum relative compressive deflection across a joint should not exceed 1/8", this refers to expansion joint locations. The live load deflection is limited to prevent snow plows from snagging. The rotational limit in *Article. 14.7.6.3.5* limits all points on the bearing remain in compression when it is subjected to simultaneous compression and rotation. Shear deformations are limited to 0.5T to prevent rollover at the bearing corners and reduce the potential for delamination of the steel reinforcement. When computing shear forces to be transferred to the substructure, take into account that lower temperatures increase the shear modulus and thus increase the shear force.

AASHTO currently allows two methods for designing Elastomeric Expansion Devices, Method "A" or Method "B"; Method "A" is preferred by KDOT. Use Method "A" unless circumstances require a bearing with less bearing area and more flexibility. See Appendix C for 3.14.C Elastomeric Bearing Design Example (Method A) for further information.

Design Method "B" is intended for higher compressive stresses and more slender bearings. Bearings designed by Method "B" must be subjected to more rigorous testing. The plans must show what method was used for design to indicate more stringent testing is needed on the bearings.

The Designer must verify that the method used for design appears on the Shop Drawings.

Use the following note and verify in shop detail review:

NOT2223 BEARING (TFE/ELASTOMERIC)(Method _):
Bearing devices at abutment(s) X and pier(s) X shall be fabricated with an elastomer satisfying:
- Shear Modulus of XX psi @ 73F, tested and reported per AASHTO M -251, Section 8.8.4
- Shore A Durometer Hardness of XX
- Low Temperature Grade 3 requirements
- Type A certification for elastomeric bearing device acceptance is required

*** Use either "A" or "B". Bearings designed by Method "A" are preferred. Designer must fill in X and the __ for the particular bearing design
*** For Method "A" design remove bullet item for shear modulus, for Methods "B" design remove bullet item for shear hardness.

The reinforcement shall consist of steel plates (fabric not allowed) and shall be designed for tension as per *Article 14.7.5.3.5*. The KDOT minimum thickness of the reinforcing plates shall be 1/8". Holes in plates should be avoided. KDOT Specifications cover the steel types allowed for the reinforcement, and therefore, unless there is reason to use a different type steel, it is not necessary to call out the type on the plans.

The elastomer shall be neoprene with a durometer of 60 unless a TFE sliding surface is used, in which case a durometer of 70 should be used for method "A". Tapered elastomer layers shall not be used. For Method "B" use a maximum shear modulus of $G \leq 175$ PSI.

A load plate should be vulcanized to the laminated bearing and attached to the beam to equally spread the load on the pad. Tapered load plates may be used to reduce eccentricity on the bearing. The load plate may be attached to the bearing seat or girder by bolts or welding. When welding the load plate to the girder, use a minimum 1 in. thickness of load plate. This thickness is needed so the bond between the pad and the sole plate is not compromised when the plate is welded to the girder flange.

Adhesive bonding is not recommended for attaching the bearing to the bearing seat or girder, because cold bonding of rubber is not reliable.

Designers should provide accommodations to inspect, repair or replace shallow elastomeric bearings, including: a provision for jacking the girders. Check all details and address constructability, functionality, and maintenance issues. It is critical for elastomeric devices to be adequately loaded, or equip them with “keepers” to prevent them from “walking out”.

Place elastomeric pads on a raised concrete step. The reinforced step shall be a minimum of 3 in. and a maximum of 8 in. high.

3.14.10 Other Bearing Devices

Other types of bearings associated with the elastomeric bearings are the pot bearings, or “float” type.   The principle characterizing pot bearings as different from other types is the structure “floats” on a specially designed hydraulic cylinder in which the “liquid-like” medium is an elastomer. Pot bearings allow for rotation, deflection, and horizontal movement for high loads. These bearings are available with self-aligning features, which make them adapted to use on curved or skewed bridges. The basic rotational element can be combined with a Teflon-Stainless Steel sliding surface to allow translation in structures with or without guide bars to control the direction of movement. Because of the high pressures the coefficient of friction between these sliding surfaces is generally less than 0.06. <u>Do not use weathering steel for pot bearings.</u>

If grout bearing pads are used, they shall be a minimum of 1 in. thick. Use steel plates for thickness less than 1 inch. If more than one steel plate is needed, use a seal weld to connect the plates.

3.14.11 Hardware

<u>Anchor Bolts:</u>

Configure the details of the Bearing Device to allow practical and convenient filling of the anchor bolt well.

Detail the reinforcing bars below the bearing devices to clear the anchor bolts. Preformed anchor bolt holes are an advantage for keeping the pier cap reinforcing steel out of the anchor bolt area. Use corrugated polyethylene tubing to form holes so the anchor bolts will not pull out. Place a note on the plans requiring the holes to be filled with glycol alcohol if the temperature is below freezing.

For flexibility of construction, on steel rockers or bolsters, use field-welded lugs on the masonry plate. Construction practices and thermal changes can create problems in the fit-up of girders. The bearing plates may need field adjustment and welded lugs facilitate this correction

See Figure 3.2.4-5 Alignment of Bearing Devices for alignment of bearing devices on curved bridges.

For expansion type devices, detail the threads on the anchor bolt so it is impossible to tighten down on the shoe plate or sole plate and restrict rotations.

Retainers:

Angle type retainers are preferred to long anchor bolts through the sole plate. See Figure 3.14-7 Example-Elastomeric Bearing Device for details. Option (B) should be used when the height of the device exceeds 5 inches or large lateral forces exist.

Side retainers are to be designed for all appropriate limit states including the transfer of a percentage of the live and dead load if so required by KDOT's seismic detailing requirements.

Figure 3.14-6 Rocker Clearance(See 3.14.E Rocker Clearance Calculator)

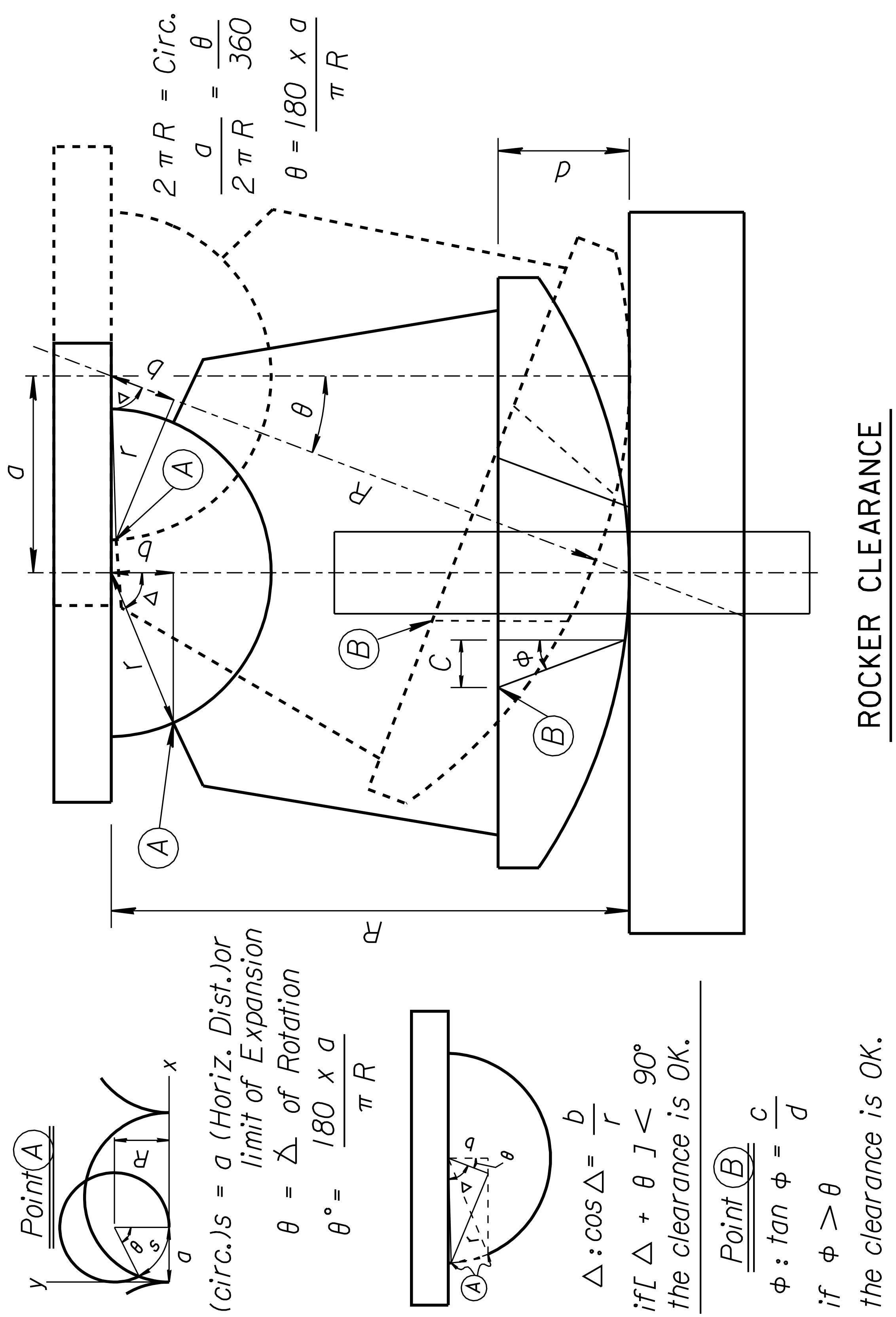


Figure 3.14-7 Example-Elastomeric Bearing Device

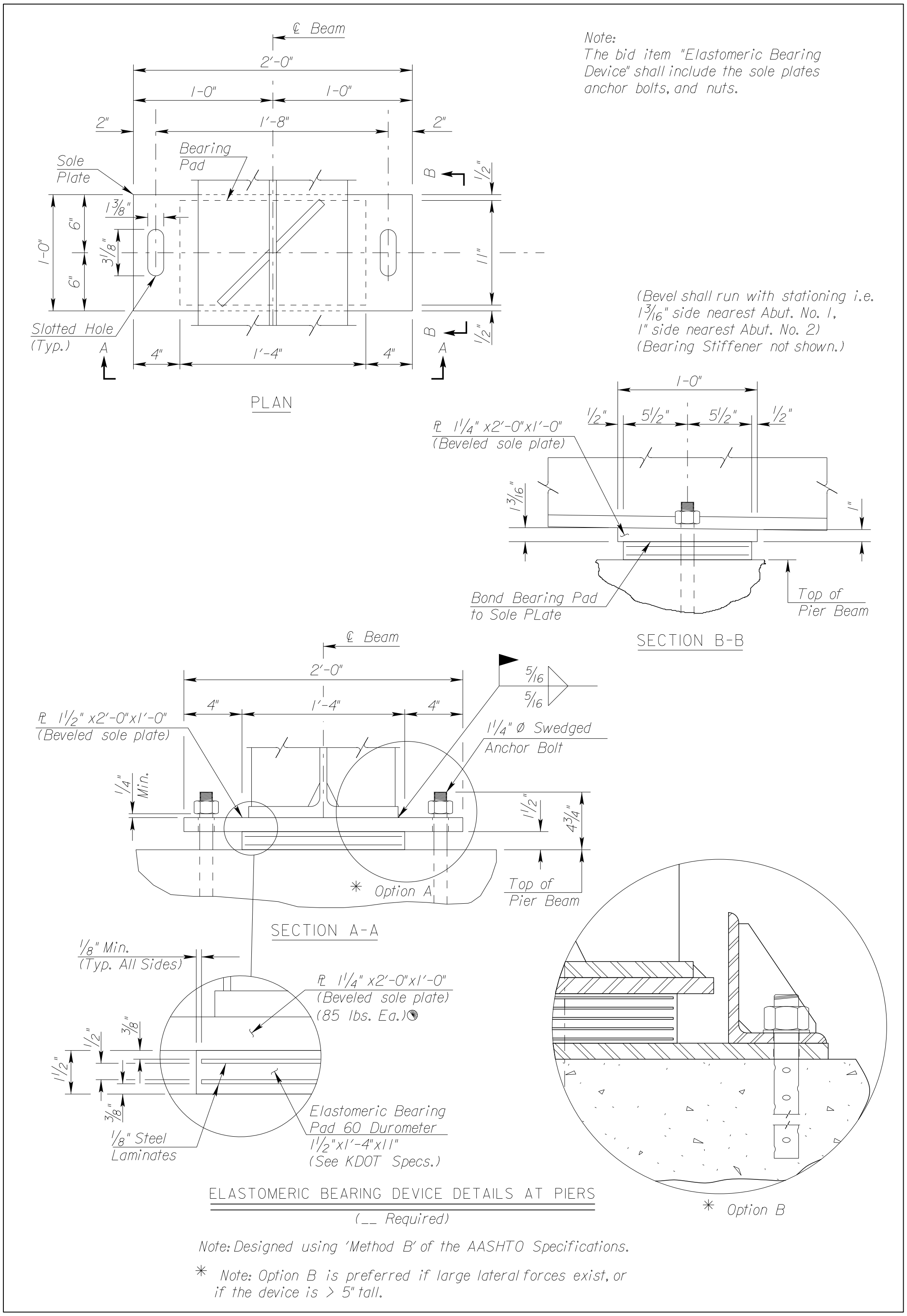
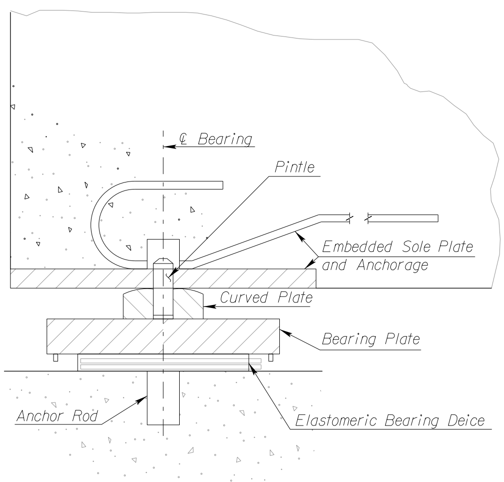
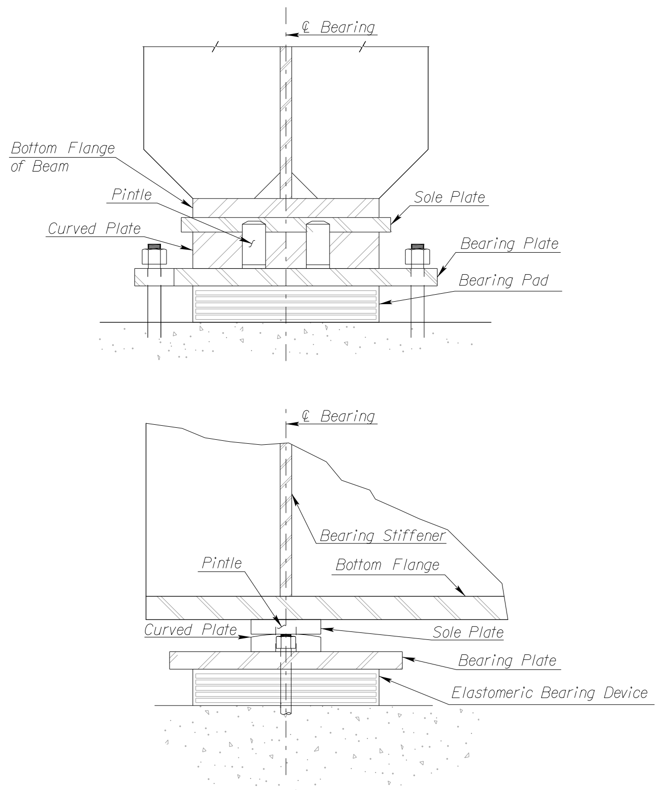


Figure 3.14-9 Combination Bearing Device (Steel/Elastomer)



Combination Device

Prestress



Combination Device

Steel

Figure 3.14-8 Example- TFE Elastomeric Bearing Device

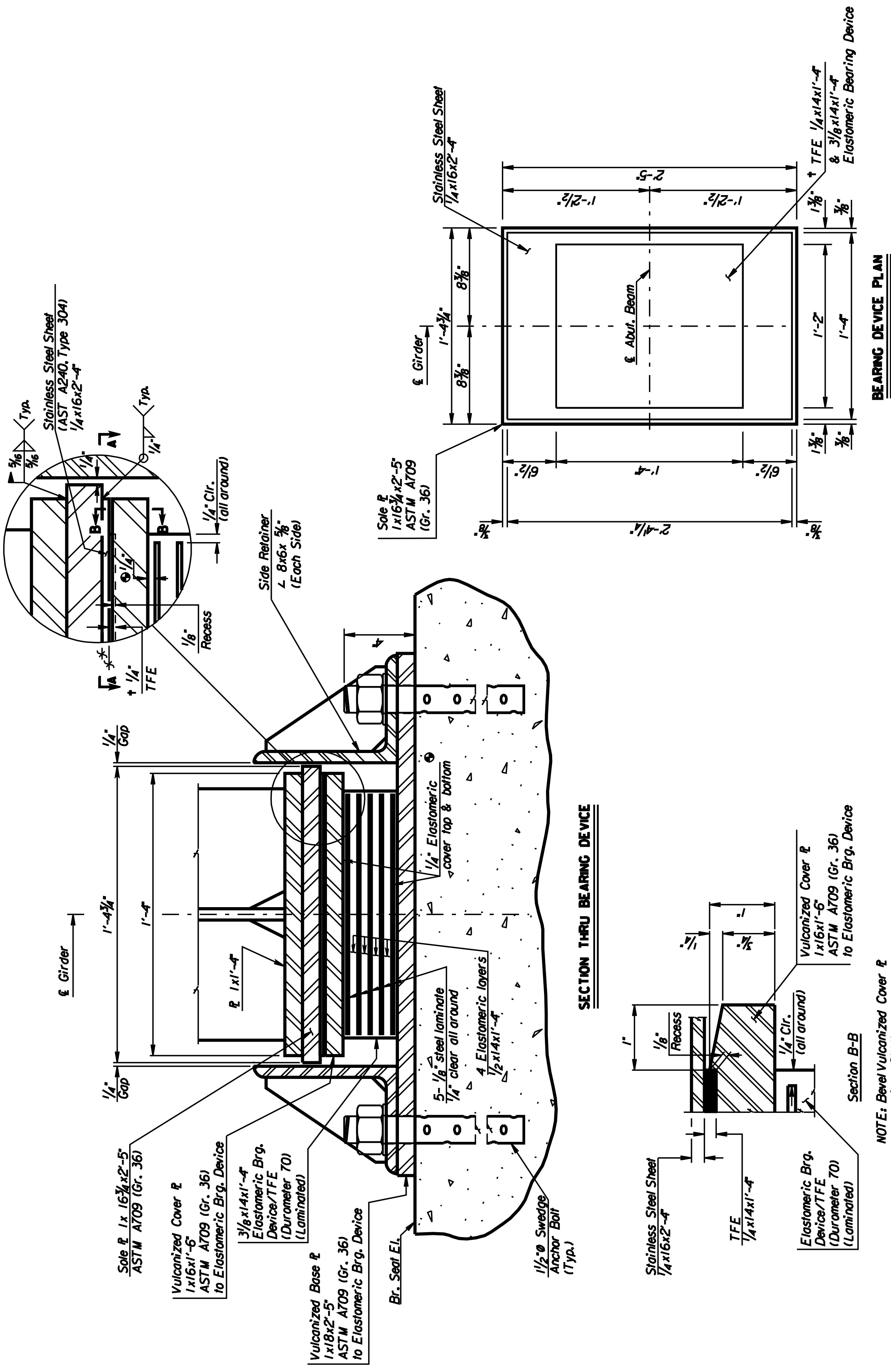


Figure 3.14-10 Typical Details of Rocker Bearing Device

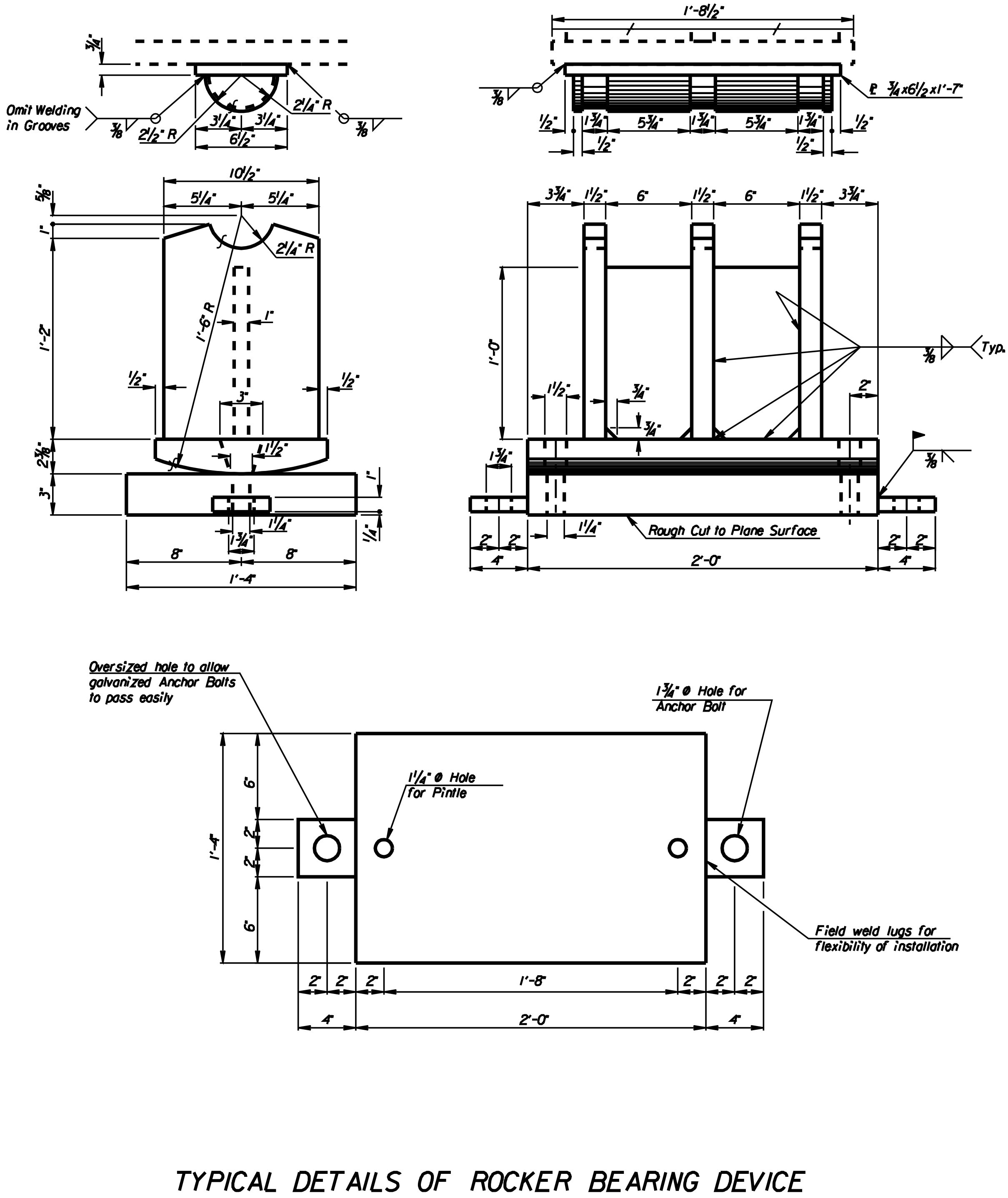


Figure 3.14-12 Elastomeric Bolster Alternative

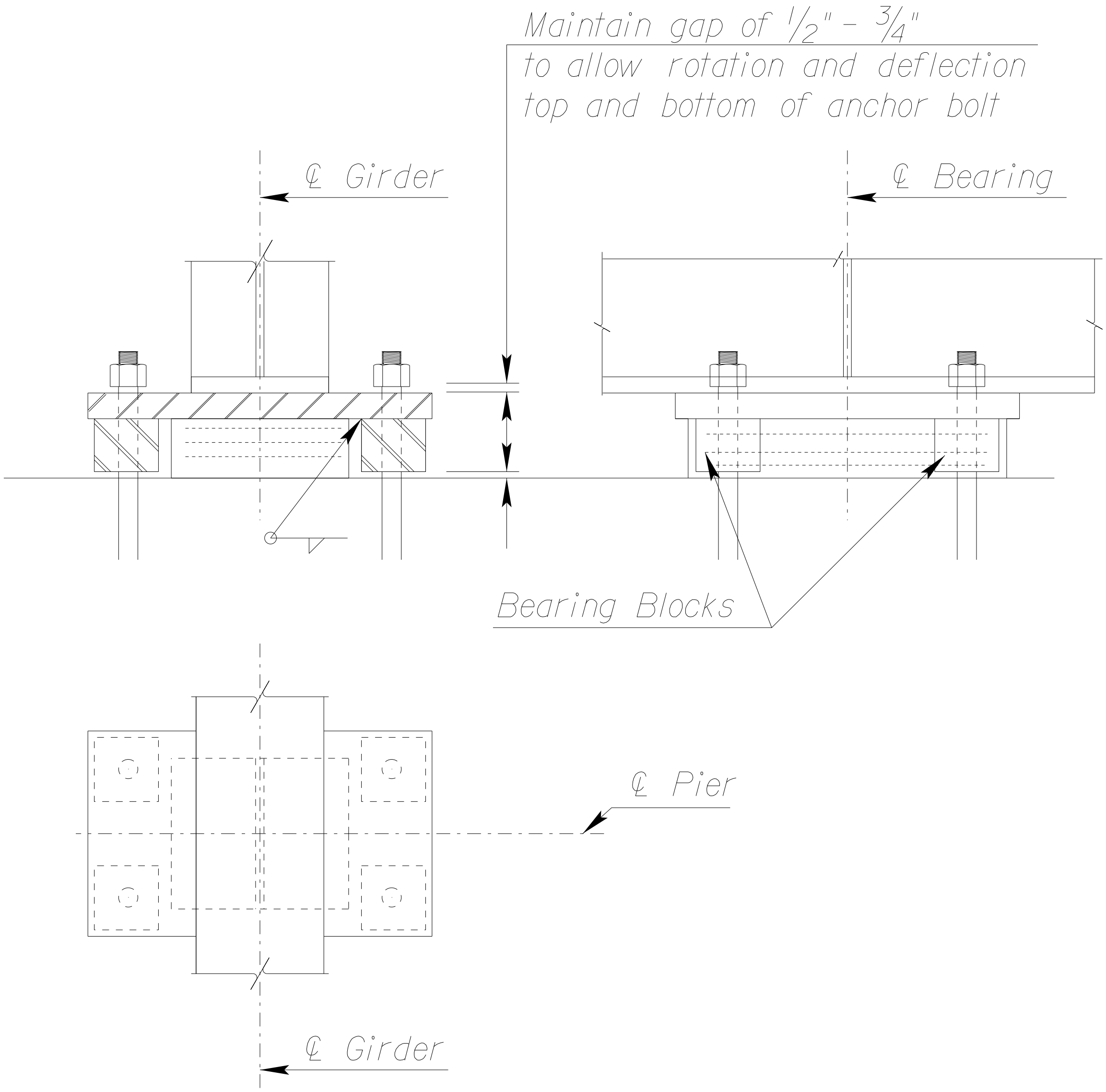
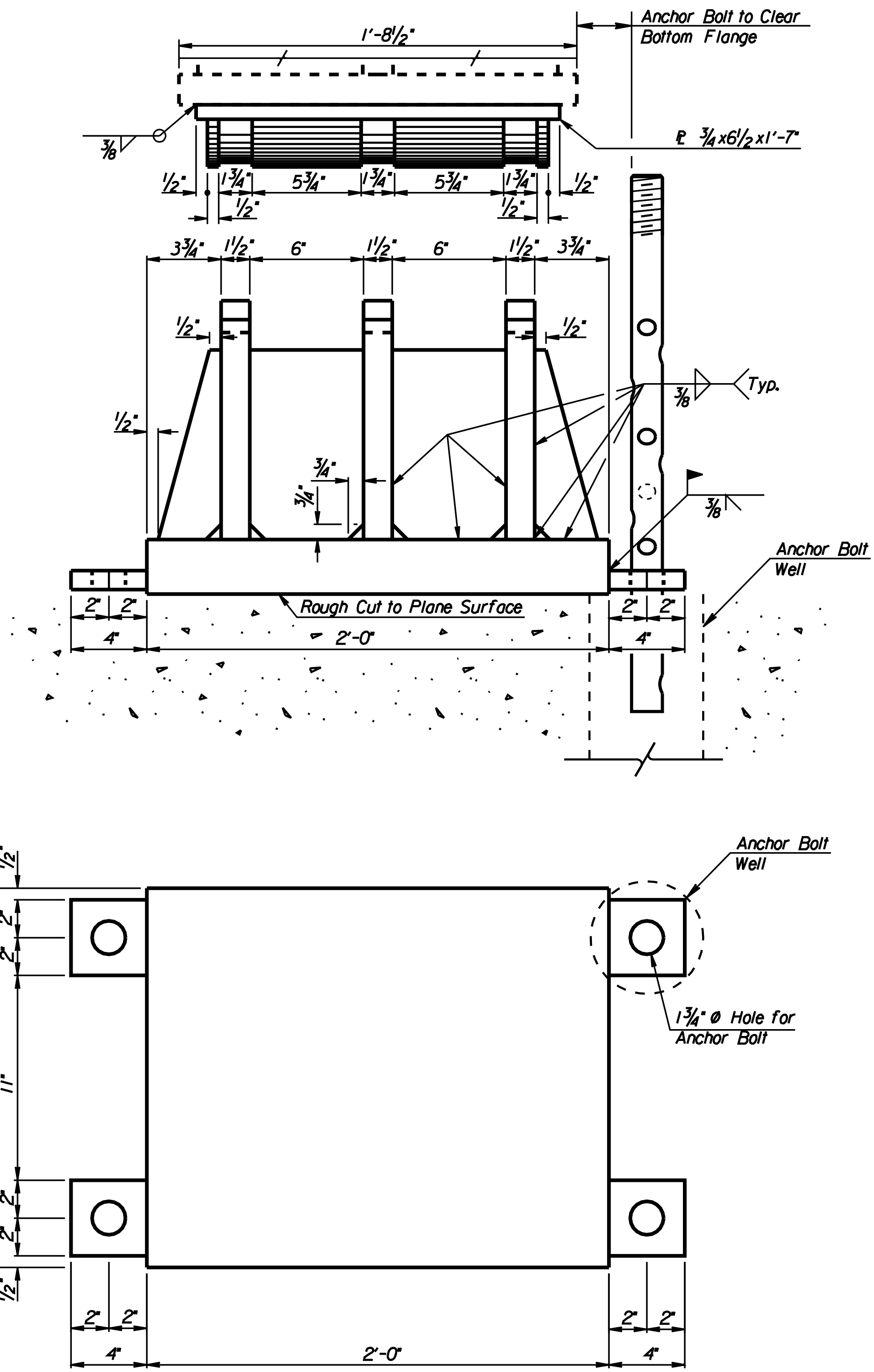
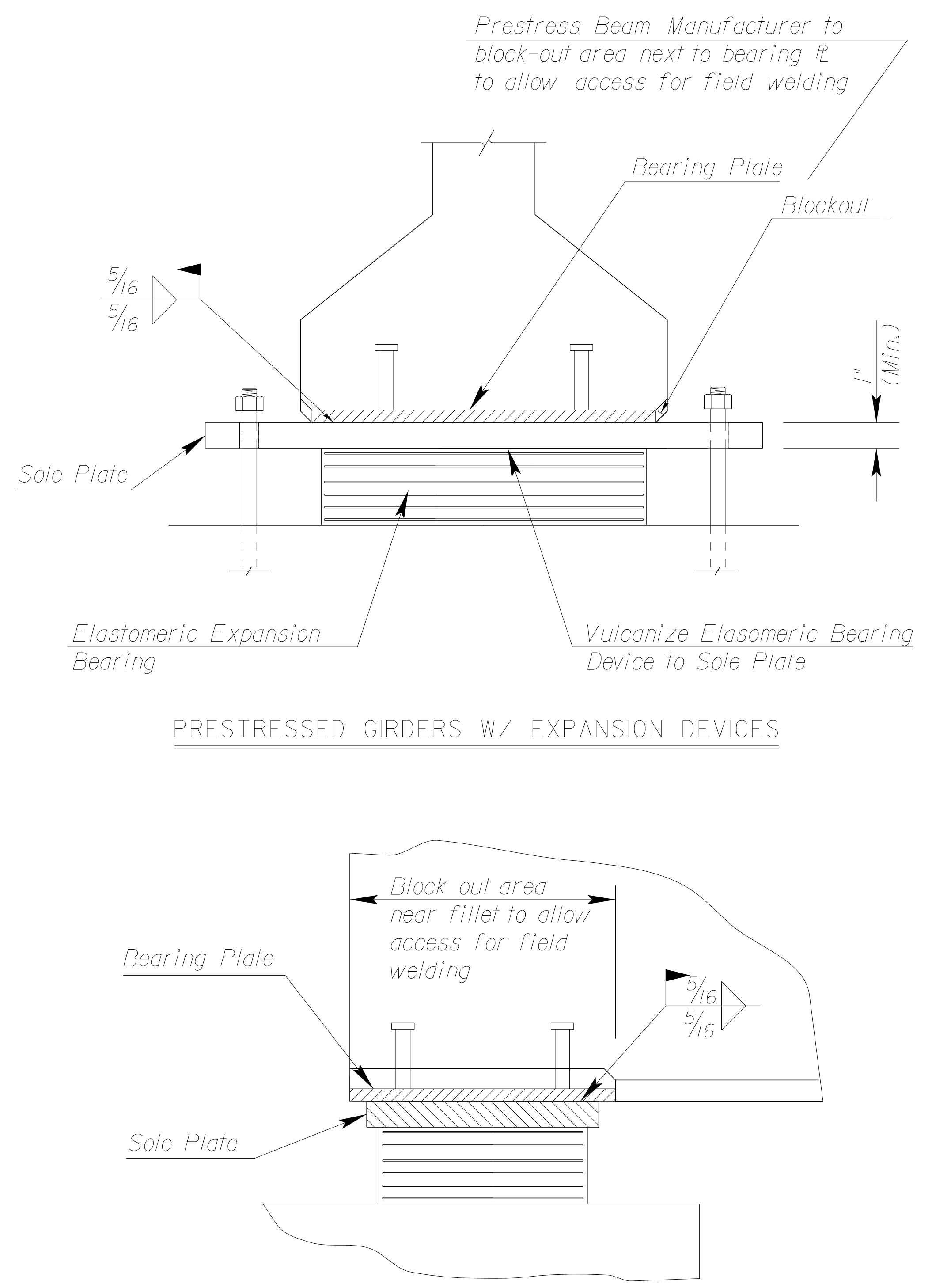


Figure 3.14-11 Typical Details of Bolster Bearing Device



TYPICAL DETAILS OF BOLSTER BEARING DEVICE

Figure 3.14-13 Prestressed Girders W/ Expansion Devices

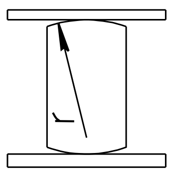


Note: Show required block-out on Bearing Device Details Sheet as well as on Standards BR300 or BR304 "Standard Prestressed Concrete Beam Details".

Figure 3.14-13 Expansion Bearing Friction

EXPANSION BEARINGS

Linticular Type

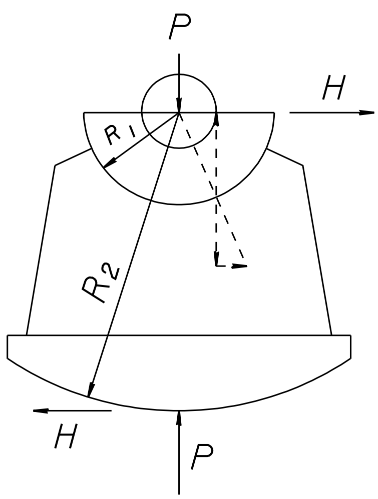


$$y = r - \sqrt{r^2 - a^2} \qquad H = \frac{Va}{r+y}$$

H = Horizontal Force
a = Horizontal Movement
y = Vertical Movement

Note: Rolling friction to be added

Pin & Rocker Type



Assume line bearing pin in rocker
Coeff. sliding friction = Ks
Coeff. rolling friction = K_R

H = P[(Sliding + Rolling)friction]
Consider Rocker Rotating about Pin.

Pin Friction = Pks at bottom Pin
Pin Friction Torque = Pks x R_1

$$\text{Pin Friction Force} = Pks \times \frac{R_1}{R_2}$$

(at bottom of Rocker)

$$H = P\left(Ks\frac{R_1}{R_2} + K_R\right)$$

$$= P\left(.2\frac{R_1}{R_2} + \frac{0.508}{R_2}\right)$$

$$= P\left(\frac{20\ R_1 + 50.8}{100\ R_2}\right)$$

R_1 & R_2 are in inches

BEARING ℙ

$f = Mc/I \qquad c = t/2$

$$20 = \frac{M(t/2)}{t^3/12} = \frac{6M}{t^2}$$

$$t = \sqrt{0.3M}$$

$M^{\prime\prime K}$ @ $f = 20\ K/in^2$

3.14.A Longitudinal Temperature Forces and Movements

The force on a column due to a thermal change in length of the superstructure is:

a) One end free, one end fixed:

$$P = 3\,\frac{EI(a\ T\ L)}{(144)\ h^3} \qquad \& \qquad M = Ph$$

b) Both ends fixed:

$$P = \frac{12\ EI(a\ T\ L)}{(144)\ h^3} \qquad \& \qquad M = Ph/2$$

where:

E = Modulus of Elasticity of column, ksi
(For concrete bridge use E = 1,000 ksi)

I = Moment of Inertia of column, $in.^4$

a = Coefficient of Thermal Expansion of superstructure
= 6.5×10^{-6}/°F (Steel)
= 6.0×10^{-6}/°F (Cast-in-Place & Prestressed Concrete)

T = Temperature change of superstructure, °F

L = Expansion length of superstructure, Feet

h = Column height, Feet

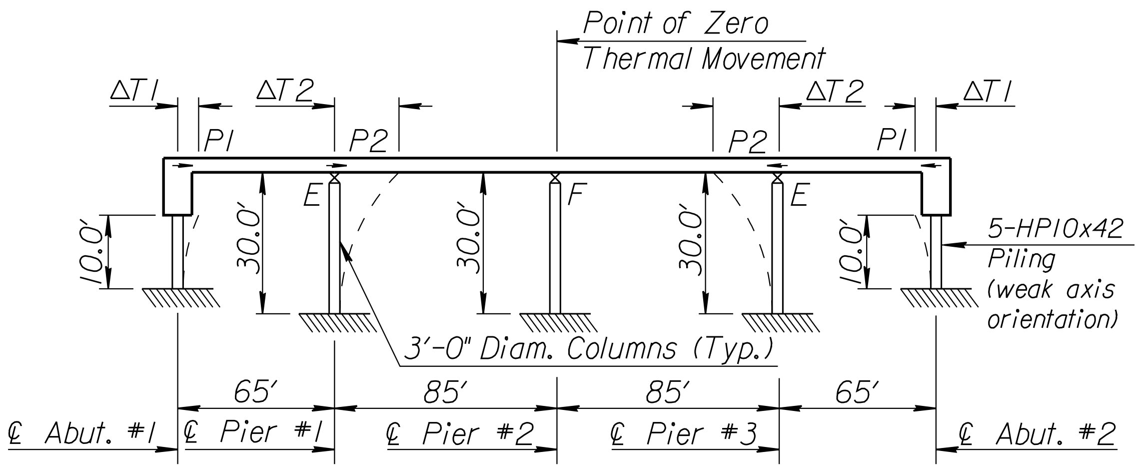
P = Force per column, Kips

See the next page for a method of determining distribution of longitudinal temperature forces to columns.

3.14.A.1 Distribution of Longitudinal Temperature Forces (Symmetrical Bridge)

If the superstructure is supported by elastomeric bearing pads, the thermal force on the columns must take into account the deflection of the column and the deflection of the pad.

If the bridge is symmetrical, the point of zero thermal movement is known and the following procedure may be used to compute forces.



Elevation of Steel Girder Bridge

Thermal Coefficient: Steel = 6.5×10^{-6}

Design Temperature Range: Steel = 90°F

(See Loads on Piers, (e) Temperature)

Total Deflection at Abut. #1 & Pier #1

$\Delta T1 = (85' + 65')\ 90°\ F \times 6.5 \times 10^{-6} \times 12$ in/ft. = 1.05"

$\Delta T2 = (85')\ 90°\ F \times 6.5 \times 10^{-6} \times 12$ in/ft. = 0.60"

Deflection at Piers:

$$\Delta\ Pier = \Delta Pad + \Delta Col$$

a) Elastomeric Pad deflections are calculated as follows:

$$\Delta\ Pad= \frac{P(T)}{L(W)(G)(N)}$$

ΔPad = Deflection (in.)
P = Force (lbs.)
L = Length Pad (in.)
W = Width Pad (in.)
T = Total thickness of Elastomer Layers (in.)
G = Shear Modulus (psi.)
N = Number of pads

The Shear Modulus (G) varies with durometer, temperature and time. Use 60 durometer pads with a G(max) = 300 psi. for temperature fall and G(min) = 150 psi for temperature rise. Run two sets of calculations.

b) Column deflections are calculated as follows:

$$\Delta\ Col = \frac{P(h)^3}{3(E)(I)}$$

ΔCol = Deflection (in.)
P = Force (lbs.)
h = Height (in.)
*I = Gross Inertia (in.^{4})
E = Modulus of Elasticity (psi.)

* For skewed, free-standing piers, increase moment of inertia as shown following these examples.

<u>At Abut. #1 = Abut. #2</u>

$$\Delta Col= \frac{P1(10'x12\ in/ft.)^3}{3(29x10^6)(5x71.7\ in.^4)} = 5.54x10^{-5}\ (P1)$$

$\Delta T1 = \Delta Col$

1.05" = $5.54x10^{-5}$ (P1)

P1 = 18,952 lbs./Abut.

<u>At Pier #1 = Pier #3</u>

$$\Delta Pad = \frac{P2(2'')}{18(12)(300)(6\ pads)} = 0.51x10^{-5}(P2)$$

$$\Delta Col = \frac{P2(30' \times 12\ in/ft.)^3}{3(3.6 \times 10^6)(3 \times 82,448)} = 1.75x10^{-5}(P2)$$

$\Delta Pad + \Delta Col = 2.26x10^{-5}$ (P2)

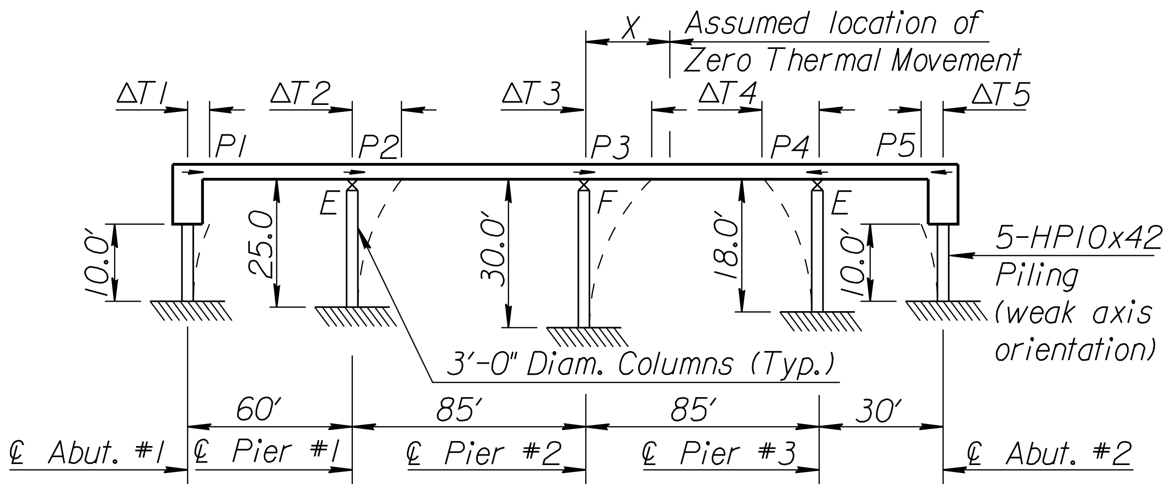
$\Delta T2 = \Delta Pad + \Delta Col$

0.60" = $2.26x10^{-5}$ (P2)

P2 = 26,549 lbs/Pier

3.14.A.2 Distribution of Longitudinal Temperature Forces (Unsymmetrical Bridge)

If the bridge is unsymmetrical and/or with different column lengths, the point of zero thermal movement is unknown and must be solved for:



Elevation of Steel Girder Bridge

Note: Use the same coefficients, temperature ranges and bearing pads as in previous example.

Total Deflection of Bents

$\Delta T1 = (60 + 85 + X)\ 90° \text{ F x } 12 \text{ in/ft. x } 6.5 \times 10^{-6}$ = 118+ 0.00702 (X) in.

$\Delta T2 = (85 + X)\ 90° \text{ F x } 12 \text{ in/ft. x } 6.5 \times 10^{-6}$ = 0.597+ 0.00702 (X) in.

$\Delta T3 = (X)\ 90° \text{ F x } 12 \text{ in/ft. x } 6.5 \times 10^{-6}$ = + 0.00702 (X) in.

$\Delta T4 = (85 - X)\ 90° \text{ F x } 12 \text{ in/ft. x } 6.5 \times 10^{-6}$ = 0.597 - 0.00702 (X) in.

$\Delta T5 = (85 + 30 - X)\ 90° \text{ F x } 12 \text{ in/ft. x } 6.5 \times 10^{-6}$ = 0.807- 0.00702 (X) in.

P1 + P2 + P3 = P4 + P5

@ Abut. #1:

$$\Delta \text{Col} = \frac{P(H)^3}{3(E)(I)} = \frac{P1(10' \times 12 \text{ in/ft.})^3}{3(29 \times 10^6)(5 \times 71.7 \text{ in}^4)}$$

$$= 5.54 \times 10^{-5}\ (P1)$$

$$= \Delta T1$$

@ Pier #1:

$$\Delta Pad = \frac{PT}{LWGN} = \frac{P2(2'')}{18(12)(300)(6)} = 0.514 \times 10^{-5}\ (P2)$$

$$\Delta Col = \frac{P2(25' \times 12)^3}{3(3.6 \times 10^6)(3 \times 82,448)} = \underline{1.011 \times 10^{-5}}\ (P2)$$

$$\Delta\ T2 = 1.525 \times 10^{-5}\ (P2)$$

@ Pier #2:

$$\Delta Col = \frac{P3(30 \times 12)^3}{3.6 \times 10^6(247,344)} = 1.747 \times 10^{-5}\ \ (P3)$$

$$= \Delta\ T3$$

@ Pier #3:

$$\Delta Pad = \frac{P4(2'')}{18(12)(300)(6)} = 0.514 \times 10^{-5}\ (P4)$$

$$\Delta Col = \frac{P4(18 \times 12)^3}{(3.6 \times 10^6)(247,344)} = \underline{0.377 \times 10^{-5}}\ (P4)$$

$$\Delta\ T4 = 0.891 \times 10^{-5}\ (P4)$$

@ Abut. #2:

$$\Delta Col = \frac{P5(10 \times 12)^3}{(29 \times 10^6)(5 \times 71.7)} = 5.540 \times 10^{-5}\ \ (P5)$$

$$= \Delta\ T5$$

<u>Solve for P:</u>

@ Abut. #1: $$P1 = \frac{\Delta T1}{5.54 \times 10^{-5}} = \frac{1.018 + 0.00702(X)}{5.54 \times 10^{-5}}$$

@ Pier #1: $$P2 = \frac{\Delta T2}{1.525 \times 10^{-5}} = \frac{0.597 + 0.00702(X)}{1.525 \times 10^{-5}}$$

@Pier #2: $$P3 = \frac{\Delta T3}{1.747 \times 10^{-5}} = \frac{+ 0.00702(X)}{1.747 \times 10^{-5}}$$

@Pier #3: $$P4 = \frac{\Delta T4}{0.891 \times 10^{-5}} = \frac{0.597 - 0.00702(X)}{0.891 \times 10^{-5}}$$

@Abut. #2: $$P5 = \frac{\Delta T5}{5.540 \times 10^{-5}} = \frac{0.807 - 0.00702(X)}{5.540 \times 10^{-5}}$$

Since P1 + P2 + P3 = P4 + P5, the above equations can be solved for "X":

-18,375.5	126.7 X	
-39,147.5	460.3 X	
0.0	401.8 X	
+67,003.4	787.9 X	
+14,566.8	126.7 X	
+24,047.2	1,903.4 X	X = 12.6 ft.

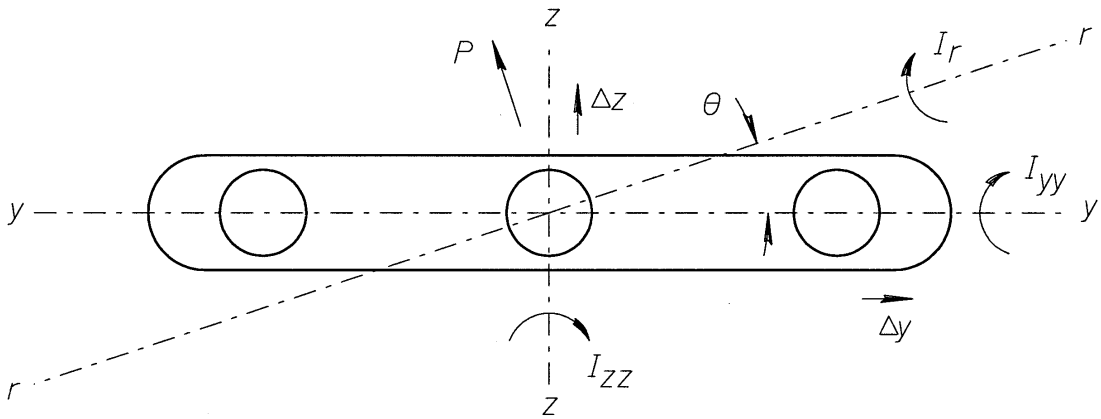
Therefore,

P1 = 18,375.5 + 126.7(12.6) = 19,972 lbs.
P2 = 39,147.5 + 460.3(12.6) = 44,947 lbs.
P3 = + 401.8(12.6) = 5,063 lbs.
P4 = 67,003.4 - 787.9(12.6) = 57,076 lbs.
P5 = 14,566.8 - 126.7(12.6) = 12,970 lbs.

The controlling column temperature force is located at Pier #3 (P4). If it is determined this force is too large, the designer could select one of the following options; (a) Increase the height of the pad to make it more flexible; (b) Specify an isolation bearing design to redistribute the forces; or (c) Equip the elastomeric pad with a teflon sliding surface.

Moment of Inertia Adjustment for Free-Standing Skewed Piers

A skewed, free-standing column bent pier will inherently be stiffer in the longitudinal direction then a non-skewed pier. This increase in stiffness is due to the skew producing larger moments in the columns. To compute the resultant Moment of Inertia for the Pier (I_r), the following procedure may be used:



Resultant $I_r = I_{yy}\cos^2\theta + I_{zz}\sin^2\theta$ *(Standard equation for oblique force thru center of gravity)*

For two, three, four and five column piers of equal height and size of column;

$I_{zz} = (4)\ I_{yy}$ (see derivation below)

$I_{yy} = I_o\ (N)$ N = Number of columns
I_o = Moment of Inertia of one column

Skew	I_{yy}	I_{zz}	I_r
0	1	4	10
10	1	4	19
20	1	4	1.35
30	1	4	1.75
40	1	4	2.24
50	1	4	2.76
-	-	-	—
90	1	4	4.00

Adjustment of moments of inertia should be used for skews greater than 20 degrees.

Derivation:

Stiffness is inversely proportional to deflection, therefore;

$$I_{zz} = \frac{k}{\Delta y} \text{ and } I_{yy} = \frac{k}{\Delta z}$$

$$\frac{I_{zz}}{I_{yy}} = \frac{\Delta z}{\Delta y} \text{ or } I_{zz} = (I_{yy}) \frac{\Delta z}{\Delta y}$$

$$\Delta z = \text{Deflection in Z direction} = \frac{P\,l^3}{3\,EI_o(N)}$$

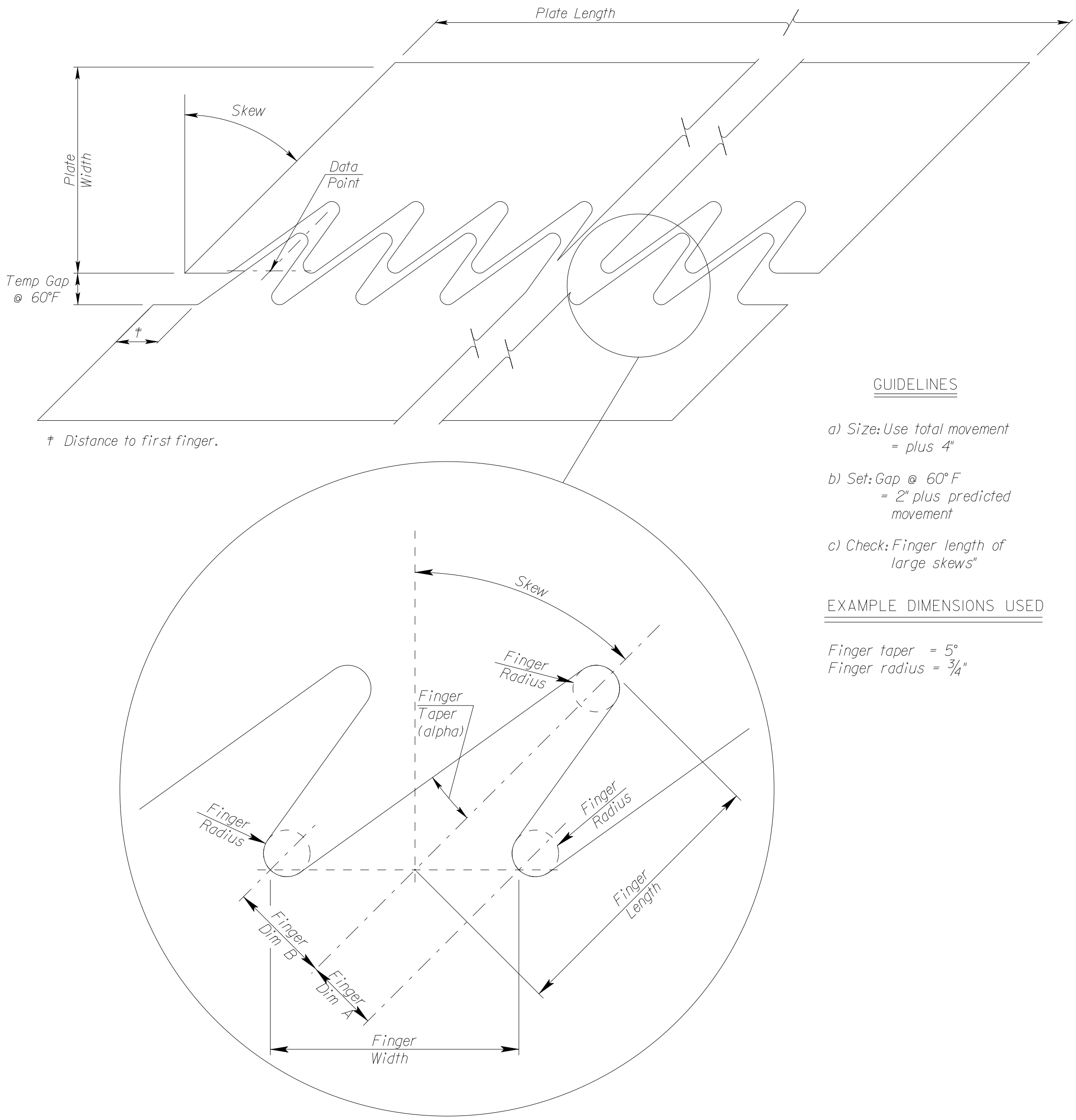
$$\Delta y = \text{Deflection in Y direction} = \frac{P\,l^3}{12\,EI_o(N)}$$

$$I_{ZZ} = (I_{yy}) \frac{\Delta z}{\Delta y} = I_{yy} \frac{P\,l^3 / 3\,EI_o(N)}{P\,l^3 / 12\,EI_o(N)}$$

$$I_{zz} = I_{yy}\ (4)$$

3.14.B Finger Joint Geometry

Finger Plate Diagram



GUIDELINES

a) Size: Use total movement = plus 4"

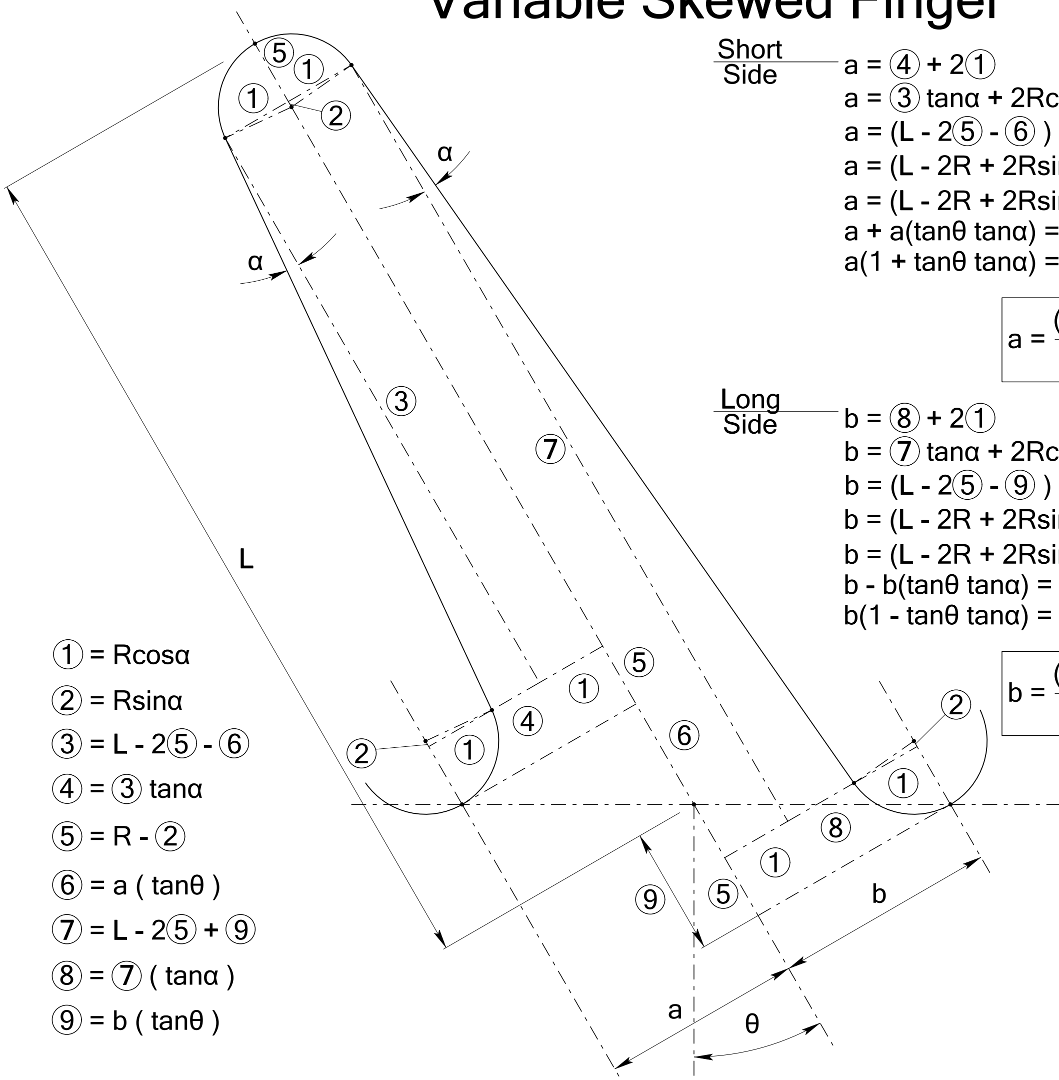
b) Set: Gap @ 60° F = 2" plus predicted movement

c) Check: Finger length of large skews"

EXAMPLE DIMENSIONS USED

Finger taper = 5°
Finger radius = ¾"

Variable Skewed Finger



Short Side

$a = ④ + 2①$

$a = ③ \tan\alpha + 2R\cos\alpha$

$a = (L - 2⑤ - ⑥) \tan\alpha + 2R\cos\alpha$

$a = (L - 2R + 2R\sin\alpha - a \tan\theta) \tan\alpha + 2R\cos\alpha$

$a = (L - 2R + 2R\sin\alpha) \tan\alpha - a(\tan\theta \tan\alpha) + 2R\cos\alpha$

$a + a(\tan\theta \tan\alpha) = (L - 2R + 2R\sin\alpha) \tan\alpha + 2R\cos\alpha$

$a(1 + \tan\theta \tan\alpha) = (L - 2R + 2R\sin\alpha) \tan\alpha + 2R\cos\alpha$

$$a = \frac{(L - 2R + 2R\sin\alpha) \tan\alpha + 2R\cos\alpha}{(1 + \tan\theta \tan\alpha)}$$

Long Side

$b = ⑧ + 2①$

$b = ⑦ \tan\alpha + 2R\cos\alpha$

$b = (L - 2⑤ - ⑨) \tan\alpha + 2R\cos\alpha$

$b = (L - 2R + 2R\sin\alpha + b \tan\theta) \tan\alpha + 2R\cos\alpha$

$b = (L - 2R + 2R\sin\alpha) \tan\alpha + b(\tan\theta \tan\alpha) + 2R\cos\alpha$

$b - b(\tan\theta \tan\alpha) = (L - 2R + 2R\sin\alpha) \tan\alpha + 2R\cos\alpha$

$b(1 - \tan\theta \tan\alpha) = (L - 2R + 2R\sin\alpha) \tan\alpha + 2R\cos\alpha$

$$b = \frac{(L - 2R + 2R\sin\alpha) \tan\alpha + 2R\cos\alpha}{(1 - \tan\theta \tan\alpha)}$$

① = $R\cos\alpha$

② = $R\sin\alpha$

③ = $L - 2⑤ - ⑥$

④ = ③ $\tan\alpha$

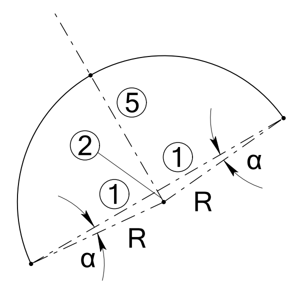
⑤ = $R - ②$

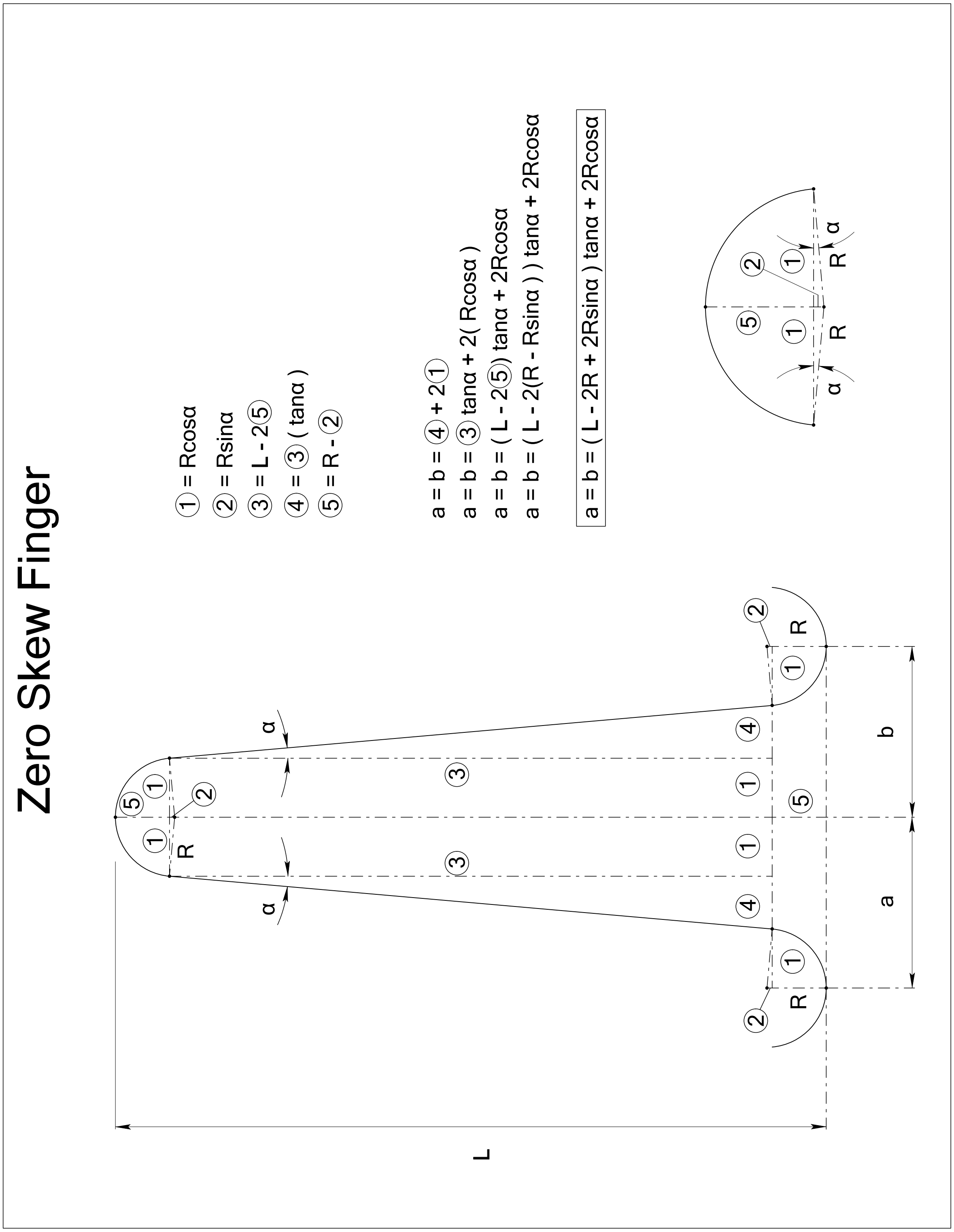
⑥ = $a (\tan\theta)$

⑦ = $L - 2⑤ + ⑨$

⑧ = ⑦ $(\tan\alpha)$

⑨ = $b (\tan\theta)$




Zero Skew Finger
① = Rcosα
② = Rsinα
③ = L - 2⑤
④ = ③ (tanα)
⑤ = R - ②
a = b = ④ + 2①
a = b = ③ tanα + 2(Rcosα)
a = b = (L - 2⑤) tanα + 2Rcosα
a = b = (L - 2(R - Rsinα)) tanα + 2Rcosα
a = b = (L - 2R + 2Rsinα) tanα + 2Rcosα
L
a
b
R
α

3.14.C Elastomeric Bearing Design Example (Method A)

Elastomeric Bearing Device Design LRFD 2010

AASHTO LRFD 5th Ed. 2010

Reactions

(Do not include Dynamic Load (Impact) AASHTO 14.4.1)

Min Dead Load Reactions (kips/girder)....... $DL := 100.0\,kip$

Max Dead Load Reactions (kips/girder)....... $DL_{max} := 102.12\,kip$

Live Load Reactions (kips/girder)....... $LL := 102.8\,kip$

Rotations

(DL + LL + Uncertainties + Lack of Parallelism AASHTO 14.4.2.1)

LL rotation (radians)............ $LL_{\Theta} := 0.0023$

DL rotation (radians)............ $DL_{\Theta} := 0.0001$

Uncertainties (radians).......... $U_{\Theta} := 0.005$

LP (radians)........................ $LP_{\Theta} := 0.0011$

Static Rotation (radians)... $\Theta_{s.st} := DL_{\Theta} + U_{\Theta} + LP_{\Theta}$

Cyclic Rotation (radians)... $\Theta_{s.cy} := LL_{\Theta}$

Translations

$\Theta_s := \Theta_{s.st} + \Theta_{s.cy}$ $\Theta_s = 0.0085$ rads.

(Movements AASHTO 14.4.2, 14.7.5.3.4 and 14.7.6.3.4)

(Use Cold Climate -30ºF - 120ºF)(Datum = 60 F)

Length for Expansion .... $Length_{exp} := 100ft$

Thermal Coef..... $\alpha := 6.5 \cdot 10^{-6}$ $T_{range} := 150$

$\Delta_s := T_{range} \cdot \alpha \cdot Length_{exp}$ $\Delta_s = 1.1700\,in$

Override Translation..... $\Delta_s := 1.17in$ $\Delta_s = 1.17 \cdot in$

Fixed for Long. translation(1=yes,0=no) ..... $fixed_L := 0$

Fixed for Trans. translation(1=yes,0=no) ..... $fixed_T := 1$

Assume a Pad Size

Length if Device (in) .... $L := 12in$ $L = 12.000\,in$

Width of Device (in) ... $W := 16in$ $W = 16.000\,in$

Thickness of Layers (in)... $h_{ri} := 0.5in$ $h_{ri} = 0.500\,in$
(Assumed Constant)

Number of Layers (in)... $n := 4$

Elastomer Cover top and Bottom (in).... $Cover := 0.25in$

(shall be no greater than 70% of interior)

Thickness of Steel Reinforcement (in) .... $t_{steel} := 0.125in$

Bearing Device Height (in).... $H_t := (n \cdot h_{ri}) + (n+1) \cdot t_{steel} + 2 \cdot Cover$ $H_t = 3.13 \cdot in$ <===== overall height

Total Elastomer Height (in).... $h_{rt} := n \cdot h_{ri} + 2 \cdot Cover$ $h_{rt} = 2.5 \cdot in$ <===== elastomer height

Area of Perimeter Free to Bulge (in^2)..... $A_{bulge} := (L + W) \cdot 2 \cdot h_{ri}$ $A_{bulge} = 28.0 \cdot in^2$

Shape Factor (dimensionless).... $S := \frac{L \cdot W}{A_{bulge}}$ $S = 6.9$
(should be around 6 to 9)

Check $\frac{S^2}{n} = 11.8$ < 20 (AASHTO 14.7.6.1)

Constants

Shear Modulus (ksi).... $G_{min} := 0.130\,ksi$
(Table 14.7.6.2-1) $G_{max} := 0.200\,ksi$

Shore Hardness.... $Shore := 60$

Reinforcement Yield (ksi).... $Fy := 36ksi$

Allowable Fatigue Stress Range (ksi).. $\Delta F_{TH} := 24ksi$
(Table 6.6.1.2.5-3)

Long Term Strain (%)................. $a_{cr} := 35 \cdot \%$
(Table 14.7.6.2-1)

Instantaneous Strain (%)................. $\varepsilon_s := 4.3 \cdot \%$
(Using TL stress
From Table below)

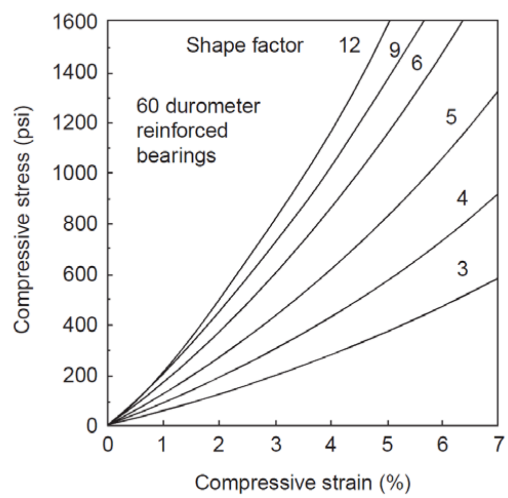
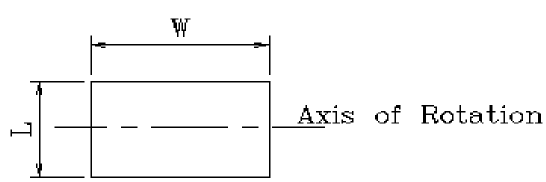


Figure C14.7.6.3.3-1 Stress-Strain Curve



Elastomeric Bearing Device Design 'Method A'

AASHTO 14.7.6.3.6 (Stability)

Maximum overall height allowed to prevent instability

$\frac{L}{3} = 4.0 \cdot in$ or $\frac{W}{3} = 5.3 \cdot in$ Stability $:= \min\left(\frac{L}{3}, \frac{W}{3}\right)$

Performance Ratio

$\frac{H_t}{Stability} = 0.781$

Overall Height Provided

$H_t = 3.1 \cdot in$

AASHTO 14.7.6.3.2 (Compressive Stress)

Compressive Stress on any Layer

$\sigma_{TL} := \left(\frac{DL_{max} + LL}{L \cdot W}\right)$ $\sigma_{TL} = 1.067 \cdot ksi$

$\sigma_{LL} := \frac{LL}{L \cdot W}$ $\sigma_{LL} = 0.535 \cdot ksi$

Performance Ratio

$\frac{\sigma_{TL}}{\sigma_{allow}} = 0.958$

Allowable Bearing Stress on any Layer

$\sigma_{allow} := \begin{cases} 1.25 \cdot G_{min} \cdot S & \text{if } 1.25 \cdot G_{min} \cdot S < 1.25ksi \\ 1.25ksi & \text{otherwise} \end{cases}$

$\sigma_{allow} := \begin{cases} 1.10 \cdot \sigma_{allow} & \text{if } fixed_L = 1 \\ \sigma_{allow} & \text{otherwise} \end{cases}$ $\sigma_{allow} = 1.114 \cdot ksi$

AASHTO 14.7.6.3.4 (Shear)

For Shear restrained a 10% increase is allowed

Minimum overall elastomer thickness required

$h_{hrt\_min} := 2 \cdot \Delta_s$ $h_{hrt\_min} = 2.34 \cdot in$

$PR := \frac{2 \cdot \Delta_s}{h_{rt}}$

Performance Ratio

$PR = 0.936$

Overall Elastomer Thickness Provided

$h_{rt} = 2.50 \cdot in$

AASHTO 14.7.6.3.5d (Rotation) *

Uplift Stress

$Uplift_{\sigma} := 0.5 \cdot G_{max} \cdot S \cdot \left(\frac{L}{h_{ri}}\right)^2 \cdot \frac{\Theta_s}{n}$ $Uplift_{\sigma} = 0.839 \cdot ksi$

Performance Ratio

$\frac{Uplift_{\sigma}}{\sigma_{TL}} = 0.786$

Compressive Stress

$\sigma_{TL} = 1.067 \cdot ksi$

Note: Uplift must be less than Compressive or delimitation can occur

* Equation modified per memo from Dr. Roeder

AASHTO 14.7.6.3.3 (Compressive Deflection) cover strain= 1/2 of layer strain

Vertical Deflection

$\varepsilon_{dl} := \frac{\varepsilon_s \cdot DL_{max}}{DL_{max} + LL}$ $\delta_{dl} := \varepsilon_{dl} \cdot (n \cdot h_{ri} + Cover) \cdot (a_{cr} + 1)$ $\delta_{dl} = 0.065 \cdot in$

$\varepsilon_{ll} := \frac{\varepsilon_s \cdot LL}{DL_{max} + LL}$ $\delta_{ll} := \varepsilon_{ll} \cdot (n \cdot h_{ri} + Cover)$ $\delta_{ll} = 0.049 \cdot in$

Maximum Vertical Deflection KDOT 3.14.9

$\delta_{allowable} := 0.125in$

max relative deflection for live load across a joint or δ_{LL}, should be 0.125".

$\delta := \delta_{dl} + \delta_{ll}$

Performance Ratio

Assume strain is approx. linear over stress range

$\frac{\delta}{\delta_{allowable}} = 0.909$

AASHTO 14.7.5.3.5 (Reinforcement)

Minimum thickness for strength

$h_s := \max\left(\frac{3.0 \cdot h_{ri} \cdot \sigma_{TL}}{Fy}, 0.0625in\right)$ $h_s = 0.063 \cdot in$

Performance Ratio

$\frac{h_s}{t_{steel}} = 0.500$

Thickness Provided

$t_{steel} = 0.125 \cdot in$

Minimum thickness for fatigue

$h_s := \frac{2.0 \cdot h_{ri} \cdot \left(\frac{LL}{L\,W}\right)}{\Delta F_{TH}}$ $h_s = 0.022 \cdot in$

Performance Ratio

$\frac{h_s}{t_{steel}} = 0.178$

Thickness Provided

$t_{steel} = 0.125 \cdot in$

AASHTO 14.6.3.1 (Horizontal Force Transferred to Substructure)

Force to Substructure

$H_m := \frac{G_{max} \cdot L \cdot W \cdot \Delta_s}{h_{rt}}$ $H_m = 17.97 \cdot kip$

Performance Ratio

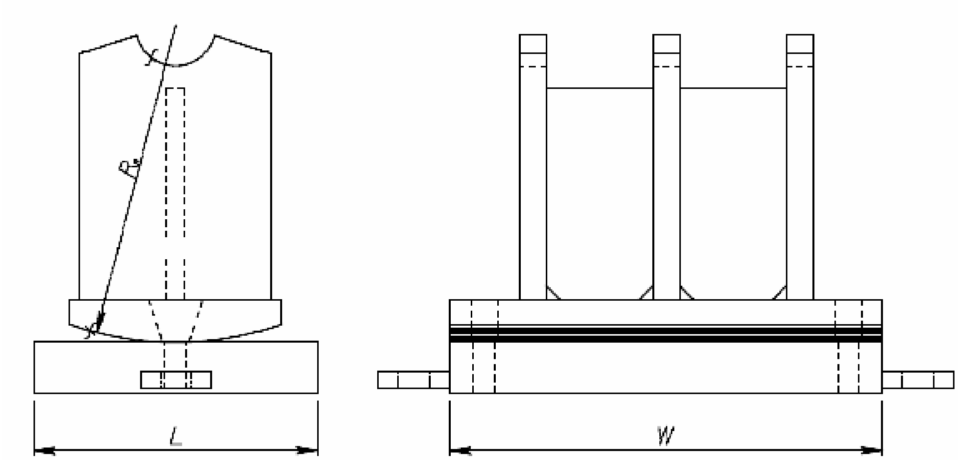
$\frac{5 \cdot H_m}{DL} = 0.899$

Requirement for anchorage

$\frac{DL}{5} = 20.0 \cdot kip$

Page2 Y:\Bridge Manuals\Bridge Design Manual\Development\LRFD\Chapter 3 Design\Section 3.14 Joints and Bearings\MathCadd_files\JSR v 1.2.0 10/05/10

3.14.D Steel Rocker Example



Unfactor Loads

A. Stage I

(Girder Self Wt. +15%)+(8.7 in Deck)+(Deck Fillet about Girder)

Combined DC Reaction = 218.2 kips

B. Stage II

(Corral Rail with out Curb)+ (15 psf future wearing surface)

Combined DC Reaction = 17.4 kips

Combined DW Reaction = 20.9 kips

C. Stage III

The controlling live load is the truck train + laneload.

LL+IM Reaction - 90% (157.4 kips +106.5 kips) = 237.6 kips

Bearing Stress on Pier Beams Concrete *(Article 5.7.5)*

Strength I Limit State

A. Factored Reaction

P = 1.25(218.2 kip - 17.4 kip)+(1.50(20.9 kip)+1.75(239.6 kip)

P = 294.5 kip+31.4 kip+415.5 kip

P = 741.8 kip

B. Factored Bearing Resistance, Pr

$P_r = \phi P_n$ (Eq.5.7.5-1)

$P_n = 0.85 f'c A_1 m$ (Eq. 5.7.4.2-2)

P_n = Nominal Bearing Resistance

A_1 = Area under Bearing Device

m = Modification Factor

ϕ = Resistance Factor = 0.70 *Article 5.5.4.2.1*

$$m = \sqrt{\frac{A_2}{A_1}} \leq 2.0$$

A_2=Area equals to the supporting of the pier beam. (Limited to 4 times A_1)

$m = \sqrt{4} \leq 2.0 = 2.0$

$P_n = 0.85 f' A_1 2$

$P_r = 0.70 \times 0.85 \times 2 \times f'c \times A_1$

To determine the required bearing area, equate P_r to the factored reaction and solve for A_1.

$$-741.8\text{kip} = 0.70 \times 0.85 \times 2 \times f'_c \times A_1$$

$$A_1 = \frac{741.82\text{kip}}{0.70 \times 0.85 \times 2(4.351)\text{kip/in}^2} = 143.26\text{in}^2 \qquad f'_c = 4.351\text{ksi}$$

Special Design Provisions for Bearing *Article 14.7*

Service I Limit State

For cylindrical surfaces, the contact loads P_s shall satisfy.

$$P_s \leq \frac{8WD_1}{\left(1 - \frac{D_1}{D_2}\right)}\left(\frac{Fy^2}{E_s}\right) \quad \text{(Eq. 14.7.1.4-1)}$$

W = Width of the bearing

D_1 = Diameter of the rocker or roller surface

D_2 = Diameter of the mating surface

F_y = Minimum yield strength of the weakest steel at the contact surface

E_s = Young's modulus for steel

A. Factored Reaction

$$P = 1.0(218.2\text{kip} + 17.4\text{kip}) + 1.0(20.9\text{kip}) + 1.0(237.6\text{kip})$$

$$P = 235.7\text{kip} + 21.0\text{kip} + 237.6\text{kip}$$

$$P = 494.2\text{kips}$$

B. Trial No.1

Calculate the required width of contact needed for an assumed diameter of rocker.
D_1 = 24.0 in.
$D_2 = \infty$ for a flat surface
F_y = 50 ksi ASTM A709M Gr.50
E = 29000 ksi

$$494.2\text{kip} = \frac{8W \times 24.0\text{in}}{\left(1 - \frac{24.0\text{in}}{\infty}\right)} \quad \frac{(50\text{ksi})^2}{29000\text{ksi}}$$

$$494.2\text{kip} = \left(\frac{192.1\text{in} \times w}{1}\right)(0.086\text{ksi})$$

$$W = \frac{494.2\text{kip}}{421.2\text{ksi}} = 29.8\text{in}$$ Too long, will increase D_1 to 35.4in.

C. Trial No.2
D_1 = 35.4in.
All other same as Trial No.1

$$494.13\text{kip} = \left(\frac{35.4\text{in}}{1 - \frac{35.4\text{in}}{\infty}}\right) \left(\frac{50.0^2\text{ksi}}{29000\text{ksi}}\right)$$

$$W = \frac{494.1\text{kip}}{963\text{kip}} = 20.2\text{in}$$ OK, Use 24.0in.

<u>Bearing on Pin</u> *Article 6.7.6.2.2* Use Type 304 Stainless Steel for Pins

<u>Strength I Limit State</u>
The factored bearing resistance, $(R_{pb})_r$, on pins shall be:

$$(R_{pb})_r = \varphi_b (R_{pb})_n \qquad \textit{Article 6.7.6.2.2-1}$$

in which:

$$(R_{pb})n = 1.5tDf_y$$

t = Thickness of plate
D = Diameter of pin
ϕ_b = Resistance Factor for bearing *Article 6.5.4.2=1.0*
F_y = 30.0 ksi ASTH A240M Type 304 Stainless steel for plate
From sheet #1 of the design calculations for bearing devices.
Factor Reaction = 741.8 kips

Calculate the required width of the bridge plates against the pin.
Assume a pin Diameter of 4.5 in.

$$741.8\text{kip} = 1.5t \times 4.5\text{in} \times 29.73\text{ksi}$$

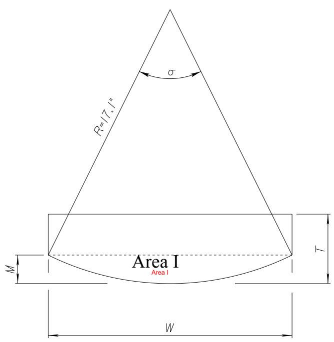
$$t = \frac{741.8\text{kip}}{1.5 \times 4.5\text{in} \times 29.7\text{ksi}} = 3.7\text{in}$$

Use 3 bridge plates. Required width of each $\frac{3.7\text{in}}{3} = 1.22\text{in}$

Use 3-1.5in wide bridge plates.

Bending of Rocker Plate

Strength I Limit State



Total temp.movement $= 6.5 \times 10^{-6} \times 150°f \times (157.5' + 157.5')$

$$= 3.7''$$

$$\frac{\sigma}{360°}(2\pi R) = 3.7in$$

$$\text{Min } \sigma = \frac{360° \times 3.7}{2\pi \times 17.7''} = 12°$$

A. Trial No. 1

$W = 11.8''$ $T = 2.4''$ $R = 17.7''$

$$\sigma = 2ArcSin\frac{W}{2R} = 38.942° ok \quad (E)$$

$$M = R\left(1 - \cos\frac{\sigma}{2}\right) = 1.0'' \quad (D)$$

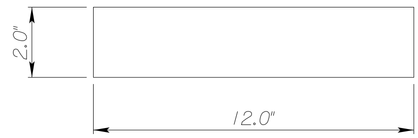
$$\text{Area I} = \frac{\sigma \pi R^2}{360°} - \frac{W(R - M)}{2}$$

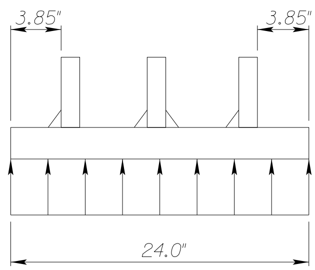
$$\text{Area I} = 106.5in^2 - 98.5in^2 = 8.0in^2$$

$$\text{Total Area } 8.0in^2 + W(T - M)$$

$$\text{Total Area } 8.0in^2 + 16.52in^2 = 23.95in^2$$

$$\text{Avg. Thickness} = \frac{24.0in^2}{W} = 2.0'' \quad (C)$$





$$I = \frac{12''(2.0'')^3}{12} = 8.0\text{in}^4 \quad \text{(B)}$$

$$W = \frac{741.8\text{kips}}{24.0''} = 30.9\text{kip/in} \quad \text{(A)}$$

$$\text{Moment} = \frac{WL^2}{2} = \frac{30.9\text{kip/in} \cdot 3.85\text{in}^2}{2} = 229\text{kip} \cdot \text{in}$$

$$f_s = \frac{M_c}{I} = \frac{229\text{kip/in} \times \frac{2''}{2}}{8.0\text{in}^4} = 28.6\text{ksi}$$

$$f_s = 28.6\text{ksi} \text{ ok Factored resistance} = 50.0\text{ksi}$$

Bending of Base Plate

Strength I Limit State

The area of the Base plate must be greater than 143.3in^2 to satisfy the Concrete Bearing shown on page 1.

A. Trial No.1
Width = 15.7”, Length 24.0”, Thickness 2.5”

$$\text{Area} = 15.7'' \times 24.0'' = 378.2''^2 \text{ Ok}$$

$$\omega = \frac{741.8\text{kip}}{15.7'' \times 24.0''} = 1.96\text{kip/in}^2$$

$$I = \frac{24.0''(2.50'')^3}{12} = 31.25\text{in}^4$$

$$\text{Moment} = \frac{\omega L^2}{2} = \frac{1.96\text{kip/in}^2 \times 24'' \times (7.9'')^2}{2} \qquad \text{Moment} = 1,467\text{kip}\cdot\text{in}$$

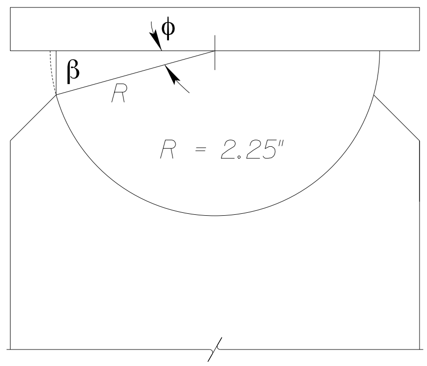
$$f_s = \frac{Mc}{I} = \frac{1,467 \cdot \frac{2.5''}{2}}{31.25} = 58.7\text{ksi} \geq 50\text{ksi} \quad \text{NG}$$

B. Trial No.2
Width = 15.75”, Length = 24.0”, Thickness = 2.75”

$$I = \frac{24.0''(2.75'')^3}{12} = 41.6$$

$$f_s = \frac{Mc}{I} = \frac{1,467 \cdot \frac{2.75}{2}}{41.6} = 48.5\text{ksi} \leq 50\text{ksi} \quad \text{OK} \quad \text{Factored resistance = 50.0 ksi}$$

Rocker Clearance



To confirm that the rocker has sufficient movement capacity ϕ must be greater than 1/2 of the total temperature movement rotation. From page 5 that rotation was calculated as $12°$. To provide tolerance use a ϕ of $12°$.

$$\beta = R\sin\phi = 0.47''$$

Use β of .50" which gives a ϕ of $12.83°$

Pier Bolster Bearing Device

The dead load and live load at the bolster location, Pier #3 & #7 are the same as that of the pier rockers. Therefore, the design for the pin, bearing plates, and base plate will be the same as for the rocker. As this is a bolster, it will resist the longitudinal direction of the bridge. Check Strength III Limit State.

Unfactored Loads

A. Stage I
(Girder Sepf Wt. + 15%) + (8.7" Deck) + (Deck Fillet)
Combined DC Reaction = 218.24 kips

B. Stage II
(Corral Rail W/o Curb) Do not include F.W.S. for stability.
Combined DC Reaction = 17.42 kips

C. Stage III
Live load + impact is not included in Strength III Limit State.

D. Wind Load on Superstructure *Article 3.8.1.2.1*
The structure is < 30' above ground line or low water elevation. Therefore, do not need to adjust base design wind velocity, V_B, of 100 mph.

$$\text{Design Long Wind Press, } P_D = P_B \frac{V^2_{DZ}}{10,000}$$

P_B = 0.019 ksf *Table 3.8.1.2.2-1* for $60°$ skew

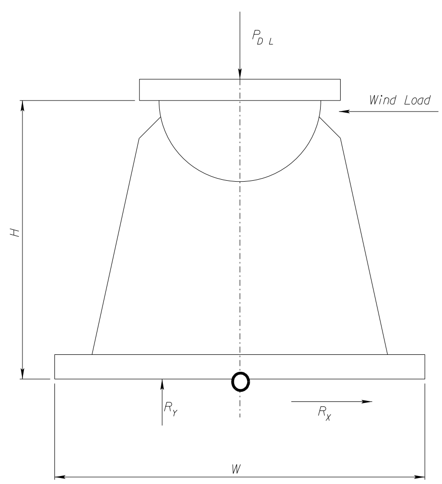
$$V_{D^2} = V_B = 100\text{mph}$$

$$P_D = 0.019\text{ksf}\frac{(100)^2}{10,000} = 0.019\text{ksf}$$

Exposed Area = [Web Depth + Bolt Flange Thickness + Deck Thickness + Rail Height]
(141.3’ + 3@ 157.5’ + 118.1’)
Exposed Area = (65.0” + 1.6” + 8.7” + 32.0”)731.9’
Exposed Area = 107.5” x (731.9x12) = 944,151 in^2
Total Long Wind Load = 6,556 ft^2 x 0.019 ksf = 124.6 kip

$$\text{Long Wind Load/Bolster} = \frac{124.6\text{kip}}{5\text{Bolster}} = 24.9\text{kip}$$

Stability



For stability, R_y should remain within the middle 1/3 of the width (kurn), W, of the base plate.

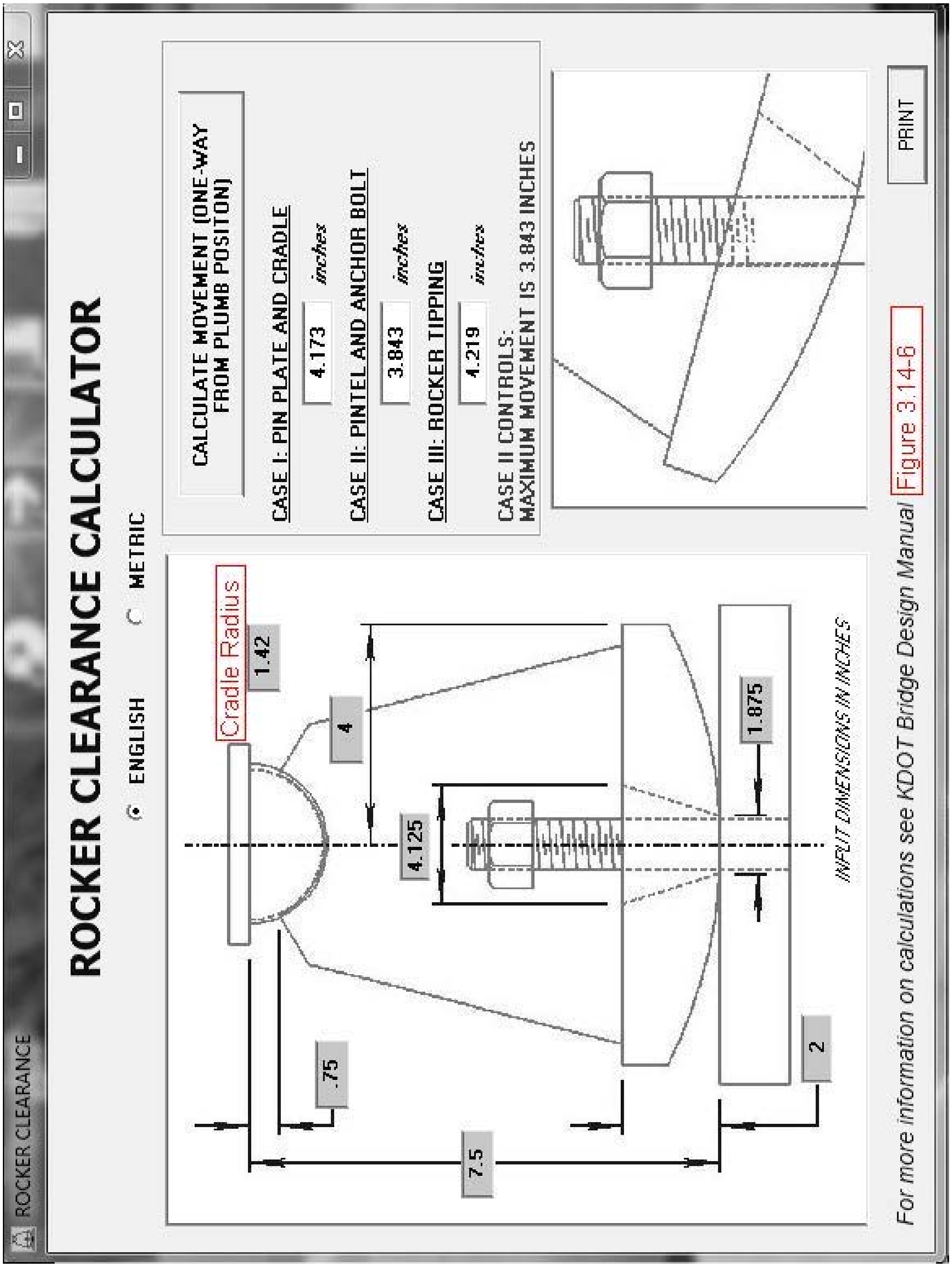
For Strength III Limit State will use 0.90 load factor for dead load and 1.40 load factor for wind load.

To satisfy stability: Sum moment about **o** (the center of the bottom plate)

$$0.9P_{DL} \times \frac{W}{6} = 1.4\text{xWindLxH} \qquad 0.9(218.2\text{kip} + 17.4\text{kip})\frac{W}{6} = 1.4 \times 23.8\text{kip} \times H$$

$$W = \frac{1.4 \times 24.9\text{kip} \times H \times 6}{0.9(235.6\text{kip})} = 0.986H \text{ <== required size}$$

3.14.E Rocker Clearance Calculator



Rocker Tip Clearance Example:

The above input results in a desirable first contact on the pintle, the next contact is the pin plate to cradle and lastly the rocker tips excessively. This is the required modes in sequence. See 3.14.8 Roller, Rocker, and Pedestal Bearings for preferred modes.