EXPANSION JOINT & BEARING INSTALLATION ISSUES:
AN OWNER’S PERSPECTIVE

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ABSTRACT

The durable performance of modern bridge expansion joint and bearing systems depends upon high-quality design, fabrication, installation, inspection, and maintenance. High-quality installation and inspection practices are often overlooked as key aspects in ensuring optimal performance and durability. Most public transportation agencies will confirm that a disproportionate percentage of bridge serviceability issues are related to expansion joint and bearing devices. By presenting a series of case studies, this paper will provide an owner’s perspective in discussing some typical construction and handling problems commonly encountered during the installation of bridge expansion joints and bearings. Collaborative measures that can be taken by manufacturers, owners, and construction contractors to enhance installation quality and mitigate or prevent these problems will be discussed.

Keywords: bridges, expansion joints, bearings, construction, installation, inspection, communication, training
INTRODUCTION

Expansion joint and bearing components and their anchorages experience severe loading often under harsh environmental conditions. As a consequence of their geometric configuration and multiple-axle vehicle loading, expansion joint elements are generally subjected to a significantly higher number of load cycles than other structural elements. Exacerbating this loading environment is the fact that expansion joints are often the last components designed and installed in a new bridge. As such, expansion joints and bearing systems are often relegated a secondary level of importance by designers, construction contractors, and inspectors. As a result of these adverse influences, these systems are some of the first elements of a new bridge to manifest distress. To mitigate this reality, special attention must be given to design, fabricate, transport, install, and maintain these systems to assure satisfactory performance throughout the intended service life of the structures in which they are installed.

Heavier axle loadings and burgeoning traffic volumes in recent years have further challenged the durability of expansion joint and bearing systems. The failure of federal, state, and local governments, since about 1980, to add lane miles commensurately with vehicle miles traveled, particularly in highly urban areas, has worsened traffic gridlock in many large U.S. cities. This increased gridlock has imposed strong political pressures on transportation agencies to minimize the closure periods needed to satisfactorily rehabilitate aging bridges and roadway. In many urban environments, rehabilitation work is restricted to night-time and / or weekend closures. In order to accommodate these reduced closure periods, transportation agencies have structured rehabilitation contracts using incentive clauses for early completion. These agencies have additionally allowed construction contractors to utilize new, in some cases marginally proven, materials and technologies in addition to reduced concrete curing times. The use of limited closures and incentive clauses for early completion can lead to shortcuts and omissions if not properly managed. These adverse consequences are attributable not only to materials, technology, and labor deficiencies but also to poor handling of materials and reduced inspection oversight by contracting agencies. This technical paper will present several case studies in Washington State in which well-designed and fabricated systems were either handled or installed in an unsatisfactory manner, resulting in poor performance, premature failure, and the need for subsequent repair or replacement. Discussion of collaborative methods to employ to preemptively avoid these kinds of failures will be subsequently presented.

I-5 SB Blakeslee Junction Bridge – Armored Strip Seal Expansion Joint Failure

The southbound I-5 Blakeslee Junction Bridge was constructed in 2013 as part of an I-5 capacity enhancement project near Centralia, Washington. This three-span prestressed concrete girder structure has a total length of 400 feet. An armored strip seal expansion joint was installed at each abutment to accommodate a seasonal thermal movement range of about 1-1/2 inches. The bridge was opened to traffic about eight months after the installation of the expansion joints had been completed. Soon after the bridge was opened to traffic, the upper portion of the concrete adjacent to one of the strip seal steel frame rails at the north abutment began to crack and spall out, exposing the detached frame rail, as shown in Figure 1. An investigation ensued to determine the cause of this strip seal expansion joint failure.
This strip seal expansion joint used two hot rolled steel frame rails to armor the expansion gap. Two rows of 5/8-inch-diameter x 6-inch-long steel headed studs were shop welded to each frame rail to anchor the rail into concrete placed into preformed blockouts. One row of studs was oriented horizontally while the second row was staggered and oriented at an angle of 20 degrees to the horizontal. Visual inspection revealed that the bottom of the spall was approximately coplanar with the horizontal row of steel headed studs. (Figure 1)

The manufacturer's approved shop drawings (Figure 2) showed the strip seal expansion joint system as being temporarily suspended into a preformed blockout on each side of the expansion gap prior to concrete placement using an erection angle or equal provided by the contractor. Threaded steel studs were welded to the tops of the frame rails at 10'-0" maximum spacing. These threaded studs were detailed to engage slotted holes in the horizontal legs of the erection angles. A pair of nuts engaging each threaded stud, one above and one below the horizontal leg of the erection angle, were detailed to allow the contractor to set the expansion joint assembly to the specified grade and elevation. The intent of the slotted holes in the horizontal legs of the erection angles was to allow the steel frame rails to be set at a gap opening corresponding to the superstructure temperature at the time concrete was placed in the blockouts. A temperature versus gap opening table was shown on both the contract drawings and the approved shop drawings. The intent of the erection angles, threaded studs, double nuts, and slotted holes was to allow the contractor to set the frame rail gap opening immediately before concrete placement and to immediately release the restraint after concrete set-up in order to allow unimpeded opening and closing movement of the system. Figure 3 shows the strip seal expansion joint system suspended in its blockouts prior to concrete placement.

Closer review of Figure 3 revealed that short segments of steel reinforcement bar were intermittently welded across the tops of the steel frame rails. (Figure 4) Comparison of date stamps on the photographs with information contained in inspector daily reports indicated that the bars had been welded at least five days prior to concrete placement in the blockouts. This was clearly in nonconformance with the contract drawings and specifications as well as the manufacturer’s approved shop drawings. The inspector daily reports provided no indications as to when the welded reinforcement bars might have been removed following concrete placement.

Official temperature records for Centralia, Washington, showed that air temperatures had varied over a 30°F range during the 24-hour period following concrete placement. The same records showed that air temperatures had increased about 6°F during the hour following commencement of concrete placement. Recognizing that the temperature of a structure typically lags ambient air temperature, resulting in a variation of temperature of the structure that is somewhat less than the variation of air temperature, it is still quite likely that the unimpeded range of motion of the expansion joint during the 24-hour period following concrete placement would have been as much as 3/8 inch.

The presence of the delamination plane coincident with the plane of the horizontally oriented steel studs welded to the steel frame rail suggested that the immature concrete had experienced distress as a consequence of being unduly restrained. The investigation concluded that the contractor’s failure to remove the welded steel reinforcement bars immediately following concrete placement was the most likely cause of this expansion joint failure. The restraint imposed by the welded bars would have restrained the expansion joint from moving with the
bridge deck in response to variation in the temperature of the structure. This condition would have imposed undue stress in the uncured concrete, creating a delamination in the concrete coincident with the plane of the horizontal steel studs anchoring the frame rails. After the bridge was opened to traffic, wheel impact caused the concrete above this delamination to spall away. This situation could have been avoided had the contractor followed the installation procedure delineated in the approved shop drawings.

**I-5 SB BNSF / Dike Road Overcrossing Bridge – Armored Strip Seal Joint Failure**

A 675-foot long steel plate girder bridge spans over the BNSF rail line and Dike Road, carrying southbound I-5 traffic near Woodland, Washington. Originally built in 1972, this structure was designed with steel sliding plate expansion joints at each abutment. After a 40-year maintenance-prone service life, these joints were replaced with armored strip seal expansion joint systems in 2012. The strip seal expansion joint systems were installed in two stages to accommodate traffic flow. This required the elastomeric strip seals to be installed full width of the roadway after the steel frame rails had been installed for both stages and concrete placed in blockouts. After several months of service, the new strip seal expansion joint frame rails, embedded in concrete with welded reinforcement bar loops, began to fail over the abutments. After less than two years of service, the frame rails at both abutments became loose and had to be removed in the heavily traveled rightmost lane of the bridge.

WSDOT commenced an investigation in 2015 to attempt to determine the cause of the premature failure of this armored strip seal expansion joint installation. An inspection revealed that the remaining frame rail that was embedded in concrete over the abutments was perceptively displacing under vehicular loading. This condition suggested that either the welds of the reinforcement bar loops had failed or the reinforcement bar loops were somehow moving within concrete that was not adequately restraining the loops. The inspection also revealed that the elastomeric strip seal element at both abutments had become unseated and was drooping underneath the bridge deck. This condition is extremely rare for properly installed armored strip seal expansion joint systems.

A review of construction photographs taken during the installation of the strip seal expansion joints showed that the steel shipping clamps were used to set the expansion gap opening prior to concrete placement over the abutments. Figure 5 shows that the threaded stud was positioned at the extreme end of the slotted hole in the shipping angle, corresponding to maximum possible closure. Had the bridge superstructure expanded, due to temperature rise following concrete placement, the threaded studs would have been bearing against the ends of the slotted holes of the shipping angles. If the construction crews had merely loosened the nuts securing the angles to the steel frame rail without removing the angles, the reinforcement bar loop anchorages would have been pushed back into the uncured concrete atop the abutment wall. This could have created voids where the reinforcement bar loops bore against the freshly placed concrete. This scenario would explain the perceptible displacement of the steel frame rails under load after the expansion joint was put into service. Although it was not possible to render a definitive conclusion, this was deemed to be the most likely cause of the failure.

The drooping elastomeric strip seal elements were carefully examined to determine the most likely reason that they were not seated in their respective steel frame rail recesses. Lane striping
paint was observed on the top side of the elastomeric seals as well as on the lobes that should have been inserted into the recesses of the steel frame rails. (Figure 6) The paint on the lobes attested to the improper installation of the elastomeric strip seal elements. Inspector daily reports showed that this deficiency was apparently identified on a punch list following installation, but was not corrected. A qualified installation technician or trained inspector should have been able to identify this deficiency immediately after the contractor attempted to install the seals.

**I-5 Capitol Lake Overcrossing Bridge – Preformed Silicone Strip Seal Adhesion Failure**

The I-5 Capitol Lake Overcrossing Bridge is a 4-span, 392-foot-long, conventionally reinforced concrete box girder bridge crossing Capitol Lake near Olympia, Washington. After three decades of relatively maintenance-free service, the armored strip seal expansion joints at both abutments failed and were replaced, in 2014, with an unarmored preformed silicone strip seal system. Replacement entailed removal of the existing steel frame rails, associated anchorages, and adjoining concrete, placement of new cementitious concrete headers, and installation of a continuous preformed silicone seal element at each joint. The silicone seal elements were installed with a silicone adhesive, as recommended by the manufacturer.

Several days following installation, the silicone seal strip seal elements detached from the newly placed concrete headers, as shown in Figure 7. Because rain had fallen following placement of the concrete headers, the system supplier initially asserted that moisture had interfered with the bonding of the preformed silicone seals. Based upon this information, the contractor removed the failed seals and installed replacement seals under dry conditions. Within two days of the second set of seals being installed, they also failed by detaching from the substrate concrete. Further investigation revealed that a concrete admixture, presumably used to accelerate rapid strength gain, had been used in the cementitious concrete headers. The system supplier subsequently concluded that the admixture had apparently caused a chemical reaction involving magnesium. This caused outgassing through the concrete, inhibiting the bond of the preformed silicone seals to the new concrete headers. The second preformed silicone seal was removed and replaced with a competitor’s system, which has performed satisfactorily.

This experience demonstrates the importance of good communication between the contractor, the expansion joint system supplier, and concrete and admixture suppliers. Because the concrete admixture was marketed by the same parent company as the expansion joint system, it also demonstrates some of the complexity associated with using new products. Experimentation with new products is best done on projects that have significantly less traffic demand than the I-5 Capitol Lake Overcrossing Bridge.

**Triangle Project Ramp Bridge – Modular Expansion Joint – Concrete Consolidation**

The Triangle Project reconstructed the I-5 / SR18 interchange near Federal Way, Washington. As part of the overall project, a continuous curved steel box girder bridge was built, in 2012, to connect westbound SR 18 to southbound I-5. This structure was designed with 9-inch motion range modular expansion joints at each end to accommodate service movements. Shortly after the bridge was opened to traffic, surface cracks, in the direction of traffic, were observed in the top of the concrete deck adjacent to the modular expansion joint edge rails. Maintenance staff
further reported that loud pounding noises were heard in the vicinity of the modular expansion joints. In one instance, a chunk of concrete deck material spalled out adjacent to one of the modular expansion joint edge rails. A field investigation and review of construction records ensued in response to these complaints.

The thickened concrete superstructure adjacent to each side of a modular expansion joint functions as a deep beam stiffening the edge of the deck slab and carrying loads transmitted over the joint through the modular expansion joint support boxes. As such, the concrete blockouts into which a modular expansion joint is placed are generally designed and detailed with continuous steel reinforcement bars atop the support boxes, parallel to the edge rail, to carry negative bending moment over longitudinal girders. Construction records showed that the contractor had not installed these continuous bars consequent to a misunderstanding of the contract plans and specifications, which required a minimum cover over the top of all deck reinforcement bars. Because the tops of the modular expansion joint support boxes were too high to allow the specified minimum top cover, the contractor omitted the bars. While this explained the surface cracks in the deck, it did not explain the pounding noise or the concrete spall.

During the subsequent field investigation, a tactile inspection of the tops of the modular expansion joint edge rails revealed perceptible vibration in some portions of the edge rail when subjected to heavier axle loading. This included the section of the edge rail adjacent to the spalled concrete. The inspection team subsequently entered the two steel box girders to inspect the modular expansion joints from underneath. It was immediately observed that the pounding noise was originating from one of the support boxes. Visual inspection of that support box revealed that it was displacing vertically relative to the concrete deck when subjected to heavy axle loads, indicating inadequate concrete consolidation underneath the support box. The presence of water draining around the support box from the deck above further indicated collateral damage to the concrete above and adjacent to the support box. Water was observed to be draining out of the concrete adjacent to several other support boxes, suggesting inadequate concrete consolidation underneath those support boxes also.

The concrete underneath modular expansion joint support boxes is part of the critical load path transferring vehicular loads from the bridge superstructure to the substructure. Given its importance, the WSDOT special provision for modular expansion joints cites the importance of achieving adequate consolidation. The special provision required that a qualified installation technician, employed by the manufacturer of the modular expansion joint system, be present during the installation of the modular expansion joint. On this particular project, the concrete placement into the modular expansion joint blockouts was delayed one day from the anticipated schedule. The installation technician departed the jobsite after leaving the contractor written instructions for completing the installation. Although those instructions included the need to achieve adequate consolidation underneath all support boxes, those instructions, if conveyed, appear to have not been heeded.

Following the investigation, a weekend closure was scheduled for the contractor to correct these deficiencies. The concrete in all blockouts was removed to the tops of the support boxes, as shown in Figure 8, to allow placement of the steel reinforcement bars that originally had been omitted. Additionally, concrete was removed full depth of the blockout at suspect support box locations, as is also shown in Figure 8. After reinforcement bars were installed and forming
placed, concrete was placed, with particular attention given to achieving complete consolidation underneath support boxes. Figure 9 shows the existing modular expansion joint and reinforced blockouts immediately prior to concrete placement.

I-90 WB East Channel Bridge – Modular Expansion Joint Replacement – Handling Issues

The I-90 East Channel Bridge connects Mercer Island to Bellevue, Washington. Built in 1981, the westbound 2,224-foot-long steel box girder structure has 12-inch motion range modular expansion joints at each of two superstructure hinge locations. The original modular expansion joints, designed and fabricated prior to the advent of fatigue resistant design and test requirements, manifested multiple welded centerbeam field splice failures after three decades of service, as shown in Figure 10. Emergency repairs were subsequently performed and a project programmed to replace the two modular expansion joints.

WSDOT prefers avoiding centerbeam field splices as a consequence of poor performance on earlier generation modular expansion joint installations. However, in order to mitigate traffic disruptions on this major route across Lake Washington going into Seattle, WSDOT decided very early during project development to stage the replacement of the joints approximately one-half of the roadway width at a time. Traffic lane configuration for each stage dictated centerbeam field splice locations. WSDOT specifications require that fatigue susceptibility of field splices be mitigated by reducing support box spacing and optimizing the location of the splice between adjacent support bars. WSDOT policy allows the use of welded or bolted centerbeam field splices, further requiring that all welded splices be ultrasonically inspected. The contractor and modular expansion joint system supplier opted for welded field splices. The ends of the centerbeams of each modular expansion joint segment were machined with bevels at the field splice location prior to final assembly and painting, as shown in Figure 11.

Low-friction bearings in the support boxes of a modular expansion joint allow support bars to move relatively freely as the expansion joint opens and closes with movement of the superstructure. Low-friction properties are facilitated by the relative movement of the bearings against a polished stainless steel slide plate. While the modular expansion joint assemblies for this project were being stored in the contractor’s staging area, a work crew was directed to prepare the machined ends of the centerbeams for field welding by removing surface paint. In lieu of using a grinder or similar tool, the workers, without soliciting guidance from the manufacturer’s installation technician, used sandblasting equipment to accomplish this task. In the process, the No. 8 mirror finish was eroded on many of the stainless steel slide plates, as shown in Figure 12. WSDOT staff was advised of this situation less than six hours before roadway closures were scheduled to commence, leaving the agency in the difficult position of having to decide whether to proceed with the project.

WSDOT immediately contacted the manufacturer for assistance in determining whether the stainless steel slide plates could be quickly and easily replaced or repaired without delaying the project. The manufacturer advised that it would be infeasible to replace the stainless steel sheet without disassembling the bearings inside the modular expansion joint support boxes. The manufacturer recommended that the contractor use a rotary tool and Scotch-Brite™ pads to attempt to re-polish the damaged stainless steel surfaces. They further advised that a No. 2B finish was likely attainable in the field, while a No. 8 mirror finish was not. Following the
manufacturer's recommendations, the contractor's work crew was able to reestablish a No. 2B finish to the satisfaction of WSDOT fabrication inspectors. AASHTO LRFD Bridge Construction Specifications\(^2\) state that stainless steel bearing surfaces shall be polished to a No. 8 mirror finish. Recognizing research done by Stanton and Taylor\(^3\) regarding the use of No. 2B surface finishes in stainless steel / PTFE sliding bearings, WSDOT directed the contractor to proceed with the project, accepting the No. 2B finish and its associated tradeoffs.

**Nalley Valley SW-Line Bridge**

The Nalley Valley SW-Line Bridge is a 4-span precast concrete segmental box girder structure having a total length of 1,056 feet. This ramp bridge connecting northbound I-5 to westbound SR 16 near Tacoma, Washington, was constructed in 2010 using the balanced cantilever method of construction. Each end of the superstructure is supported on a pair of sliding disk bearings. One of these bearings is shown, during installation prior to grouting, in Figure 13. Each of these disk bearings incorporates polished stainless steel – PTFE sliding interfaces that can accommodate a total longitudinal movement range of 12 inches. The masonry plate of each disk bearing is anchored with four 1¼-inch diameter anchor bolts. Each sole plate is anchored into the precast concrete superstructure segment with four 1½-inch diameter steel pintles, oriented in a square arrangement. The pintles are post-grouted into recesses formed into the bottom of the precast concrete end segment, as shown in Figure 13.

The construction sequence required that the precast concrete superstructure end segment at the abutment or end pier cap be lowered down over the bearing pintles, which were welded to the tops of the disk bearing sole plates, and set temporarily onto timber blocking. After post-tensioning each precast concrete end segment to the remainder of the concrete superstructure, the end segment was jacked vertically to the specified dead load reaction. The sole plates and pintles were then grouted. Once the grout achieved adequate strength, the jacking loads were released, transferring the specified dead load reactions onto the bearings.

Following placement and bolting of the disk bearing masonry plates to the end pier, it was determined that the anchor bolts had been set in the wrong locations and needed to be relocated. In the process of lifting and reinstalling the disk bearing assemblies on the new anchor bolts, the sole plates were inadvertently rotated 90 degrees relative to the masonry plates. The construction crews failed to recognize and correct this error by rotating the sole plates back to their original orientation before the precast concrete end segment was lowered into position and post-tensioned to the adjacent superstructure segment. With the polished stainless steel sliding plates seal welded to the bottoms of the sole plates, their directional orientation was now perpendicular to the longitudinal movement direction of the superstructure.

With the 13-inch long pintles now extending upward into the as-yet-ungrouted recesses in the bottom of the post-tensioned precast concrete end segment, the entire superstructure would have had to be lifted above I-5 mainline traffic in order to free the pintles and rotate each disk bearing sole plate 90 degrees back to its correct orientation. Collaborating with the bearing manufacturer, the contractor developed a repair procedure to cut the pintles within the limited clearance between the soffit of the precast concrete end segment and the top of each sole plate, rotate the sole plate 90 degrees back to its correct orientation, and re-weld the pintles. Wire feed, in lieu of stick feed, was used to re-weld the pintles in the very limited vertical clearance between the
soffit of the precast concrete end segment and the top of each sole plate. The ground lead of the welder was attached to the sole plate in order to prevent welding current from arcing the pin of the disk bearing to the upper bearing plate. Temperatures of the sole plate were carefully monitored during welding, using temperature crayons, to assure that neither the polyether urethane disk nor the PTFE would be damaged.

**DISCUSSION AND RECOMMENDATIONS**

Largely all of the aforementioned construction issues or failures involved high-quality proven expansion joint or bearing systems that were either handled improperly or installed incorrectly. All cases involved basic misunderstandings of how the system was intended to perform and / or the rationale behind procedural methods provided to install them. All of these issues could have been avoided with the intervention of a knowledgeable installation technician, construction foreman, or owner agency inspector. In essence, these failures were systemic failures of communication between owners, manufacturers and their installation technicians, contractors, and inspectors. Without attempting to assign culpability to any specific entity, it is worth discussing measures that could be taken to mitigate the potential for such issues occurring in the future.

**Use of Qualified Installation Technicians**

Many owner agencies, including WSDOT, have required that a qualified technician be present during the installation of more complex systems such as modular expansion joints. The installation technician is generally required to be an employee of the system manufacturer. The installation technician’s cost is typically borne by the contractor and built into the total bid price. The installation technician's role is to provide guidance to the contractor in the proper handling and installation of the system, and to assist the contractor and owner agency in resolving construction issues encountered during installation. Inherent in this role is the recognition that an experienced, trained installation technician is most knowledgeable in the aspects of installation that are critical to achieving long-term satisfactory performance. In fulfilling his duties, the technician adds value both for the contractor, by helping to avert costly mistakes during system installation, and for the owner agency, by assuring that the installation will provide the expected performance and service life. Problems have occurred when handling or installation operations have proceeded in the absence of the installation technician. Aforementioned examples include the failure to achieve adequate concrete consolidation underneath the support boxes of the modular expansion joints installed on the I-5 / SR18 Triangle Project ramp bridge and the haphazard sandblasting of the polished stainless steel slide plates constituting the modular expansion joint support box bearings of the I-90 East Channel Bridge. A more thorough appreciation of the value added to a project by the installation technician and more stringent specification requirements and enforcement on when the installation technician must be present could avert such construction errors.

**Improved Owner Agency Inspection**

Owner agency inspectors serve a vital role as gatekeepers in assuring that construction is completed in accordance with their agency's contract documents and the manufacturer's
approved shop drawings. In many aspects, an inspector's importance is elevated for projects not requiring the presence of a qualified installation technician. However, the effectiveness of an inspector in recognizing potential problems depends substantially upon his knowledge and experience on projects of similar work scope. Maintaining an experienced cadre of construction inspectors can be challenging for agencies experiencing budgetary restraints and employee retention issues.

**Specialized Training of Design and Inspection Staff**

Many transportation agencies, including WSDOT, internally schedule regional construction, design, and maintenance conferences outside of the regular construction season. These conferences provide venues for exchange of information between different offices and disciplines. The WSDOT Bridge and Structures Office regularly participates in these conferences by providing instructional presentations related to expansion joint and bearing systems. Depending upon the target audience, these presentations may focus on the selection and design of systems or to the operational characteristics, installation, and inspection of such systems. In advance of a contract to replace modular expansion joints on several Columbia River bridges in east-central Washington State a few years ago, just-in-time training was provided to inspectors to familiarize them with modular expansion joint operational characteristics, critical aspects of installation, and key things to look for during inspection. In addition to the educational benefit of such training, these sessions facilitate development of working relationships between different disciplines. Such training would, hopefully, impart the knowledge needed for an inspector to recognize the unacceptability of such actions as welding steel reinforcement bars across the steel frame rails of a strip seal expansion joint in advance of concrete placement or sandblasting polished stainless steel bearing surfaces.

**Understanding Roles and Effectively Coordinating**

As implied in the introduction, a high-quality, durable expansion joint or bearing system requires the input of many different disciplines, from the engineer designing and detailing the system to the construction worker installing the system. Recognition of the different skills and backgrounds of all the individuals involved contextualizes the kinds of communication that need to occur to achieve desired performance and durability. For example, the bridge structural engineer and the expansion joint manufacturer’s design engineer best understand the load path associated with vehicular axle loads crossing a modular expansion joint. The installation technician, having been trained by the manufacturer, understands the load path and critical aspects of installation that affect it. On the other hand, construction workers placing and vibrating concrete into the pre-formed blockouts likely don’t understand the load path. In fact, it is quite likely that they have never placed concrete anchoring a modular expansion joint. Value can be added to the installation process by briefly explaining the load path concept in a manner that emphasizes the workers’ nexus in a successful installation. A simple five-minute conference between the installation technician and the construction crew prior to concrete placement would provide the opportunity to convey how concrete placement and vibration should be performed in the vicinity of each support box. This communication may well suffice in assuring that the job is done right the first time, obviating the need to make very expensive repairs later.
Documentation and Review of Installation Procedures

Project specifications typically require contractors to submit written procedures, for review and approval, prior to undertaking more complex or novel construction operations. With respect to expansion joint and bearings systems, articulating such procedures is particularly important when shop drawings are vague or don’t provide explicit guidance. These procedures assure that means and methods are carefully developed and vetted before construction.

In 2009, WSDOT contracted the replacement of 65-year old steel finger joints on the southbound I-5 North Fork Lewis River Bridge near Woodland, Washington. Early in the design process, a decision was made to replace the continuous finger joint plates with a proprietary segmented finger joint system that would be post-tensioned to concrete elements underneath. A cross section showing the replacement system is depicted in Figure 14. This system allowed the work to be staged to accommodate traffic flow requirements for the project. Unlike a typical armored strip seal or modular expansion joint installation, in which the entire system is set as a single unit, locked down, and cast in concrete within a relatively short time period, the installation of the individual finger joint segments occurred over several hours. In the absence of a procedure provided by the manufacturer or supplier to recognize the variation in the structure temperature while the joint segments were being sequentially installed, WSDOT worked with the contractor and the system supplier to develop a procedure to assure that the modular segments were installed correctly. This procedure relied upon using the ambient air temperature at sunrise as a proxy for the temperature of the superstructure for the purpose of establishing where the individual panels would be set. Base lines were then inscribed on each side of the expansion joint to reference panel positioning. The general procedure is described by Dornsife4. A photograph of the newly replaced steel finger joint system on the southbound I-5 North Fork Lewis River Bridge is shown in Figure 15.

Consideration of Handling Issues during Design

High load multi-rotational bearings should be designed to fully accommodate future inspection, maintenance, and replacement of all elements subject to wear or other deterioration5. Additionally, consideration should be given during design, wherever possible, to detail systems and their connections to superstructure and substructure elements, to minimize the potential for incorrect or improper installation. For instance, had the pintles welded to the tops of the sole plates of the disk bearings of the Nalley Valley SW-Line Bridge been detailed in a rectangular, rather than square, pattern, the misplacement of the sole plate assembly would have been identified and corrected while the precast concrete superstructure end segment was being lowered rather than after it had been post-tensioned into position.

High load multi-rotational bearings should be conspicuously marked by the manufacturer, before shipment, to show the position of the bearing within the structure and indicate the direction ahead on station5. Manufacturers generally ship bearings with temporary straps connecting major components together. These straps assure that individual components do not separate and get misoriented or damaged during shipment or installation. The manufacturer's shop drawings generally state that bearings shall not be disassembled after leaving the factory without the authorization of the manufacturer or designated installation technician. Figure 13 shows the shipping straps still intact on one of the disk bearings installed at the abutment of the Nalley
Valley SW-Line Bridge. The repairs to the disk bearing at the end pier would likely not have been required had the contractor complied with the manufacturer's shop drawing admonishment to not remove the shipping straps prematurely.

CONCLUSIONS

It is extremely difficult to overestimate the importance of high-quality installation practices as they relate to the long-term durability of bridge expansion joint and bearing systems. This paper has presented a series of case studies in which expansion joint and bearing systems have been either mishandled or installed in an unsatisfactory manner resulting in serious bridge serviceability issues requiring unplanned repairs or replacement. Observations and investigative conclusions were presented for each of these cases. Regardless of culpability, owner agencies, contractors, inspectors, manufacturers and public end users are all adversely affected when hardware is mishandled or installed improperly.

Recognizing the diverse role of each of the disciplines involved in installing a system and the importance of communication between these entities, a discussion of collaborative methods and suggestions to better assure high-quality installation was presented. These concepts included specialized inspector training, use of qualified installation technicians, enhanced communication with construction contracting crews, development and stringent enforcement of written procedures and shop drawings, and recognition of potential installation issues in the design and detailing of system hardware. The costs associated with implementing these suggestions are far outweighed by the impacts of unanticipated premature failures of otherwise proven systems. Beyond the financial costs associated with repairs or replacement, these impacts include the public perception and reputation of manufacturers, construction contractors, inspectors, and owner agencies.
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Figure 10 – I-90 WB East Channel Bridge – Failed Centerbeam Field Splices
Figure 11 – I-90 WB East Channel Bridge – Beveled Centerbeam Ends

Figure 12 – I-90 WB East Channel Bridge – Sandblasted Stainless Steel Slide Plates
Figure 13 – I-5/SR 16 Nalley Valley SW-Line Bridge – Guided Disk Bearing

Figure 14 – I-5 SB North Fork Lewis River Bridge – Expansion Joint Cross Section
Figure 15 – I-5 SB North Fork Lewis River Bridge – Installed Modular Steel Finger Joint