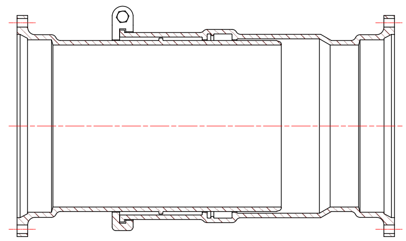
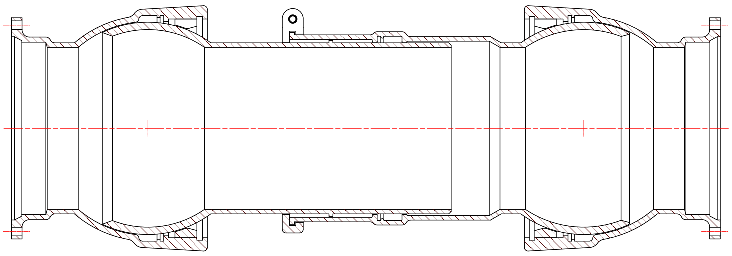
EBAA IRON Connections™
TECHNICAL DATA FOR THE WATER & WASTEWATER PROFESSIONAL
FT - 5

Bridge Crossings and the Proper use of EX-TEND®, FLEX-TEND®, and Force Balanced FLEX-TEND Products

Bridges can serve as very convenient structures for routing utility piping over obstacles such as rivers, canyons, or highways. Where allowed, there can be multiple lines utilizing the crossing. Of particular interest for this discussion is the locating of pressurized water lines on and under bridge structures. Pressurized pipelines can present a number of unique challenges to the design engineer and utility owner.



EX-TEND
Expansion Joint



FLEX-TEND
Flexible Expansion Joint

Bridge designs and water pipe designs vary widely across the country. Include in that mix the variety of municipal requirements and differences in environment and it's possible to understand that developing hard and fast rules regarding the design and installation of waterline bridge crossings is difficult. This discussion, however, does not speak to all aspects of the design of a crossing pipeline. Its purpose is to bring forward a number of considerations and challenges that must be addressed during the design and construction process with the incorporation of the Flex-Tend family of products from EBAA Iron, Inc., plus the simplification that a Force Balanced Flex-Tend offers. This family of products provides a variety of expansion and flexible-expansion joints to protect pipeline connections from the adverse affects of differential movement.

Pipeline Location

Generally, it is preferred that the pipelines be constructed in a straight alignment as they enter, cross, and exit the bridge structure through some type of abutment penetrations. Doing so greatly simplifies the crossing design by minimizing thrust forces and avoiding bending moments that can occur at fitting offsets. Flexible penetrations can allow for a minimal amount of flexibility in the longitudinal, transverse, and vertical directions. They should also provide a means of sealing around the pipe to prevent soil moisture from migrating to the abutment structure. If flexible penetrations are used any thrust that is generated in the piping in the soil can transmit thrust forces to the piping and must be accommodated. (Expanded discussions on thrust forces and fitting offsets follow a little later.) Another is a "rigid" penetration such as a cast-in-place wall sleeve with a wall flange to prevent the transfer of forces from one side of the abutment to the other.

Expansion Joint Considerations

Expansion joints are called for on many waterline bridge crossings. Generally this is to accommodate differences in thermal expansion between the bridge structure and the pipeline. The pipeline expansion joints are typically located at abutments and, depending on the bridge design and length, at active expansion joints in the bridge. In seismically active locations consideration must also be given to the differential movement associated with bridge decks at abutments.

Thrust Forces

Thrust forces can come from two phenomena. First is the hydraulic thrust force and second is expansion force resulting from the different expansion coefficients of the pipeline and bridge materials. If not dealt with properly, the effects of these thrust forces can be manifested through "snaking", or over-deflection, of the pipeline-even pipelines in straight alignment. Each unrestrained pipe joint and each typical expansion joint, when pressurized, acts like a hydraulic cylinder. The force that is generated by the "hydraulic cylinder" is equal to the cross sectional area of the pipe (based on the outside diameter) multiplied by the internal pressure. Second, because pipeline and bridge structures are made of different materials they react differently to changes in temperature. Particularly for pipe crossings with fixed ends (straight crossings and structurally supported fitting offsets at abutments usually qualify as fixed), an increase in temperature can result in compressive thrust force like that generated by the internal pressure. A decrease in temperature can act to place tensile forces at pipe joints that could lead to joint separation. With the dimensional and material parameters of the pipeline and how it reacts relative to the bridge structure, the thermal force can be calculated with Euler's Equation. These thrust forces must be accommodated in some manner.

Straight pipelines, with flexible joints and no horizontal support, will snake because the pipeline is never perfectly straight and, if the pipe is not supported properly, the forces described earlier act at deflected joints and can cause additional pipe joint deflection. Even if the pipe is straight, any kind of vibration or external force can push the pipeline out of alignment and allow the thrust forces at the joints or from an expansion joint to "compress" the pipeline. That acts to further deflect the pipeline joints. The introduction of fitting offsets often compounds the problem because of the bending moments acting on the offsets.

Accommodation of these thrust forces involves several considerations. One is proper pipe support design and location. Another is the proper restraint of the pipeline joints. A third is the use of structural supports, especially around fitting offsets.

Pipeline "Snaking" Due to Inadequate Lateral Support

Pipe Support

This is one of the more critical considerations. It is very important to support the pipe as recommended by the pipe manufacturer. Depending on the bridge design and local requirements there are a number of options for support including, but not limited to, pipe hangers, rollers, and concrete pipe saddles. In the case of ductile iron pipe the recommendation from the Ductile Iron Pipe Research Association (DIPRA) is "to use one support per length of pipe positioned immediately behind the bell." Also from DIPRA is the statement "It is of the utmost importance that sufficiently sturdy and properly located pipeline support structures be provided to prevent lateral and vertical movement of the pipe or joints and to also prevent any detrimental axial bending of the supports in response to axial pipeline movements." Another appropriate admonition for proper pipe support comes from Bharil. "A poorly designed or installed hanger support system not only can undermine the pipeline durability but also could cause significant damage to the host bridge."

Pipe Joint Considerations

When using expansion or flexible-expansion joints to protect bridge crossing pipelines it is important that the pipeline joints be restrained. This forces any movement or change in the pipeline to be transferred to the expansion joints. Additionally, care should be exercised when utilizing proprietary push-on bell restrained joints. These joints typically have slack that must be removed after the joints have been assembled. If this is not done completely, thrust force will be generated at these joints when the pipeline is pressurized as if the joint were not restrained at all. Use of a no-slack restraint like the Megalug® mechanical joint restraint helps to alleviate this issue.

Please remember that welded steel and flanged pipelines are fully "restrained".

Structural Support of Fitting Offsets

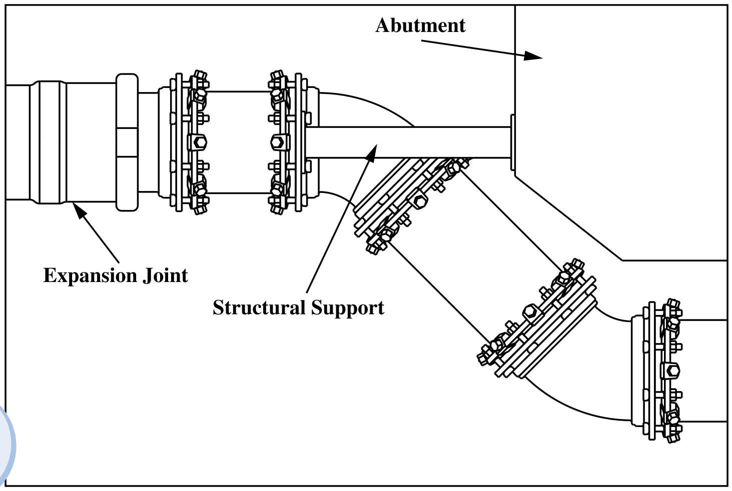
A straight, underground pipeline usually doesn't require any kind of restraint consideration. This is because the thrust force from one joint tends to offset the force from adjacent joints. Plus, that balance in combination with the weight of the surrounding soil keeps the pipeline intact. One of the most familiar means of restraining underground piping is the use of thrust blocks. Thrust blocks take the unbalanced thrust force that develops at pipeline fittings and transfers it to the surrounding soil.

In like manner thrust forces for bridge crossings that utilize expansion joints must be constrained. For completely straight runs of exposed piping this can be accomplished via proper lateral and vertical pipe support at each joint. When fitting offsets are present at the abutment locations the fittings must be braced against the abutment structure to, as with a thrust block, transfer the thrust force to the concrete structure. It is extremely important that this bracing be to the abutment and not the bridge itself. Otherwise any movement or change at the transition from the bridge deck to the abutment will not be transferred to the expansion joint as it should be. Remember, properly restrained pipe joints do not impart any kind of thrust force and that most expansion joints, in order to accommodate changes in pipe length, must be free to move (unrestrained). Therefore a thrust force is introduced and will impart a bending moment at fitting offsets-even if the offsets are restrained-unless the pipeline is braced to prevent it.

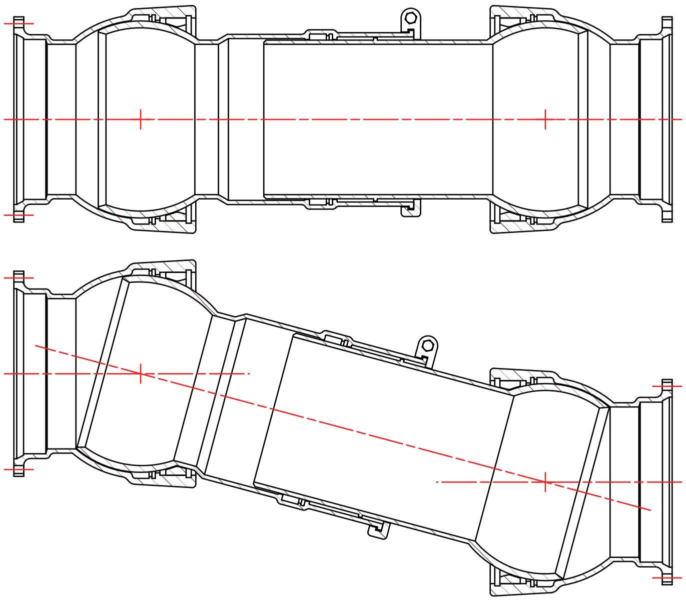
The Force Balanced Flex-Tend, on the other hand, will not impart a thrust force and does not impose a bending moment on fitting offsets.

Expansion Joint Selection

The Flex-Tend family of products from EBAA Iron, Inc. comes in a variety of configurations. This enables the pipeline designer to tailor the flexible-expansion protection provided with the specific requirements of the bridge and piping arrangement. Double ball flexible expansion joints provide the most versatility and are particularly useful at locations where the pipeline must be protected from transverse as well as linear movement (think seismic action or connection locations subject to settlement.)



Schematic of Structural Support for and Offset



Double Ball Flex-Tend Unit Without and With Offset

For more information regarding the FLEX-TEND product line by EBAA Iron, please visit us at

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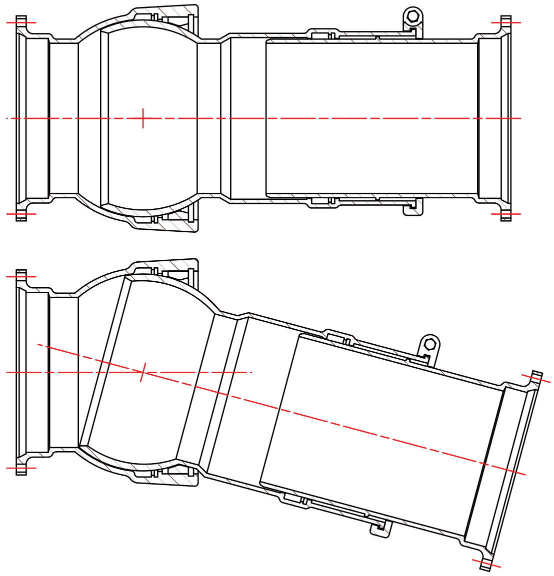
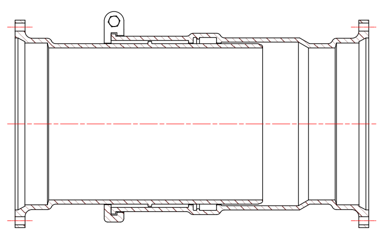
The single ball Flex-Tend product offers protection for locations subject to linear movement and angular deflection (but no offset). This can be useful for flexible bridge designs at the transition back to fixed abutments.



Single Ball Flex-Tend Unit Without and With Angular Deflection

Finally the Ex-Tend can be incorporated into bridge crossing designs needing only linear accommodation.



Ex-Tend Expansion Joint

Eliminating the Thrust Force

Providing adequate support and means for protecting a pipeline against the thrust forces that accompany expansion and flexible expansion joints can, at times, be cumbersome and expensive. An attractive alternative exists to provide that protection without the thrust forces - the Force Balanced Flex-Tend (see EBAA Iron, Inc. Force Balanced Flex-Tend brochure and Connection Bulletin FT-04 for more details). This innovative new design provides the same flexibility as the standard Flex-Tend but without the thrust force.

It is important to remember that this unit will not remove the thrust forces that can develop at unrestrained pipe joints or improperly assembled restrained joint piping. The line piping must still be assembled AND supported correctly.

Summary

With a pipeline bridge crossing the optimal routing takes the most direct route across the bridge structure- a straight line. This simplifies the construction and operation of the pipeline. Oftentimes actual conditions and specific requirements do not permit optimum design. Therefore, be sure to keep the following in mind during the design and construction of these pipelines.

1. Provide expansion/contraction accommodation for the differential movement that will occur.

2. Properly restrain pipeline joints so that changes are transferred to the expansion joints. (With proprietary restraint designs remember to remove the slack.)

3. Support the pipe correctly. Place supports immediately behind each pipe bell. Those supports must prevent lateral as well vertical movement of the pipeline.

4. Use the Force Balanced Flex-Tend to eliminate thrust forces and, therefore, protect the pipeline and bridge from thrust forces. Otherwise structural support must be provided at fitting offsets to keep the thrust forces that develop from subjecting the bridge and fitting configuration to potentially damaging bending moments resulting at conventional expansion and flexible expansion joints.

References:

Ductile Iron Pipe Research Association, “Bridge Crossings with Ductile Iron Pipe”, BC/3-07/4M. Published 12-96, Revised 3-07

Raj Bharil, Mark Pierepiekarz, and Web Chandler; “Guidelines for Bridge Water Pipe Installations”; ASCE Pipelines 2001