PRACTICAL IDEAS FOR WATER OPERATORS

American Water Works Association

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Thrust Restraint

New Systems Squeeze Joint Separations

Next-generation joint-restraint products promise to improve pipeline construction, replacement, and maintenance. BY SHAH RAHMAN

UNBALANCED FORCES that occur in a pressure pipeline caused by changes in flow direction or in the pipe's cross-sectional area are referred to as thrust. Thrust also occurs at dead-ends and during valve and hydrant opening and closing. If thrust isn't counterbalanced with an equal and opposite reaction force, joint separation in bell-and-spigot push-on joints will occur.

The common methods water utilities in the United States and Canada use to contain thrust include setting of concrete thrust blocks and use of external mechanical joint restraints, called lug-type restraints, or a combination of the two. When only lug-type restraints are used, it's usually necessary to restrain one or more pipe-to-pipe joints on either side of a fitting.

THRUST RESTRAINT METHODS

Thrust blocks and lug-type joint restraints are external to a piping system and pose several disadvantages, including time-consuming installation, corrosion of metallic parts—lug-type devices are completely metallic—and human error during assembly.

Concrete Thrust Blocks. Thrust blocks are masses of concrete that transfer and distribute pipeline thrust forces to the surrounding soil structure, preventing separation of unrestrained joints. A thrust block's bearing surface area is its most critical design factor because it distributes and transfers thrust forces to the soil mass adjacent to the fitting. The block's size and shape is determined by the forces to be restrained, the pipe fitting's size and type, and in-situ soil strength and conditions.

Although nonreinforced concrete thrust blocks resist corrosion, their use presents several challenges:

- Thrust blocks constructed in the field rarely replicate the engineer's design. At best, a mass of concrete is poured into the targeted location. Forms are rarely used to replicate the dimensions specified for thrust blocks. In the worst case, installation crews will place entire bags of quick-setting cement behind fittings and hope that groundwater will eventually infiltrate the bags and cause the contents to solidify. This practice can lead to catastrophic failures.
- The soil must be able to withstand the weight of the concrete's mass without settling over time. Gradual block settlement results in movement of the fitting and part of the pipeline until joint separation eventually occurs.
- Adequate space is necessary for accommodating a block, a requirement that's particularly challenging in developed urban environments.
- Until the concrete block has dried, usually requiring about 24 hr, the line can't be backfilled or hydro-tested.
- Future excavations in the area may be limited because the soil around and beneath the thrust block can't be disturbed.

Joint Restraints. Acceptance and use of joint-restraint devices have increased steadily since their introduction more than 40 yr ago for use with ductile-iron pipe. Polyvinyl chloride (PVC) joint restraints have been widely used in North America for at least 15 yr.

Although joint restraints eliminate many of the problems associated with thrust blocks, they too have disadvantages:

- Lug-type restraints are susceptible to corrosion because they are external to the pipeline, metallic, and must be installed on the outside of a pipe joint.
- Installation is time consuming and subject to human error. The tightening of nuts, bolts, and wedges is arduous and time-consuming, which leads to higher costs.
- Most PVC pipe-to-pipe joint restraints in North America don't meet requirements set forth in ASTM F1674, Standard Test Method for Joint Restraint Products for Use with PVC Pipe. Most products meet UNI-B-13, a less stringent standard writ-

Traditionally, the most common methods water utilities in the United States and Canada use to contain thrust are concrete thrust blocks and external mechanical joint restraints (top). Next-generation joint-restraint products include integral PVC joint restraints and self-restraining gaskets (bottom)—internal systems that minimize corrosion and installation time.

PHOTOGRAPHS: SHAH RAHMAN

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ten by the Uni-Bell PVC Pipe Association, but that standard was withdrawn in 1996 after publication of ASTM F1674. More than a decade later, many manufacturers still comply with UNI-B-13, and numerous municipalities continue to accept that compliance. Accordingly, products are being made and accepted based on specifications withdrawn more than a decade ago.

- Overtightening of wedges in joint restraint subjects the pipe wall to point loading. Even torque-off bolts commonly cause deformities in PVC pipe walls. Ultimately, uneven tightening of nuts and bolts, as well as use of torque-off bolts, can undermine the structural integrity of pipe and cause joint failure or leakage.
- Generally, serrated-type products can't sustain internal pressures as high as those sustained by products that meet ASTM F1674 and can therefore subject a system to leakage and failure. In particular, restraining rods contribute to these devices' failure.

NEXT-GENERATION PRODUCTS

The next generation of joint restraints attempts to resolve the various installation, corrosion, standardization, and logistical problems associated with concrete thrust blocks and lug-type joint restraints.

PVC Integral Joint-Restraint System. The integral joint-restraint system for PVC pressure pipe is designed for pipe-to-pipe connections and meets all ASTM F1674 requirements. The current version is designed for integration in pipes manufactured to AWWA Standard C900, PVC Pressure Pipe and Fabricated Fittings, 4 in. Through 12 in. (100 mm Through 300 mm). The mechanism consists of a metal casing that sits adjacent to the Rieber gasket in the bell, and the casing is molded into the raceway of the bell during pipe belling. A C-shaped grip-ring with several rows of unidirectional serrations is manually inserted into the casing after pipe hydro-testing and belling. The casing and grip rings are made of ductile iron and coated with an NSF-approved water-based rubber-toughed phenolic resin coating that exceeds 1,200 hr of salt-spray testing, equivalent to more than 50 yr of buried conditions.

When the pipe arrives at a jobsite, the two-piece restraint mechanism is already in the pipe bell. In the field, the joint is assembled like a regular push-on joint—the spigot is pushed into the bell up to the insertion mark.

Unidirectional serrations on the grip ring allow the spigot to enter but won't allow it to withdraw. When the spigot is inserted through

the grip ring, any opposing spigot movement causes it to engage by friction. In other words, the ring's serrations "bite" circumferentially and uniformly onto the spigot wall. Once the pipe is put into service, the hydrostatic pressure tends to push the spigot out of the bell; the opposing movement of the spigot causes the grip ring serrations to become evenly wedged into the spigot wall, fully engaging the restraint mechanism. The depths to which the serrations penetrate the spigot wall don't exceed 10 percent of the wall thickness, as allowed by AWWA standards for thermoplastic pipes.

Integral joints present major advantages over traditional external restraints:

NEXT-GENERATION PRODUCTS IN ACTION

McKinney, Texas

When the city of McKinney, Texas, was faced with replacing approximately 1,100 ft of a 6-in. cast-iron pipeline that was causing water quality issues because of extensive tuberculation, the utility used an 8-in. DR18 PVC pressure pipeline manufactured to meet AWWA C900. Tie-ins at both ends of the pipe required multiple fittings, horizontal bends, reducers, and tees that would have to be installed using lug-type restraints or concrete thrust blocks. To eliminate both external restraints and thrust blocking at the first tie-in beyond a 6x8 reducer, the utility used several 8-in. self-restraining mechanical joint gaskets for fitting-to-pipe connections and a PVC integral joint-restraint system for pipe-to-pipe connections.

A McKinney water distribution crew used self-restraining mechanical joint gaskets at valve tie-ins and integral joint restraints for pipe-to-pipe connections.

At the second tie-in, the integral restrained joint and self-restraining gasket were used for pipe-to-pipe and pipe-to-appurtnance restraint. Appurtenances included valves, 45° bends, and a 6x8 reducer. After installation, the system was pressure tested to 150 psi without any problems. No concrete was used in the job.

Subsequently, the utility needed to replace a corroded 6-in. cast-iron main and opted to use integral restrained-joint fabricated fittings meeting AWWA C900 guidelines to tie together an 8-in. DR18 PVC pressure line with the new 6-in. cast-iron main. Even though fabricated PVC fittings are widely used in sewer force-main applications, this was the first known installation of fabricated PVC fittings in a potable water system in the Dallas-Fort Worth Metroplex. Using the integral restrained joint eliminated the need to use lug-type joint restraints or concrete thrust blocks. Self-restraining gaskets were used to restrain a sleeve. Following installation, the system was pressure tested to 150 psi.

Garland, Texas

In summer 2007, the city of Garland, Texas, needed to replace a pipeline through a bored casing beneath an apartment complex parking lot. The pipeline serviced 29 houses. After the cast-iron line was replaced with PVC pipe, the pipeline's dead-end section was connected to the main line with 260 ft of 6-in. DR 18 (pressure class 150 psi) integral joint-restraint pipe manufactured to AWWA C900.

In Garland, operators minimized the risk of over-inserting the spigot into the bell during joint assembly by aligning the casing spacer edge with an insertion mark on the pipe spigot.

The dead-end was removed and converted to a looped line to eliminate stagnant water issues at area residences. The integral restrained-joint pipe was installed through a 12-in. metal casing pipe that was bored underneath the parking lot. Valves were placed at both tie-ins. Casing spacers were placed around the outside of the pipes before insertion into the casing. In particular, over-insertion of the spigot into the bell during joint assembly was prevented by aligning the casing spacer edge with the insertion mark on the pipe spigot.

The next generation of joint restraints is already proving to be an important addition to the water utility industry.

- Installation and assembly costs are negligible because installation is the same as a regular bell-and-spigot push-on joint.
- Human errors and PVC pipe wall point loading are eliminated.
- The potential for restraint mechanism corrosion is dramatically reduced because the casing and grip ring are coated. If the metallic casing is exposed to groundwater or soils entering through a gap between the bell-lip and spigot, the coating provides protection.
- The joints meet all ASTM F1674 requirements. Most lug-type PVC pipe-to-pipe restraints available on the market today do not.

PVC Fabricated Fitting Restraint. Fabricated PVC fittings manufactured to meet AWWA Standard C900 are used in water and wastewater force mains, and municipal use of them continues to grow. Traditionally, fabricated fittings have been restrained with concrete thrust blocking or lug-type restraints.

The newest next-generation joint- restraint product is a fabricated PVC pressure fitting that incorporates the integral joint-restraint system. Fittings incorporating integral joint-restraint systems include 45° and 90° bends and tees. The joints function the same way as the pipe-to-pipe restraints, eliminating the need for lug-type restraints and concrete blocking. Installation involves inserting a pipe spigot end into each fitting's bell-end, permitting the restraint mechanism to engage when the line is placed into service.

Mechanical Joint Gaskets. The self-restraining mechanical joint has been on the market for more than two years. It's specifically designed for use in ductile iron fitting-to-PVC pipe joints, in lieu of traditional lug-type restraints.

This restraining device has two components: a serrated C-ring and a rubber gasket. The C-ring is inserted in a groove on the rubber gasket's inside wall, forming a snug fit between the rubber and ring. Installation involves inserting the self-restraining gasket into the mouth of a ductile-iron fitting. The adjoining piece of PVC pipe is fitted with a gland and inserted through the ring into the mouth of the mechanical fitting. The ring's unidirectional serrations allow the pipe to go through but not to be withdrawn. The gland on the PVC pipe is then bolted to the fitting flange. Compression of the gasket between the flange and gland forms a positive seal, and the serrations simultaneously embed themselves into the outside wall of the pipe.

This device has passed Underwriter Laboratories certification and is currently available in 4-in. (100 mm) through 12-in. (300 mm) sizes. Assembly time is reduced because there are no wedges to drive into the pipe wall, and there's no need for point loading.

LOOKING AHEAD

Technological developments are key to the long-term survival of any industry, and the water utilities industry is no exception. Although municipalities are cautious about embracing new technology, the market for products that resolve operational and maintenance problems grows rapidly. The next generation of joint restraints is already proving to be an important addition to the water utility industry.

RESOURCES

- AWWA Standard C900-07, Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 in. Through 12 in. (100 mm Through 300 mm), for Water Transmission and Distribution
- AWWA Standard C907-04, Injection Molded Polyvinyl Chloride (PVC) Pressure Fittings, 4 in. Through 12 in. (100 mm Through 300 mm)
- AWWA Standard C905-97, Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings 14 in. Through 48 in. (35 mm Through 1,200 mm)
- AWWA Standard C909-02, Molecularly Oriented Polyvinyl Chloride (PVC) Pressure Pipe, 4 in. Through 24 in. (100 mm Through 600 mm), for Water Distribution
- AWWA Standard C605-05, Underground Installation of Polyvinyl Chloride (PVC) Pressure Pipe and Fittings for Water

Editors Note: This article was summarized from a technical paper presented at the Texas Section meeting of the American Society of Civil Engineers by Shah Rahman and Harlyn Farrel, superintendent of Water and Wastewater with the city of McKinney, Texas.