Storm Sewer Joints Repaired After Causing Settlement Problems

by Timothy V. Gumina

A general contractor recently installed a buried precast concrete storm sewer line as part of a larger project involving the rerouting of two city blocks in Denver, Colorado. The new storm sewer line was connected at each end to an existing brick-lined sewer system. The seven foot (2 m) diameter precast pipe was jointed approximately every ten feet (3 m) with a bell and spigot configuration.

Shortly after the project was completed, heavy rains surcharged the new storm sewer line. Following the storm, fairly widespread settlement of the backfill materials was noted and a series of sinkholes developed in the street above the sewer line. The road was shut down due to the extent of the damage.

Various experts were retained by the parties involved on the project to evaluate the causes of the failure. It was speculated that the settlement and erosion of the soils surrounding the sewer line were the result of saturation and liquefaction of these soils, caused in part by water escaping from the surcharged sewer line. As part of the repair, the city required that all of the sewer line joints be resealed.

The general contractor hired the consulting engineering group of Wiss, Janney, Elstner Associates, Inc. to perform a condition survey of the pipeline and to make specific recommendations for the joint repairs. Existing joint widths varied from ¼ to 2 ¼ inches (6 – 55 mm) and it appeared that, in certain locations, the original gasket material was either missing or no longer fully engaged within the joint. There were 139 joints in the sewer line.

Although the soils around the pipe had been excavated and re-compacted at several locations prior to reopening the street, it was assumed that some voids in the vicinity of the joints remained. The engineer partnered with Restruction Corporation to develop a repair solution. Critical to the success was the material selection and application.

Material Selection

The joint sealant material had to be dimensionally stable, insensitive to moisture, abrasion resistant, and tough enough to resist deformation under anticipated service loads. The material also had to have an initial placement viscosity low enough to flow readily through the variable annular space of the joints to fill any exterior voids and to completely fill the pipe joints. Once placed, the material must rapidly transition to a solid state to prevent slumping out of the joints.

A single component hydrophilic urethane provided the best mix of needed properties. A bonus was that the set time, expansive volume and mechanical properties could to some extent be adjusted on site by the contractor as necessary to meet performance requirements. The ratio of water to resin can be adjusted depending on specific properties desired. For example, as the water to resin ratio is increased, the viscosity decreases, the pot-life is extended, and the grout changes from a semi-rigid foam to a soft, low-strength gel. At a ratio of 1:1 and temperature of 60° F (16° C), the urethane grout will set in approximately 90 seconds. At a 5:1 ratio, the grout will set in 345 seconds. Lower temperatures also increase the viscosity and gel time.
The grout's mechanical properties such as tensile strength, elongation, and bond strength also change with the ratio of water to resin. Depending on the conditions, the contractor can adjust the ratio to produce the desired viscosity and set time to fill the joint and voids.

**Application Method**

The joints were prepared for grouting with low pressure water cleaning at 3,000 psi to remove debris which had lodged in the joints. The mechanical flushing action of water removed any materials from the concrete surfaces which might interfere with the flow of grout into the joint or preclude the intimate contact needed to bond the grout to the concrete surfaces.

The next challenge was to fill the voids and confine the material to the joints from inside the pipe. The solution was to chemically grout the joints using a modified expanded gasket technique. The original expanded gasket technique was developed in the field years ago. This technique utilized non-oiled jute oakum (loosely wound rope) saturated in a neat urethane resin which, when packed into the joint, provided a dense watertight seal capable of accommodating some movement. On this project, the expanded gasket technique was used both as a seal and to provide confinement of the urethane grout pumped into the joint and voids. This belt and suspenders approach was consistent with the risk and scrutiny of the project.

Once the joints were clean, pre-cut sections of the oakum packing material were submerged in a pail containing the urethane resin until completely saturated. The oakum strips were then dipped into a bucket of water to activate the resin. As the expansive reaction began, the oakum was immediately packed into the joint. The expansion of the oakum exerted pressure on the joint side walls to hold the seal in place. The packed oakum was further wetted at the surface to smooth the interior joint seal.

A theoretical volume for each joint had been calculated using the information collected earlier during the condition survey. This provided the contractor with a target volume to pump. A pneumatically driven multi-ratio pump was used to deliver the grout through the 2 inch (16 mm) diameter holes drilled in the spigot. The holes were drilled about 4 inches (100 mm) from the joint at an angle to intercept the existing joint behind the activated oakum.

At the start of the project, the urethane grout was pumped at a 5:1 ratio. At this ratio, the grout had a placement viscosity of 50-75 cps. The grout would flow readily from the invert injection port all the way around the pipe. The flow of the material could be monitored visually by its appearance at injection ports drilled at the spring line and crown. However, very little transmission was observed even when volumes up to six times the theoretical volume were pumped with little resistance. To remedy the problem, a staged injection procedure was attempted. The joint...
was injected with a specific volume of grout and allowed to set. The joint was then re-injected until back pressure on the fluid line began to increase. Ideally, the first injection would set up and seal any major voids outside the pipe and the subsequent injection would then completely fill the joint.

**Adjustment Yields Success**

Little success was achieved with staged injection using the urethane at a 5:1 ratio. The team concluded that adjustments in material properties were needed. Either the voids outside the pipe were much larger than expected or, at the 5:1 ratio, the reaction time was too slow to keep the very low viscosity grout from slumping out of the joints and traveling down the outside of the pipe. The team decided to change the grout ratio to 1:1. The faster reacting, high viscosity grout would minimize material travel length and expand faster to fill any potential voids.

After the adjustments, the grouting operation proceeded as expected. Generally, the flow was observed around the pipe, and the joint was filled in the first injection. Typically, the volume pumped was higher than the calculated volume for each joint. If the pumped volume was less than the target volume (1.2 x calculated volume), re-injection was attempted.

All of the joints were visually inspected at the surface, and about fifty percent of the joints were physically penetrated to verify that the annular space of the joint was filled with grout. Only ten percent of the joints injected with the 1:1 grout had to be re-injected.

With a versatile material, the project team of an experienced repair contractor and a knowledgeable engineer was able to provide the owner with a very serviceable storm sewer pipe.