Manhole makeover

Engineering solutions for a successful renewal program

BY JOHN JURGENS

Manholes are the most visible point in identifying the condition of our underground infrastructure, and with the advent of effective pipe-repair technologies, manholes are receiving increased attention from municipalities. Leaks sealed out when pipes are lined are likely to travel to the next weakest part of the system — the manholes. And when any part fails, the whole system fails. Thankfully, manholes are the easiest segment to investigate and the most cost-effective to repair.

There are approximately 20 million manholes in the United States. Like pipelines, they come in a variety of sizes and materials, and more than half of them were installed before 1960. Often, one can determine the age of a system just by looking at the manhole lid. In older systems, the lids are often 18 inches in diameter and have numerous vent holes. The manhole chamber below the lid of older systems generally is constructed of brick and mortar. Newer systems, on the other hand, have 24- or 36-inch-diameter lids with only one or two pick holes and chambers constructed of precast concrete.

Old manholes in particular can suffer from serious problems. They are subject to erosion from groundwater intrusion, corrosion from liquids and gases, wear from dynamic traffic loads, and general deterioration from age. Any of these processes create structural fatigue or cause substantial inflow or infiltration. Out of sight, degradation is not easily monitored, but when neglected, complete collapse is likely.

Other influences that contribute to the structural decline of a manhole include soil movement and water table fluctuation (hydrostatic loading). Soil movement can be caused by naturally occurring events, such as earthquakes or freeze-thaw cycles, or it can be induced by nearby construction activities.

Once a rigid structure experiences movement, the foundation is set for deterioration to begin. A fracture in the wall of a manhole also can open up the possibility for erosion. More than half of the manholes installed in the United States never were pressure tested to ensure water/air tightness, and many have experienced ongoing infiltration. Over time, this constant intrusion takes a toll on a rigid structure. On a brick manhole, water movement will remove mortar between bricks, contributing to the loss of bricks and increasing the potential for failure of the structure.

Chemical attack is caused by effluent discharges and corrosive gases that eat away the channel and base of a manhole. These discharges have low pH levels, which cause concrete materials to deteriorate. Most public agencies have eliminated issues concerning chemical

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attack from contributor discharges. Nevertheless, microbiologically induced corrosion (MIC) is a process where aerobic bacteria metabolize hydrogen sulfide gas (H_2S) and oxygen to produce sulfuric acid (H_2SO_4). Generally, MIC is most aggressive in manholes with a great deal of turbulence.

Selecting the proper repair method, however, is critical to a successful renewal program. Each type of problem demands an engineered solution. Regardless of the rehabilitation mechanism, adhering to the original substrata is crucial. Understanding the environment, the steps needed in preparing the surface, and the products being used also are important issues.

Manhole defects and repair methods

Being aware of various types of problems aids in the investigation of manholes in a system. Once manhole defects are identified, they can be classified into different types and then related to an effective repair method.

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Type I single defects can be repaired easily and usually inexpensively. Repairs generally range from $50 to $500 per manhole. These defects include frames and covers that leak because of poor fit, multiple vent holes, damaged adjusting rings, and shifted frames. They can be replaced or fitted with under-the-cover inflow protectors. Internal or external chimney seals are applied to correct damaged adjusting rings. Internal seals are available in mechanical or hand-applied versions made of a flexible membrane.

Individual leaks that have not resulted in structural erosion can be sealed with water plug or chemical grouts. Likewise, eroded benches and leaking channels can be patched and sealed. Additionally, damaged steps create a serious hazard and should be removed. In fact, most U.S. cities choose not to replace steps to reduce liability for unauthorized entry. Workers use safety harnesses and tripods for entry.

Type II defects are more serious and are identified as areas where some structural damage has occurred from unplugged leaks, resulting in voids or missing bricks and mortar joints; or where multiple Type I problems are evident. In these cases, a structural liner that reinforces and seals the damaged wall is warranted. Cementitious liners can be hand-sprayed, troweled, or centrifugally cast onto the prepared interior of old manholes to create a structural shell of sufficient strength to withstand groundwater pressure and dynamic traffic loads. The diameter and condition of the manhole determines the thickness of the hardened, cementitious shell.

Similar to SDR ratings for pipe, large-diameter manholes require correspondingly greater thickness for the same strength value. For example, manholes that are 72 inches in diameter require a liner to have a thickness of 1.5 inches to attain a strength value equal to that of a 0.5-inch-thick liner in a 48-inch-diameter manhole. Likewise, deep manholes are subjected to greater groundwater pressures, thereby requiring thicker liners in the lower portions of the structure. Structural reinforcement and sealing with a cementitious lining costs about $8 to $12 per square foot of coverage.

Type III defects relate to corrosion, the most common cause of deterioration in concrete sanitary sewer structures. Industry studies estimate that corrosion is the primary source of structural damage in three-fourths of all precast concrete manholes and lift stations installed during the last 30 years, with repair and replacement costs totaling billions of dollars.

The source of this corrosion can be chemical or bacteriological. When corrosion occurs in the areas contacted by the flow, chemicals are present in sufficient concentrations and temperatures to corrode the lower portions of the manholes. This type of corrosion is common in industrial sewers.

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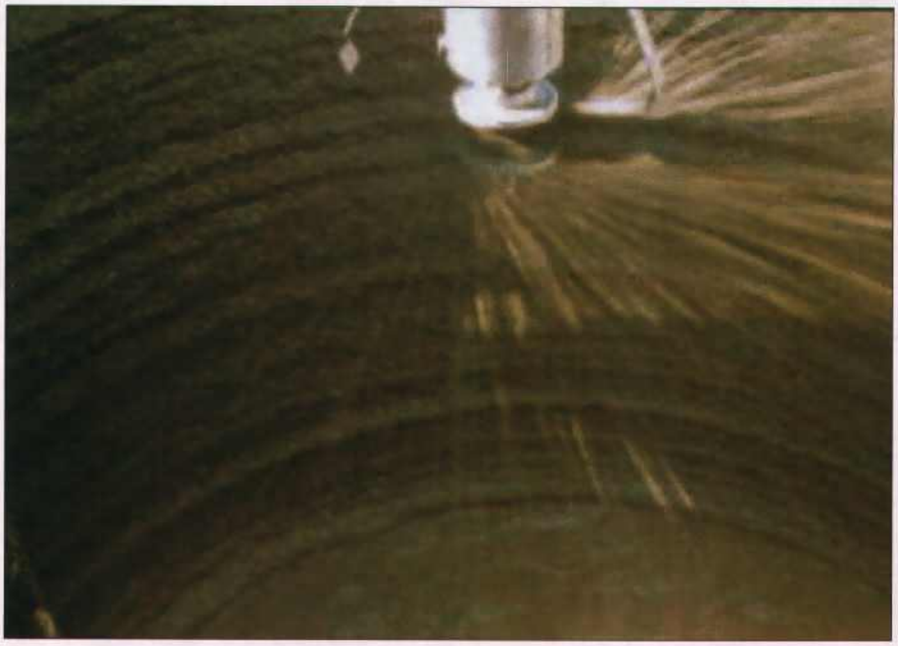

Cementitious liners can be centrifugally cast onto the prepared interior of an old manhole to create a structural shell sufficiently strong to withstand groundwater pressures and dynamic traffic loads.

MIC, caused by acid-generating bacteria, is the most common corrosion in municipal sewerage. Thiobacillus bacteria thrive in the slime layer above the flows and secrete sulfuric acid. Wherever hydrogen sulfide gas is produced, these bacteria grow rapidly because the gas is their source of nourishment. Their rate of growth and the consequent damage is increased by high nutrient levels; long retainage times, which allow the sewerage to go septic; very warm temperatures; and turbulence, which releases the hydrogen sulfide gas. Understandably, MIC is most severe in coastal plains and warm climates with a great number of lift stations.

The corrective action for this type of manhole and lift station damage is to place a protective barrier between the corrosive bacteria and the structural substrate. The most appropriate solution depends upon the severity of the deterioration, which is related to two sub-classes of Type III defects.

Type III-A defects are defined by corrosion that has done little damage or, on new structures, that has not yet begun. In such cases, a polymer coating may be applied to a properly prepared surface for protection. Thorough preparation and expert application is key to the success of this method. A high-pressure washing or sand blasting followed by an acid neutralizing rinse is best. The industry offers a variety of coating materials — such as epoxies, polyurethanes, polyureas (the reaction product of an isocyanate component and a resin blend component), and blended hybrid polymers — that can be brushed, roller-applied, spray-applied, or centrifugally cast. The coating thickness (commonly 65 to 100 mils) must be sufficient to prevent vapor penetration, and it must be free of any holidays or pinholes that would permit bacteria to grow behind the coating. Prices for coatings used to remedy Type III-A defects are commonly $10 to $15 per square foot of coverage.

Type III-B defects are identified as structurally deficient walls caused by corrosion. The coating in this case must be applied at a thickness that will compensate for the structural value of the lost wall. This can be done by using a polymer coating of sufficient strength and applied at a thickness of 1/4 to 3/8 inch, or by using a composite or laminated liner that combines structural reinforcement and corrosion protection at similar combined thickness and strength values. Common solutions for the latter methods are cementitious liner/polymer composites and fiberglass/polymer composites (FGP). FGP liners may be hand-laid, or installed as a custom-fitted bag that is expanded and cured in place with steam. Costs for these methods range from $20 to $30 per square foot of coverage.

Separate and distinct alternatives to correct Type III-B defects are cementitious liners that retard or prevent production of acid-producing bacteria. Calcium aluminate cements generally retard the growth of bacteria by making surface conditions less favorable to their development. During the past six years, a U.S. Environmental Protection Agency-registered, anti-bacterial additive has proven to prevent growth of the bacteria. In either case, the applied thickness is the same as for Type II repairs with correspondingly lower costs.

Type IV defects are indicated by severe structural damage that requires replacement. These problems are determined easily because field staff can recognize structures in this category. Excavation, removal, and resetting of a new structure is the most costly option because it requires bypassing flows, interrupting traffic, allowing for other buried utilities, and general social disruption. Depending upon the pipeline's location, size, depth, and diameter, costs for replacement can range from $1,500 to $3,000 per vertical foot.

Two, less expensive options are no-dig and partial-dig solutions. No-dig methods use forms, which can be passed through existing openings and assembled entirely within the old manhole. An annulus space between the forms and the old wall is filled with standard, department of transportation-specification ready-mixed concrete and vibrated into place creating a new, joint-free wall about 3 inches thick. In corrosive environments, a plastic liner with interlocking protrusions is fitted onto the form before placement of the concrete so that when the forms are removed, a fully plastic-lined concrete manhole remains in place.

In corrosive environments, a manhole can be replaced without digging by installing a plastic liner fitted to a form, and filling the annulus space between the form and the old wall with concrete.

Partial excavation is required to sleeve the old structure. For this option, the entire cone is removed and a smaller-diameter fiberglass or plastic pipe is sleeved inside. The annulus between the sleeve and the old wall also is filled with ready-mixed concrete and then a new cone is installed and the pavement is replaced. These options offer substantial savings, with costs ranging from $500 to $1,000 per vertical foot.

Inspection and testing

The most important part of manhole renewal is at the end of the project. When plastic linings, polymer coatings, or polymer composites are used, the project is not finished until the final repair product is tested thoroughly to verify installation integrity. The owner's inspector can visually verify that the manhole is leak free and coated as specified. Spark testing or the use of a holiday detector verifies that the new polymer coating or plastic lining is free from pinholes and voids, and is uniform in thickness. The National Association of Corrosion Engineers' publication, "High Voltage Electrical Inspection of Pipeline Coating Prior to Installation" (NACE RP0274), is an excellent reference for inspectors.

Verification of bond is another important test that can be conducted on polymer coatings after the installed products have cured. The American Society for Testing and Materials' document, "Pull-off Strength of Coatings Using a Portable Adhesion Tester" (ASTM D-4541), describes the use of a portable adhesion-testing device to verify the bond of a polymer coating to a prepared substrate. Two testing options are used commonly: the bond may be tested to failure and a value recorded; or a predetermined bond strength is selected, and the polymer coating is tested up to that point.

The testing process gives data on two types of failure: when the polymer coating pulls away cleanly from the substrate and when the polymer coating pulls free with some of the substrate attached. In the latter case, the value recorded at failure represents the tensile strength of the substrate surface. The inspecting engineer must plan how to use these two types of data in the bond evaluation.

A drawback to this testing method is that it is destructive and requires repair of the test locations. However, it gives a good indication of how well the substrate surface was prepared and how well the polymer coating bonded to the substrate. In addition, deficiencies can be rectified before installation crews leave the jobsite.

Conclusion

Although many older manholes in the United States are in need of crucial renovations or even replacement, there is no need for newer systems to reach a critical state of disrepair. The technology and technical know-how is available to solve the myriad of deterioration issues that municipalities face. And acting now to preserve manhole quality and integrity certainly is more responsible from a financial point of view than waiting for the structural stability of a manhole to be compromised fully. ■

John Jurgens is principal of Trenchless Resources International based in Seattle. He specializes in manhole and trenchless pipeline rehabilitation. Jurgens can be reached at 425-487-3325 or via e-mail at nodig@aol.com.