Inspection, Design, Installation Guidelines When Relining Sewer Manholes

By Steve Henning, MS

Sanitary sewer pipeline collection systems and manholes are a vital component in every city's infrastructure. These systems are designed to transport wastewater to treatment facilities. When infiltration enters the sanitary system through the sewer manhole, it creates a multitude of problems at the treatment plant, including sanitary sewer overflows (SSO's). The occurrence of these events are under strict government guidelines and are a serious threat to public health. Infiltration causes treatment costs to rise and may create the situation where newer large treatment plants must be constructed to handle the wet weather overflows.

Stopping infiltration from entering into the system is a cost effective method with a very high return on investment dollars. With treatment costs varying from $3 to $4 per thousand gallons, rehabilitating even the smallest leaks make economic sense. For example, a one gallon per minute leak in a single manhole generates 525,600 gallons a year of excess water to treat, at an annual treatment costs ranging from $1,576.80 to $2,102.40. These treatment costs do not begin to represent the true cost of infiltration if a new treatment plant needs to be constructed to handle wet weather overflows. For this article, a typical manhole will be defined as 8-feet deep with a diameter of 4 feet. This standard manhole example, if easily accessible and located in the Gulf Coast region, can typically be rehabilitated at a cost ranging from $900 to $3,200 in 2005, depending on the level of rehabilitation needed. The lower cost is for the application of a structural cementitious liner and the upper cost includes a cementitious liner with an epoxy coating applied over the liner. Manholes have been successfully lined from Alaska to New York, and south to Mexico City with this same technology.

At a time when municipalities are facing shrinking budgets and are being forced to meet federal guidelines, rehabilitation techniques that pay for themselves in the shortest amount of time are highly desirable. The described manhole rehabilitation techniques also involve minimal disruption, if any, to the general public.

Proper inspection, operation and maintenance of the sewer system will help municipalities to meet federal government Capacity, Management, Operation and Maintenance (CMOM) regulations and the Government Accounting Standards Board (GASB) Statement 34.

Inspection

Physical inspection is critical to understanding the current condition of the manhole. Effective inspection techniques can help determine the amount of infiltration attributed to the manhole and determine the most cost-effective manhole rehabilitation techniques. Defective manholes are known by the United States Environmental Protection Agency (EPA) to be significant contributors of inflow and infiltration (I/I).

Physical inspection can either be full blown inspections or manhole surveys. The manhole survey does not provide the in-depth information that an inspection does but allows the system operator to review more of their manholes.

Dr. C. Vipulanandan, chairman of the Civil and Environmental Engineering Department, University of Houston, has developed a Life Cycle Cost Model for waste water systems. This model was based on extensive information gathered from 26 municipalities of all sizes. His model suggests that for every 100,000 people, there are approximately 6,500 manholes in the sewer system. Because of the sheer number of manholes within the system, most municipalities find that conducting detailed inspections of all manholes is not cost effective.

Manhole inspection

The American Society of Civil Engineers has produced a Manhole Inspection and Rehabilitation Practice Manual No. 92 that describes the inspection process in detail. This engineering practice serves as the basis for the majority of inspections done in the U.S. today. The National Association of Sewer Service Companies (NASSCO) has created a uniform Manhole Assessment Certification Program (MACP) based on their successful Pipeline Assessment Certification Program (PACP). The manhole assessment certification program provides a national standard with unified inspection guidelines. A uniform inspection code makes it possible to compare reports from different companies and cities. The information gathered through this type of survey can be used for extensive computer modeling. This manhole inspection process differs from a manhole survey in that more complete information is gathered but at a greatly increased cost.

A thorough survey or inspection should provide enough data to understand the current condition of the manhole, determine if the manhole is subjected to higher than normal flow erosion/ abrasion characteristics, determine if chemical attack variables may be heightened or if the location of the manhole itself places it in a higher risk category. The location and the accessibility of the manhole must also be taken into consideration. Many cities now subscribe to the find it and fix it philosophy. That means that when an obvious problem has been determined, it is immediately fixed. This provides an immediate cost savings to the city, reduces I/I at the treatment plant and keeps catastrophic failure from occurring.

Determining appropriate rehab methods

Surveys and inspections reveal the construction type, location, condition, historical and current flow conditions, and try to quantify actual I/I. All manhole rehabilitation methods need to be made on a case-by-case method. No two manholes are identical or are subject to identical soil and placement conditions. Two adjacent manholes from the same manufacturer and constructed by the same crews can exhibit very significant differences in their condition in a limited amount of time.

When determining the most appropriate rehabilitation method you should begin by asking the following questions:

1) What is the desired end result?
2) Is there ground water present?
3) Are there visible leaks?
4) What is the estimated volume of the leaks?
5) Where are the leaks concentrated?
6) Is the manhole in danger of catastrophic failure?
7) Does the location of the manhole limit our rehabilitation options? and
8) Can the reason for deterioration be determined? For example, is there high hydrogen sulfide, high flow rates, abrasive materials in the system, others? The USEPA has stated that the vast majority of manholes are exposed to a pH between neutral and 3 occurs 95 percent of the time. Typically, the ma-

jority of manholes are exposed to a pH of less than three due do the presence of sulfuric acid only about 5 percent of the time. This leaves only 5 percent of the nation's manholes being exposed to a pH of less than three.

Determining these factors during the inspection and design phase of the project assure that you address the most important aspects of the rehabilitation program. With these questions addressed, you can then design your program to fit your specific conditions.

Manhole rehabilitation options

While there are multiple manhole rehabilitation techniques available, this article addresses the two most common techniques. The structural lining of a manhole with a cementitious liner and the application of an epoxy coating over the liner, when needed, will be addressed.

Cementitious liner systems

A cementitious liner system for rehabilitating the sanitary sewer manhole is installed to restore the structural integrity of the manhole, to stop water infiltration and provide increased levels of protection from chemical attack.

The advantages of a Microsilica-based liner should be considered in the initial design phase of the project. The ability to stop water infiltration and to provide very high compressive strengths with a thinner liner, increasing levels of protection from chemical attack, along with the ability to provide a higher resistance to hydraulic erosion/abrasion should all be taken into account during the design phase of the project. Microsilica improves the chemical characteristics of concrete by increasing the amount of calcium silicate hydrate, the good material that forms the glue of the cement and lowers the amount of calcium hydroxide produced - a weaker material. With 50,000 particles of Microsilica for each grain of cement the final product has extremely low porosity and permeability, and is very easy to trowel to a very smooth surface, effectively lowering the surface area of the liner.

Industry has chosen four physical characteristics to be critical to the successful application of cementitious liners. First, they must be able to adequately bond with the substrate whether it is composed of brick, concrete, fiberglass or some other material. This bonding property can be determined by using test protocol ASTM 882-05. Satisfactory results range from 80 to 120 psi. Bonding or adhesion above 200 psi is not usually considered advantageous as the concrete substrate will fail in those ranges.

Second, the material should have a high enough compressive strength to act as a structural repair. Compressive strength can be determined by ASTM Test method C 109. Results from 28 day strengths typically fall in the 5,000 to 10,000 psi range.

Third, the permeability is a critical factor in the performance of the liner. Permeability is determined by AASHTO Method T 277. Acceptable results are 500 coulombs or less.

And fourth, constructability, which includes: quick turnaround time, flowability and ability to trowel overhead, is required.

The test results using identical raw materials can vary widely with different water to cement ratios. The less water designed to be used in the mix results in stronger and less permeable concrete. The disadvantage of lower water ratios is that proper curing is more important and small surface cracks may result. Admixtures and additives address these and other specific situations.

Chemical characteristics for cementitious liners

Concrete is composed of cement, water, aggregates, chemical admixtures and additives. The amount of cement in the mixture is a very important indicator to the quality of material being delivered. The higher the cement ratio, the higher the performance of the concrete. Typical mixtures of concrete may vary from 325 pounds to 650 pounds of cement per cubic yard of concrete. It is interesting to note that many admixtures that have been recently developed are added by the pound to a cubic yard of cement weighing between 3,400 and 4,000 pounds. If one or two pounds of an admixture can impact the final product, imagine what 300 pounds of cement will accomplish.

Cement admixtures

Microsilica, also known as condensed silica fume, is an extremely fine particulate, with a chemical make-up of almost pure silicon dioxide (SiO2), 92-98 percent. Microsilica improves concrete through two primary mechanisms, a chemical reaction and a micro-filler effect. The chemical reaction between cement and water produces calcium silicate hydrate and calcium hydroxide. The calcium silicate hydrate serves as the binder, which holds the system together and is the preferred end product. The calcium hydroxide does not serve as a binder and weakens the entire system. The microsilica reacts with the calcium hydroxide to produce more calcium silicate hydrate, while reducing the amount of calcium hydroxide.

Along with the improved chemical reaction, the extremely small size of the particles serves as a micro-filler. This greatly reduces permeability and increases the paste to aggregate bond. The benefits of reduced permeability and increased calcium hydrate include: increased resistance to chemical attack, reduces hydraulic abrasion/

***Above**: Manhole dirty. **Below**: Manhole cleaned.*

***Above**: Manhole before lining. **Below**: Manhole relined.*

erosion, and increases compressive strength significantly.

Air Entraining Agents provide the ability to entrain air in the concrete at 4 to 8 percent. The addition of air permits a reduction in mixing water with no loss of slump, increases the workability, and increases durability of concrete to all exposures particularly freezing and thawing.

Super Plasticizers, also known as high range water reducers, produce low water/cement ratio concrete with higher strengths, produce high slump flowable concrete at no loss in strength, reduces segregation, and aids in rapid discharge of concrete from truck mixers.

Fibers, are synthetic fibers, provide secondary reinforcement and protect concrete from stresses, which cause cracking while it is most vulnerable, during the first 24 hours after placement. This reinforcement reduces the formation of all types of early cracking.

Accelerators provide faster set acceleration and increased strength of the concrete. This liquid admixture contains calcium chloride as well as other chemical to enhance the effect of calcium chloride.

Retarders slow down the initial set of concrete. At normal addition rates it will extend the initial setting time by 2 to 4 hours at 70 degrees F. Usually, 4 to 8 liquid ounces per 100 pounds of cement will produce the desired results.

Cementitious liners physical application process

The proper application of any product is critical to the success of the project. Following established guidelines for the product is imperative. If the manholes to be relined are cleaned properly, the material is mixed properly and the material is applied by experienced technicians, a successful result will be obtained.

ASTM has a *'Standard Specification for Installing a Protective Cement Liner System in Sanitary Sewer Manholes,'* currently being voted on by ASTM F-36 members.

The proper cleaning of the structure cannot be overstated. It is imperative that the manhole be cleaned so that the proper bonding may occur. High pressure washing at a minimum of 3,500 psi is highly recommended. Higher pressures may be needed, cleaning chemicals may be added, as well as the heating of the wash water.

Remove any foreign material and do not allow any soil, sand or debris to enter the sewer system. Stop any active leaks prior to lining. Repair any invert and bench section that exhibit visible damage, degradation or water infiltration. Mix the cement liner material in accordance with the manufacturer's printed recommendations. Spray applies the cement liner material to a uniform thickness of ½ inch to three inches. A one-inch minimum thickness is required to achieve structural rehabilitation. Use a stainless steel trowel to hand work and compact the cementitious material into all voids and surfaces. The surface should be hand troweled to a smooth condition, lowering both porosity and permeability. Take proper precautions for curing in hot or cold weather.

Cementitious liners post application vacuum testing

All rehabilitated manholes using a cementitious liner system should be tested for effectiveness. The preferred method, vacuum testing, should follow the manufacturer's recommendations and guidelines for safe and proper procedures. The manhole should only be tested after it has properly cured. Testing should be performed no later than 10 days after the proper curing of the lining. Any visible leakage will be repaired regardless of the test result.

Epoxy coatings

An epoxy coating system is spray applied for the protection of the cement manhole liner. The epoxy is applied when the manhole is subjected to elevated chemical attack or if the manhole is subjected to higher than normal hydraulic erosion/abrasion.

Industry has chosen four physical characteristics to be critical to the successful application of epoxy coatings. First, they must be able to adequately bond with the damp substrate. This bonding or adhesion property can be determined by using test protocol ASTM 4541 or ACI 503 R89. Satisfactory results range from 80-200 psi, the lower limit for concrete, up to the higher limit, which is the failure of the substrate. The concrete substrate will usually fail between 150 and 250 psi. Materials with higher bonding strength do not necessarily provide any material advantage, as the substrate will fail in that range. Bonding to steel can be measured and can produce results of 1,500 psi or higher.

Second, the material should be resistant to chemical attack, specifically acid attack. Chemical resistance is determined by ASTM G 20. Chemical resistance results are qualitative in that no exact measurement is recorded. Chemical resistance testing looks at potential color changes and determines if any swelling occurred to the coating to make a general observation of the effect of the acid on the epoxy coating.

Third, abrasion resistance must be high enough to protect the surface from hydraulic abrasion/erosion. Abrasion resistance is determined by ASTM D 4060. Having high or good abrasion resistance is a good indicator of how long the coating will protect the lining.

Fourth, constructability, which includes: quick curing times, having the ability to adhere to the walls without runs or sags, and having the ability to cure in the presence of water. An effective epoxy coating must be able to cure quickly, hang on the wall of the manhole at the proper thickness without runs or sags, and must function well in a wet or even submerged environment.

Chemical characteristics for epoxy coatings

Epoxies are a two-component, solvent-based, 100 percent solids coatings that provides good chemical resistance and excellent wear characteristics. Epoxies may be blended at ratios of 1:1 up to 3:1 resin to catalyst. The ratio of the resin to catalyst is designed into the product. The different ratios do not impact the strength or physical properties of the epoxy. Some manufacturers try to make a specification point out of mix ratios, although, this ratio does not affect the end products physical characteristics. In fact, the lower ratio epoxies use more of the most expensive compounds-the catalysts. Epoxy coatings used in manholes should have the ability to bond and cure properly in a moist or even wet environment.

Epoxy coating application process

Epoxy coatings are typically spray applied over cementitious liners. The liner must be properly cured and then prepared for the epoxy coating. The cementitious liner should be treated with a citric acid wash and thoroughly rinsed before the application of the epoxy coating. The epoxy should be spray applied in multiple passes with 20 to 40 mils being applied on each pass. The spray pattern should include both horizontal and vertical applications to effectively seal the surface. The final coat should be smooth and of sufficient thickness. The thickness of the coating should be physically determined at multiple locations within the manhole during the application process.

Safety

Manholes are placed in locations that expose workers to many hazards. Not only is the manhole itself a safety hazard but the location of the manhole, such as a busy intersection or a remote location, is a safety risk in itself. If the manhole is located in a street, proper precautions and measures must be taken, up to and including routing traffic around or away from the site. Because manhole entry requires a confined space entry permit they must be treated as such. The permit required confined space must be tested for atmospheric contaminants before entry is allowed. A permit required confined space tag must be completely filled out before entry is allowed. The tag should be attached to the tripod so that inspectors can quickly determine if the proper testing and protocol have been followed before allowing anyone entry into the manhole.

All required equipment including tripod, wench, harness, gas detector and the associated personal protective equipment must be being used in the appropriate manner. All personnel should be properly trained in the use and maintenance of the safety equipment. The best safety equipment in the world will not protect a worker if it is not being used, or is being used incorrectly. The safety of contractors and subcontractors personnel is a huge liability for all concerned. Properly training personnel, performing field inspections to verify that safety programs are being properly adhered to, and contractors carrying the appropriate amount of liability insurance, all decrease the financial risk to a city or municipality.

Conclusion

There are very few opportunities for a city or municipality to effectively address public health concerns, reduce water treatment plant costs and use those reduced costs to finance the maintenance and rehabilitation of their sewer manholes. Cementitious sewer manhole liners that restore structural integrity, stop water infiltration and exfiltration, and provide increased levels of protection from chemical attack are cost effective. The ability to use an epoxy coating on the lined manhole, when needed, is another advantage to having a complete rehabilitation system available. Leaking manholes are a major source of system infiltration. Manholes are the most accessible component of the sewer system and offer the highest rate of return on investment dollars.

For more information, contact ASTM at (610) 832-9716, fax (610) 834-3609 or www.astm.org

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