MANHOLE INSPECTION AND REHABILITATION, ASCE MANUALS AND REPORTS ON ENGINEERING PRACTICE NO. 92 (MOP 92), 3RD EDITION

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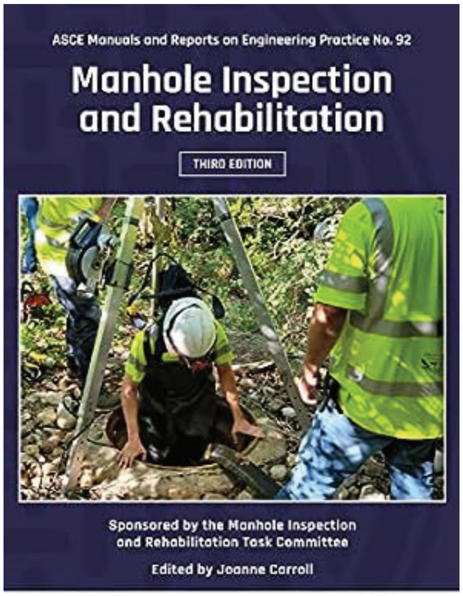

1.ABSTRACT

The American Society of Civil Engineers (ASCE) published its first manual of practice in 1992 to help the utility industry improve their manhole inventory. Since then, MOP 92 has been updated twice. The most current update is particularly helpful to anyone engaged or involved in manhole inspection, design, rehabilitation, renewal, or (and in particular) asset management. The most recent edition, which was recently available in its final published format (available on ASCE on-line Book Store for $80.00), is much more robust and detailed (and helpful) than prior editions. This article provides an overview of the updates included in this 3rd edition This article will also be helpful to anyone engaged or involved day-to-day operations, maintenance, and management of manhole structures in the following areas:

- Non-entry Manhole Inspection
- Condition Assessment
- Management
- Rehabilitation and Renewal
- Asset Management.

2.KEY WORDS

Manhole, rehabilitation methods, repair technology, ASCE, MOP, I/I, asset management, trenchless, cost, budget, NASSCO, Third Edition

3.INTRODUCTION

The idea for MOP 92 began in 1991 during the annual ASCE Pipeline Infrastructure (PINS) meeting as part of the Water Environment Federation Conference (WEFTEC) in Washington, DC. At that time, there was broad consensus and agreement that an MOP dedicated to the inspection, rehabilitation, and management of manhole structures were needed. A subcommittee was formed and over the course of then next four years MOP 92 was ready for publication which happened in 1997. This overall effort was accomplished through a partnership with the ASCE Committee on Manhole Rehabilitation of the Pipeline Division of ASCE and NASSCO's Manhole Rehabilitation Committee. A second edition followed. These two prior editions of MOP-92 addressed issues associated with inspection, scoring and prioritizing manhole structures. Finally, the recent release of MOP 3rd Edition on December 21, 2022 has significantly expanded the two previous editions.

Specifically, under this new edition, there is much more emphasis on Chapter 5 "Manhole Rehabilitation Methods". By way of summary, there are a total of nine chapters in this current release:

Chapter 1 - Introduction
Chapter 2 - Worker Safety
Chapter 3 - Inspection
Chapter 4 - Quantification of Infiltration, Inflow, and Structural Condition
Chapter 5 - Manhole Rehabilitation Methods
Chapter 6 - Examining Cost-Effectiveness of Manhole Rehabilitation
Chapter 7 - Wall Thickness Design for Full-Depth Manhole Rehabilitation
Chapter 8 - Quality Management
Chapter 9 - Summary
Glossary
Index

This article along with its numerous photos and figures will focus primarily on the particulars of what is included in **Chapter 5** so that there's time and space to do a deep dive into the content and important highlights of the specific technologies featured in this chapter. In particular, this will include nearly all technologies and products that are currently available to both private and public utilities when considering cost-effective approaches to renewing aging manholes structures. Areas of rehabilitation that are covered include (a) manhole covers and frames, (b) chimney seals, (c) wall joint seals, (d) injection grouting, and (e) coatings and liners. As part of this discussion, this article and companion tables and exhibits will be wrapped up with a high-level consideration of some asset management strategies (and particularly a condition assessment matrix that is featured in MOP 92), along with the impact that these new approaches will be added to the NASSCO codes for both PACP and MACP.

Table 5-1. Manhole Rehabilitation Options

Manhole Component/Renewal Methods	O&M	I/I	STRUC	COR	Comments and Limitations
Lid Seals and Dishes					None
Chimney, Frame and Joint Seals					Rehabilitate adjustment section for structural repair
Chemical Grouts					
Cementitious Liner (Portland Based)					pH >3
Cementitious Liner: Calcium Aluminate					pH >2
Cementitious Liner: Polymer or Additive Modified					Corrosion protection varies by material
Polymer Liner: Rigid					May be installed as composite system with cementitious basecoat for cost savings
Polymer Coating: Flexible					Installed as composite system w/ cementitious or rigid polymer coating for structural repair
Cured-in-Place Liner					
Thermoplastic Liner Composite					Uses cementitious or polymer basecoat to install and effect structural repair

4.JUMPING DIRECTLY INTO CHAPTER 5 OF MOP 92 — MANHOLE REHABILITATION METHODS

Once information is gathered through the inspection process, the recorded data are reviewed to prioritize repairs and select rehabilitation materials and methodology. Material and technology choices for rehabilitation are dependent upon the specific reasons for the implementation of the project (Table 5-1) including the correction of structural deficiencies, addressing maintenance requirements, elimination of I&I, and prevention of future corrosion.

There are many products available that may fulfill the need to satisfy maintenance requirements and control inflow that require minimal training and little or no specialized equipment. This type of work includes specialty products such as:

- Cover or lid replacement or vent hole plugs
- Cover or lid seals (gaskets) and inserts (dishes)
- Chimney seals (mechanical seals and applied sealants)

Defects in manhole covers, frames and chimneys present multiple opportunities for surface water (inflow) to enter the manhole through holes in the cover and through the space between the cover and the frame. These sources of inflow may account for a significant amount of leakage in manholes contributing to sanitary sewer overflows and costly treatment of non-wastewater flow.

Manhole Covers and Frames

Leaking manhole covers can be sealed by plugging vent or pick holes or through replacement with new watertight covers (see Figure 1). Installation of a bitumastic sealant when the seal is missing or damaged, or replacement of rubber gaskets when the frame and cover are grooved specifically for a gasket can also create a seal. The use of manhole dishes or inserts under the cover is also common to capture residual water, especially in flood prone areas.

Chimney and Wall Joint Seals

Ground movement, thermal expansion and contraction of the surrounding pavement, frost heave, and traffic loadings can cause the seal between the frame and chimney to deteriorate or break allowing surface water to enter the manhole. This water, entering the manhole after running along pavement subgrades, washes subgrade material in with it resulting in settlement of the pavement around the manhole. Concentric surface cracks may be evidence of subgrade washout.

The frame-chimney joint area can be sealed internally without excavation when frame alignment and chimney conditions permit. When excavation is required to replace the frame or to reconstruct the chimney and/or cone, the frame-chimney joint can be sealed internally and/or externally. Methods for sealing this frame-chimney joint area include mechanical frame-chimney seals, flexible epoxy and urethane applied sealants, mastic and rubber adhesive

Replacement Internal Seals Cover-Frame Gaskets New Covers (CPH) Inserts (salad bowls)

Figure 1 . Example of Manohle Cover Replacements and Inserts

Mechanical Chimney Seals | External Seals | Polymer Sealants | Cured-in-place Chimney Seals | Gasketed Seals

Figure 2 . Example Methods of Chimney and Wall Joint Renewal

laminates and cured-in-place liners.

Ground movement and/or worn, failing, or improperly installed joint gasket material may allow infiltration to occur through the wall joint. These leaks add to the overall daily dry weather flows and unnecessary treatment processes and cost. One method for sealing the wall joint is using mechanical joint seals. These seals are a non-structural repair manufactured from the same materials used in the mechanical frame-chimney seal. Flexible epoxy and urethane applied sealants may also be used but only after active leaks have been stopped. The following methods can be used to repair manholes requiring more comprehensive rehabilitation: injection grouting, spot repairs, coatings and liners.

Examples of Rehabilitation methods for this upper area of typical manhole structures are shown in Figure 2.

Injection Grouting

Injection grouting is typically used in manholes for infiltration control and void stabilization. It is also commonly used in conjunction with coating and lining technologies to stop infiltration prior to their installation. Manhole grouting does require training and equipment for proper installation and effectiveness. The success of grouts in reducing infiltration is largely dependent upon the following factors:

- Soil conditions
- Moisture conditions and groundwater table elevation
- Injection patterns
- Gel time and grout mixture
- Containment of excessive grout migration
- Selection of the proper type of grout
- Experience of the grouting crew
- Project quality control

The wide range of grouts on the market for pressure injection fall into these categories: Acrylic resins, urethane gels, hydrophobic urethane foam, and hydrophilic urethane foam.

Acrylic Gels: Thinnest of the acrylic family of resins (acrylamide, acrylic and acrylate) on the market; all with controllable set times and little or no expansion. Acrylic gels are often specified for curtain grouting to create an impermeable gel/soil matrix and positive seal outside the structure, thereby stopping infiltration and future erosion.

Urethane Gels: A prepolymer which activates and cures upon reaction with water. Urethane gels have excellent permeation properties to create an effective water barrier while providing soil stabilization.

Hydrophobic Urethane Foams: Generally injected as a single component that requires little water to activate. These grouts withstand wet/dry cycles, and with high expansion rates make them ideal for filling voids and stabilizing soil outside the structure.

Hydrophilic Urethane Foams: Single component and moisture activated with 1:1 up to 1:12 water-to-resin ratios. These chemical grouts are available with various viscosities and are well-suited to seal cracks, joints and pipe penetrations. Where the following conditions are observed, pressure grouting within manholes can be used:

- Brick manholes with somewhat tight joints
- Active infiltration
- Structurally sound manholes
- Cohesive soils with high moisture content
- Manholes with voids or unstable surrounding soil

The most common grouting techniques used within manholes include curtain grouting, expanded gasket placement technique, horizontal joint, and vertical crack injection.

Curtain Grouting: Curtain Grouting is a technique used to encapsulate a structure by drilling through the manhole walls in a pattern that begins from the bottom of the structure and rotates (serpentine or coil) towards the top of the structure. Specially designed mechanical packers are then inserted into the drilled holes and the grout is pumped to the outside of the structure to encapsulate and seal the structure preventing infiltration. Curtain grouting may be performed with acrylic gels, urethane gels or low viscosity highly expansive foam grouts. The primary uses for curtain grouting are to control infiltration and stabilize voids outside the structure. The equipment necessary to perform this task is composed of a drill and drill bits, a dual or single component pump, injection gun and packers, chemical grout and safety equipment.

The Expanded Gasket Placement (EGP) Technique: Figure 3 shows the insertion of a resin-soaked foam backer rod or dry oakum into a joint. This resin (absorbed into the oakum or backer rod) reacts with the incoming groundwater to expand and isolate the joint or pipe connections to the manhole creating a flexible, watertight gasket. This technique can also be used around the invert and pipe penetrations.

Horizontal Joint Injection: This technology targets actively leaking joints and/or the

Figure 3 . Example of Injection Methodologies for Manhole Cone/Corbel and Wall Sections

seams between precast concrete sections. Many times, the original seals were improperly installed or have eroded, allowing groundwater to leak into the manhole. The leaks are generally sealed using flexible hydrophobic or hydrophilic urethane grouts. The EGP technique may be used if the joints are separated, or holes may be drilled below the seam where the sections are joined. A mechanical injection packer is inserted into the hole and grout is injected into the crack to create an impermeable barrier to infiltration.

Vertical Crack Injection: This is a method of injecting grout into a crack, filling any defects, and bonding to the structure. The new seal in the crack will be flexible and able to handle minor movement. A low viscosity grout is recommended for thin cracks, with higher viscosity grout used for wide cracks. When using this technique all loose, friable and porous debris is removed from the leaking crack before creating injection points. Holes are drilled and grout is injected from the bottom of the crack. The drilled holes should be flushed with clean water before installing the mechanical injection packers. Upon completion of grouting, cured grout is removed even with the surface prior to application of other rehabilitation products.

A few examples of various types and methods of grouting the cone/corbel and wall portions of typical manhole structures are shown in Figure 3.

Coatings and Liners

For the purposes of defining coating and liner terminology as used in this manual, coatings provide a barrier preventing surface and groundwater from entering the manhole and to protect against future corrosion. Coatings include polymeric spray or trowel applied materials including epoxy, polyurethane and polyurea systems. Liners are used to restore manhole surfaces and renew structural integrity. Liners used in manhole rehabilitation include rigid polymers, cementitious, geopolymer, and cured-in-place manhole liners (CIPM). Composite systems, which utilize more than one of the technologies to rehabilitate the manhole, are typically comprised of a cementitious underlayment with an epoxy topcoat or embedded thermoplastic protective sheet liner.

Correcting structural deficiencies, elimination of infiltration and prevention of corrosion may require the use of a monolithic full depth coating or liner in the manhole. Knowledge of the following project criteria and manhole condition is essential to making the proper selection of material and rehabilitation technology:

- Accessibility
- Downtime available for rehabilitation process
- Presence of corrosion
- Structural deterioration
- Infiltration

In addition, an understanding of the characteristics of available products is necessary for matching needs to rehabilitation technology. The selection of rehabilitation product(s) is complicated by the sheer number of available technologies.

Preparation for installation of coatings is essentially the same for all product types. Good coating practices have been standardized through NACE and ASTM standards; the basic steps include:

- Cleaning, decontaminating, and creating adequate profile of the host substrate
- Eliminating infiltration, diverting and bypassing flows
- Repairing and/or resurfacing concrete and masonry surfaces
- Installation of the coating or liner
- Inspection and testing

Cleaning and profiling of concrete and masonry substrates includes the removal of oils, grease, waxes, form release and curing compounds, laitance, sealers, salts, existing coatings or other contaminants which may adversely affect the adhesion of the coating or liner to the substrate. Concrete and/or mortar damaged by corrosion, chemical attack or other means of degradation are also removed. The preparation process chosen should also remove all laitance and weak concrete to expose a sound surface. There are several methods available to accomplish proper surface preparation. The most common methods are low-pressure water cleaning or pressure washing (3,500 — 5,000 psi), high-pressure water cleaning (5,000 — 10,000 psi), water jetting (>10,000 psi), and dry or wet abrasive blast. The objective of surface preparation is to prepare a uniform, sound, clean, neutralized surface to meet requirements of the specified coating or liner.

Active infiltration can be stopped by use of hydraulic cements and injection grouting prior to installation of coatings or liners which rely upon adhesion for performance or where the active leaks can result in detrimental wash-out of resin or liner material.

Repair or patching products are used to fill voids, honeycombs, bug holes, spalls,

Spray Applied | Spin Cast | Trowel Applied | Composite Applied

Figure 4 . Example Rehablitation Metods Using Cementitious Technologies

cracks and other surface imperfections which would adversely affect the installation or performance of the coating or liner. This process is less intensive when utilizing cementitious liners, as the same materials are generally used for the repair/patching as the liner itself. However, it is also common to utilize cementitious coatings to resurface masonry or severely corroded concrete manholes to repair, smooth or rebuild surfaces to receive polymer coatings or thermoplastic liners. Refer to Chapter 7 for design guidelines including applied thickness when resurfacing materials are used in a composite system.

The basic types of coatings and liners include: 1) cementitious liners (Portland cement, calcium aluminate, geopolymer) and poured-in-place concrete with or without thermoplastic protective sheet liners, 2) polymer liners (epoxy, polyurethane), 3) protective coatings (epoxy, polyurea, polyurethane and hybrids), and 4) CIPM.

Cementitious Liners: Cementitious liners can provide an effective solution for infiltration, full depth structural rehabilitation and corrosion protection. Corrosion protection can be provided through the use of specialty cements, antimicrobial additives, the topcoat application of a polymer coating or thermoplastic sheet liners. Since corrosion is common to sanitary sewers as a result of MIC, any method that prevents development of acid or provides an acid resistant barrier between the acid and the substrate can provide protection. Manholes exposed directly to acids from industrial effluent require an engineered evaluation prior to selection. Cementitious materials may be applied by trowel, spray or spin cast. All systems require specialized training, and some systems require specialized equipment for installation. Example applications for cementitious liners are shown in Figure 4.

Formed-in-Place Concrete: The formed-in-place (FIP) method provides a new concrete interior wall conforming to the dimension and shape of the existing manhole. When a corrosive environment may occur, a thermoplastic sheet liner can be placed around the exterior of the inside forms prior to pouring the concrete to provide a protective barrier that is permanently anchored to the new concrete wall. Alternatively, specialty cements or antimicrobial additives may be used. Generally, the new concrete wall is about 3 inches thick. The placed concrete fills all voids or missing bricks in the existing wall making it a complexly independent, new concrete manhole. Typically, excavation is not required with this trenchless replacement method. Examples are shown in Figure 5.

Polymer Coatings and Liners: Polymers can provide effective solutions for structural rehabilitation, elimination of inflow and infiltration, and protection against future corrosion. There are many types of polymers being used in manhole rehabilitation including epoxies, polyurethanes and polyureas. These single or multi-component products can be applied by trowel, brush, spray or spin cast, curing within minutes or hours depending on the type and formulation.

- Epoxies used in manhole rehabilitation are generally formulated for moisture and surface tolerance to achieve the best bond as compared to properly prepared buried substrates. Epoxy liners are rigid, structurally enhancing formulations with excellent corrosion resistance. Flexible epoxy coatings are also used as non-structural chimney and joint sealants.
- Polyurethanes can be formulated with elastomeric properties to tolerate some movement within the structure, or rigid with structural enhancement capabilities. Although polyurethanes are less tolerant of moisture than epoxies, they

Placed Concrete | Cement + Thermoplastic Sheet Lining

Figure 5 . Example Applications of Manhole Rehablitation using FIP Methods

Epoxy Coating | Polyurethane Coating | Polyurea Coating (spray and spin cast)

Figure 6 . Manhole Rehabilitation Using Polymer Coatings (Epoxies, Polyyureethanes, Polyureas)

typically set-up (become hard to the touch) within seconds or minutes.

- Polyureas are typically formulated to offer the most elongation and flexibility of the polymer systems. However, polyureas are highly sensitive to moisture requiring a dry substrate for adhesion.
- Hybrid Systems may be formulated from one or more of the above polymers to provide a variety of characteristics which can be evaluated for specific applications.

See Figure 6 for examples. Polymer coatings should be applied at a thickness that will ensure proper wetting of the substrate to attain a good mechanical bond and adequate thickness to create a monolithic impermeable barrier against corrosive elements. A minimum of 80 mils (0.080 inch) is accepted as industry standard for application to relatively smooth surfaces. Specification at 125 mils (0.125 inch) is most common for rough surfaces such as patched or resurfaced concrete and brick manholes. Structural design may require greater thickness depending upon depth, shape, condition, traffic loading and groundwater pressure (see Chapter 7 for design guidelines). Because polymers are generally applied relatively thin (125 mils or less) and perform based upon the composite system formed by adhesion to the host structure, surface preparation is critical. Only 100% solids, solvent-free products should be considered due to safety and performance advantages. Polymer application requires specialized equipment and training.

Cured-in-Place Manhole

Cured-in-place manhole liners (CIPM) used for manhole rehabilitation generally consist of a polyester needle punched felt or fiberglass reinforced “bag” saturated with a thermoset resin. CIPM systems are most often used for structural rehabilitation where replacement is difficult or impossible. The manhole is pre-measured and each bag is custom made at the factory. Resin is impregnated into the bag at the job site and installed into the manhole. Steam pressure is used to expand and cure the CIPM. The invert and pipe inlets are cut open and sealed with trowel application of epoxy grouts before returning to service. Surface preparation is critical for adhesion of the liner to the existing manhole and should include filling recessed voids to eliminate potential problems including infiltration that may migrate along the annular space between the liner and the host manhole. A similar cured-in-place method has an expandable range that precludes prefabrication to a specific dimension. The object is to provide a tightly adhered liner that provides structural value and leak protection. Alternatively, fiberglass mat is hand applied in resin-saturated sections which overlap similar in concept to papier mâché. These processes require specialized equipment and training and are shown in Figure 7.

Composite Systems

The combination of coating and liner material results in a composite system which serves multiple purposes within the manhole structure. Most common is the use of a cementitious product for resurfacing or rebuilding deteriorated and structurally deficient manholes, and the application of a polymer coating for corrosion protection. The installation of a thermoplastic sheet liner embedded into a cementitious material or polymer mastic may be used to achieve structural renewal and corrosion protection as well. Another composite system includes an epoxy prime coat followed by a thick polyurea foam which then receives a thin polymer topcoat to complete the rehabilitation.

Fiberglass and Thermosetting Resin | Polyester and Thermosetting Resin

Figure 7 . Exmple Cured-in-Place (CIP) Technologies for Manhole Rehablitation

Before Relining System | After Cement Base is Applied | After Epoxy Topcoat is Applied

Figure 8 . Exmple Manhole Renewal Method using a Composte System (cement base + Epoxy)

5.SUMMARY

The decision making becomes easier once an understanding of the need is identified clearly. The advantages and limitations of the many rehabilitation options allow specifiers to custom design each project to meet both immediate and long-term needs. Table 5-2 provides an example decision matrix based upon a pre-designed condition rating for defects and available solutions for rehabilitating manholes.

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TABLE 5-2. MANHOLE REHABILITATION DECISION MATRIX

DEFECT RATING/SCALE		
Low	**Moderate**	**Severe**
Leaks and spot defects in structurally sound manholes	Low classified defects + leaks in w/in structural defects	Moderate class defects + broad structural issues
Isolated Leaks	>15% of area leaking >5 gal/min during a rain event	Portions of wall missing
Inflow problems (a) around cover or (b) under frame	Some missing bricks	More than 1" of precast wall corroded
Misaligned or broken casting	Repairable small void pockets	Exposed rebar
No evidence of corrosion	More than 40 years old	Subjected to heavy traffic loading
Unsafe steps	Evidence of corrosion	MH in critical area w/sewer system w/major rehab a low risk
Minor damage to bench and/or leaking in channel	Unusable or missing bench	
Dry or low groundwater present	Leaking channel + high ground water present	
CORRECTIVE ACTION		
Stop leaks using hydraulic cement or chemical grouting	Stop leaks using hydraulic cement or chemical grouting	Remove and replace manhole structure
Install manhole dish or insert	Fill voids w/ high-strength cement in prep for new liner	Resurface with high-strength cement or polymer to prepare for liner installation
Install frame and chimney seal	Reinforce and seal w/ cementitious or polymer liner, composite system with corrosion protection, or CIP liner	Reinforce and seal with full-depth rehabilitation using cementitious or polymer liner, composite system with corrosion protection, or CIP liner
Repair bench or channel	Install corrosion-resistant barrier w/polymer or plastic liner combined w/non-resistant cementitious base liner	Install corrosion-resistant barrier w/polymer or plastic liner combined w/non-resistant cementitious base liner