Meeting the Challenge of Pipeline Emergency Repair

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ABSTRACTS

The Metropolitan Water District of Southern California (MWD) is the nation's largest provider of treated drinking water. Each day during a normal year, Metropolitan moves more than 1.5 billion gallons of water through its distribution system, delivering supplies to 26 member agencies throughout six counties in Southern California. Those agencies, in turn, sell that water to more than 300 sub-agencies or directly to consumers. In all, nearly 19 million Southern Californians rely on Metropolitan for some or all of the water they use in their homes and businesses.

Metropolitan maintains and operates a regional distribution system that includes 5 treatment plants, 17 reservoirs, 16 hydroelectric power plants, 45 pressure control structures and 800 miles of pipelines. The pipelines consist of 362 miles of steel pipe, 234 miles of concrete pipe, 163 miles of Prestressed Concrete Cylinder Pipe (PCCP) and 32 miles of other pipe. The size of Metropolitan's distribution pipelines range from 16 inches to 201 inches in diameter. The age of Metropolitan's distribution pipelines range from 1 year to over 70 years.

Each year MWD schedules shutdowns to perform inspection, maintenance and repair on various pipelines and facilities throughout its system. However, when unanticipated problems occur that put the water delivery system or public at risk, an emergency pipeline repair is required. To minimize the service disruption to member agencies, it is essential to conduct the emergency repairs in an expeditious manner. Close cooperation among MWD's in-house engineering, fabrication and construction workforce makes it possible to have the pipeline repaired and returned to service in a short time. There are also times when a pipeline shutdown is not feasible, requiring an emergency repair without service disruption.

This paper provides an overview on the various emergency repair methods MWD uses to repair PCCP, precast or cast-in-place reinforced concrete pipe and steel pipe. For structural repairs of PCCP and precast concrete pipe, the repair methods include removing the distressed pipe and replacing it with steel pipe, or inserting a steel liner inside the pipe, or installing carbon fiber reinforced polymer (CFRP) liner. For water leaks of precast or cast-in-place reinforced concrete pipe, the repair methods include installing internal EPDM seals, or installing fiber reinforce polymer (FRP) lining, or external crack injection. For steel pipe, the repair methods include welding on steel patch plates, or installing a steel outlet, or installing internal or external steel bands.

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INTRODUCTION

The Metropolitan Water District of Southern California (MWD) is the nation's largest provider of treated drinking water. Each day during a normal year, Metropolitan moves more than 1.5 billion gallons of water through its distribution system. Since nearly 19 million Southern Californians rely on Metropolitan for some or all of their water it is important to make the system as reliable as possible. .

To maintain the system each year MWD schedules shutdowns to perform inspection, maintenance and repair on various pipelines and facilities throughout the system. However, when unanticipated problems arise that puts the water delivery system or public at risk an emergency pipeline repair is required.

EMERGENCY REPAIR DECISION

For a buried water pipeline, an emergency occurs when a water leakage becomes noticeable or severe structural degradation of pipe is detected. Once notified, MWD engineering staff will immediately start to investigate the probable causes of the problem, assess the condition of the pipe, evaluate the risk of continuous operation of the pipeline and propose repair options. MWD operational staff will assess the impact to the member agencies if the water delivery is interrupted and determine when and how long the pipeline can be taken out of service for repair.

If it is determined that the problem needs to be corrected immediately, an emergency repair plan has to be implemented within the available shutdown window. The repair method must be suitable for completing the repair within the limited shutdown time.

PCCP REPAIR

For PCCP, an emergency repair is required when excessive prestressed wire breaks are detected through Remote Field Transformer Coupling (RFTC) inspection or other major structural distresses are discovered during inspection. If structural analysis indicates that the PCCP with broken wires is subject to imminent failure, the pipeline must be shut down for structural restoration. The distressed pipe is normally repaired with steel pipe/liner or Carbon Fiber Reinforced Polymer (CFRP) liner.

Repair with Steel Pipe/Liner

If the distressed PCCP pipe is located in a rural area where an open cut excavation is possible, the pipe will be excavated to the bottom of the pipe. The distressed pipe will be completely removed (from joint to joint) and replaced with an equivalent length and diameter of steel pipe. The connection between the PCCP and steel pipe will be encased in concrete to provide a transition from rigid pipe to flexible pipe. The excavation does not need to fully backfilled before the pipeline can be returned to service.

Figure 1 - PCCP Replaced with Steel Pipe

If the distressed pipe is located in an urban area where an open cut excavation is not feasible, shoring will be required for excavation. This can be challenging especially when the soil cover is deep and the pipe diameter is large. To reduce the excavation and shoring installation effort, the pipe can be exposed to just below the springline. A portion of the upper half of the distressed pipe will be cut off and removed, then a few steel segements with a slightly smaller diameter than the PCCP, will be inserted into the PCCP and connected together by welding. End rings between the bell and spigot and the liner prevent water from getting behind the liner. The annular space between the PCCP and steel liner will be filled with cement grout to provide support to the steel liner. The pipeline can be returned to service once the grout reaches the minimum required strength.

Figure 2 - PCCP Repair with Steel Liner

When excavation around the distressed pipe is not feasible but a nearby location can be excavated, a PCCP segment at the nearby location will be identified for excavation. The excavation can be either full or half depth of the pipe as shown in Figures 1 and 2. A few smaller diameter, short length segments of steel liner will be inserted into the PCCP and transported to the location where the distressed PCCP is

located and connected together by welding. The diameter and length of the steel liner segment need to be carefully determined to allow the steel liner to be transported through horizontal or vertical bends. The PCCP that is cut off for access will be repaired with either a steel pipe or steel liner as described above. This method can also be used when multiple adjacent pipe segments need to be repaired.

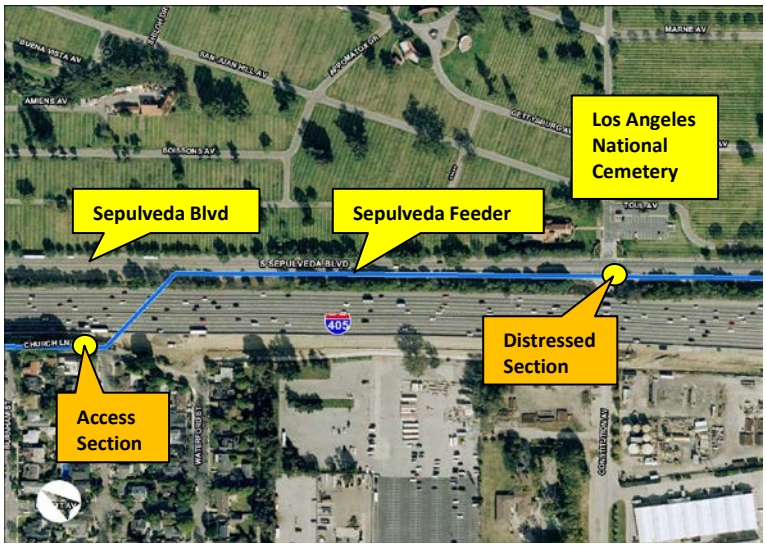

Figure 3 - PCCP Repair via Remote Access Point

Repair with CFRP

When excavation around or nearby the distressed pipe is not feasible, Carbon Fiber Reinforced Polymer (CFRP) liner will be installed to strengthen the distressed pipe. The advantage of this repair method is that no excavation is required because all the repair activities can be performed by access the pipe through an existing manhole. Permitting and planning requirements areusually minimum, therefore the repair can be done quickly. This repair method involves installing a number of layers of CFRP laminates onto the interior surface of the distressed PCCP to provide structural strength for the pipe to resist internal and external loads. The ends of the CFRP liner need to be carefully terminated and sealed to prevent water from getting behind the CFRP liner.

Figure 4 - PCCP Repair with CFRP Liner

CONCRETE PIPE REPAIR

For precast or cast-in-place concrete pipe with lower water pressure, an emergency repair is normally required to stop water leakage. Unlike PCCP where the distressed pipe segment is pinpointed, the first challenge of this type of emergency repair is to identify the origin of the leak , what caused the pipe to leak and what repair is required to stop the leakage. This information may not be available until the pipe is excavated. Significant engineering judgment has to be exercised to determine if the pipe can be safely excavated. To reduce the shutdown length different repair plans should be prepared to account for different leak mechanisms.

Internal EPDM Seal or FRP Lining

Most of the problems MWD has experienced in this type of pipe are water leaks at pipe joints or at circumferential crack which do not require structural repair. One effective repair method is to install an internal EPDM seal with steel retaining bands to cover the leaking joint or crack if the pipe interior is circular and uniform. If the pipe interior is non-circular, such as a transition from circular to rectangular shape, or non-uniform in size, such as a transition for different pipe diameters, EPDM seal with steel retaining bands will not be effective. In this case, a Fiber Reinforced Polymer (FRP) lining can be installed across the joint or crack. The installation is similar to CFRP liner but only a few layers are needed because no structural strengthening is required in this case.

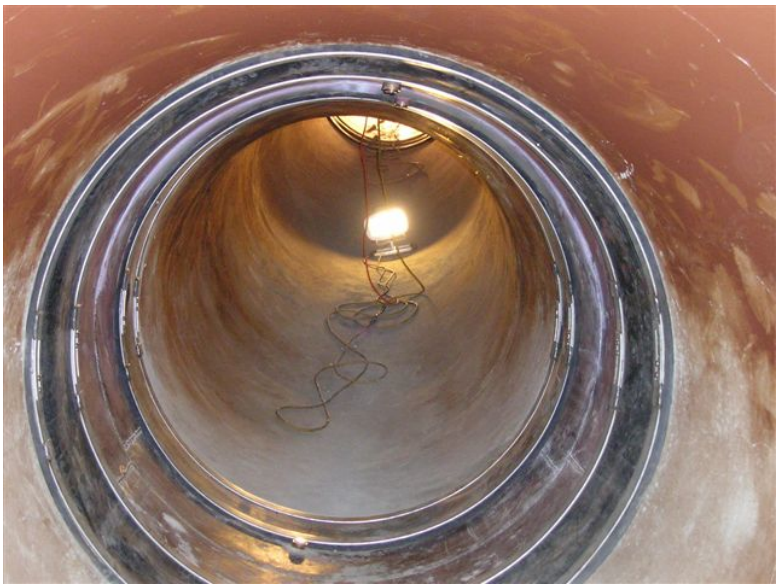

Figure 5 – Concrete Pipe Repair with Internal Seal

External Crack Injection

Installing EPDM seal or FRP lining require a shutdown and dewatering the pipeline. However, if the pipeline cannot be shutdown due to operational reasons, an attempt has to be made to seal the leak while the pipeline is under operation. This can be done effectively on very low pressure pipe by injecting sealing material into the leaking joint or crack from outside of the pipe. When the water pressure is high, there are significant challenges to inject sealant material against the water pressure and hold it in place gel so it is not pushed out by leaking water.

Figure 6 – Concrete Pipe Repair with External Injection

STEEL PIPE REPAIR

For steel pipe, an emergency repair is normally required to stop water leakage through a pinhole, a crack caused by corrosion, a welding defect or damage from adjacent construction. Due to the ductile nature of steel material, immediate structural failure generally is not a concern. However, if the problem is not addressed, it may progress to eventually cause pipe failure. Because of the workability of steel pipe, local spot repair can be used to fix the problem.

Repair with Steel Patch

If the leak is at an isolated spot and the surrounding material is structurally sound, a properly sized steel patch can be welded onto the pipe to cover the defected area, either internally or externally. Precautionary measures shall be used to prevent overheating the pipe and damaging the existing lining or coating when performing welding. Removed lining or coating needs to be repaired after welding.

Figure 7 – Steel Pipe Repair with Steel Patch

Repair with Outlet

Another repair option is to weld on a steel outlet with blind flange. The outlet can be welded to the steel pipe over the leaking area. Precautionary measures shall be used not to overheat the pipe and damage the interior lining when performing welding. If the pipe can't be shutdown then a small valve can be installed on the blind flange to allow water to drain out while welding on the outlet. The outlet can then be filled cement grout.

Figure 8 – Steel Pipe Repair with Steel Outlet

Repair with Steel Band

If the leak is a crack at a pipe joint, an internal steel band can be installed at the pipe joint to cover the crack if the pipeline can be shut down for repair. Internal steel band can be fabricated from a few short pieces steel. These pieces are then brought into the pipe through an existing manhole. The steel band pieces are welded together inside the pipe. If the pipe cannot be shut down for repair but excavating the pipe is possible, a steel band can be installed from outside of the pipe while the pipe in under operation. The pipe has to be properly supported when exposed for such repair.

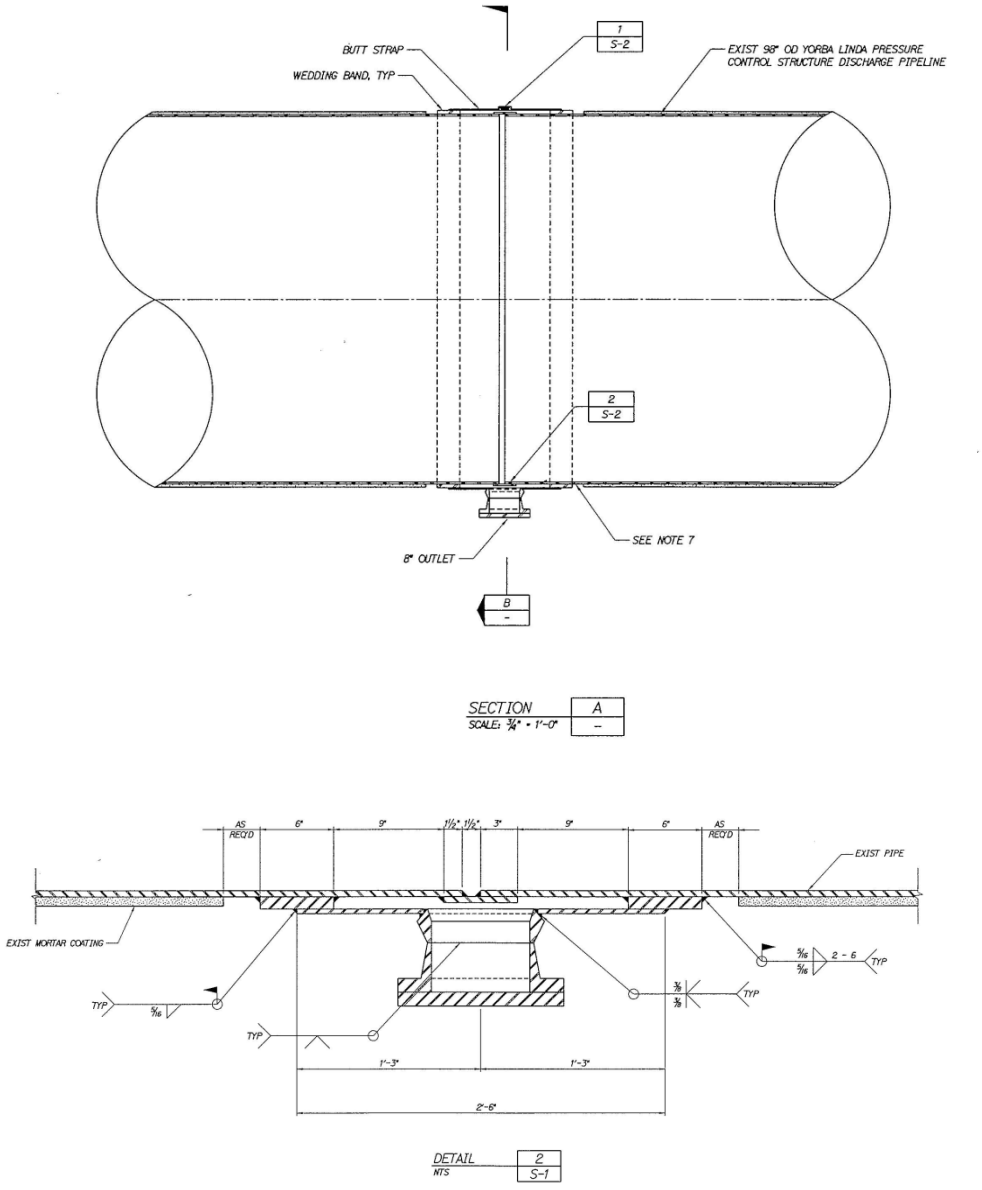

Figure 9 – Steel Pipe Repair with External Steel Band

EMERGENCY REPAIR EXECUTION

For all the above described repair methods except CFRP liner and FRP lining, MWD's workforce is capable designing, fabrication and installation of the repair. Close cooperation among various functional groups including public relations, system operations, water quality, environmental, health and safety, project management, pipeline and geotechnical engineering, production planning, fabrication, construction services, etc. make it possible to complete the emergency repair in a short time. When a pipeline shutdown is needed for the repair, the actual service interruption time is usually about five to ten days.

SUMMARY

MWD uses various repair methods to repair PCCP, precast or cast-in-place reinforced concrete pipe and steel pipe when an emergency occurs. For structural repairs of PCCP and precast concrete pipe, the repair methods include removing the pipe and replacing it with steel pipe, or inserting a steel liner inside the pipe, or installing carbon fiber reinforced polymer (CFRP) liner. For water leaks of precast or cast-in-place reinforced concrete pipe, the repair methods include installing internal EPDM seals, or installing fiber reinforce polymer (FRP) lining, or external crack injection. For steel pipe, the repair methods include welding on steel patch plates, or installing a steel outlet, or installing internal or external steel bands.

To minimize the service disruption to member agencies, it is essential to conduct the emergency repairs in an expeditious manner. Close cooperation among MWD's in-house engineering, fabrication and construction workforce makes it possible to have the pipeline repaired and returned to service in a short time.