

The Evolution of Watertight Storm Drainage Systems

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INTRODUCTION

Watertight pipe and structures have historically only been considered with sanitary systems. The cost, however, of construction, maintenance, roadway safety and stream and groundwater contamination have united previous construction industry adversaries. Federal, state and municipal agencies, contractors, pipe and precast concrete producers, and design engineers all want watertight storm drainage systems. The reasons may vary but their overall goal is the same.

Government agencies are having significant problems with non-point stream pollution, groundwater contamination, and de-watering of wet lands via leaking storm drainage systems. These agencies are starting to institute regulations to address these problems with possible ramifications on project designs. State DOT's and municipalities are implementing new specifications to address the effects of underground structural failures related to the leaking and piping of backfill materials through open joints. Contractor's, for their part, are also investigating the cost savings associated with quicker and lower priced watertight construction techniques. The final advocating group, the concrete precaster, is arguing for the benefit of a higher precast quality watertight product, over cast-in-place structures, with no additional cost to the owner.

Specific examples from federal agencies, DOT's and cities indicate there is an evolution to watertight storm drainage systems. Financial arguments from the consulting engineer's, contractor's and precaster's point of view demonstrate an alternate reasoning for this requirement. It appears we are on the crest of a new design philosophy regarding storm drainage systems.

WATERTIGHT BENEFITS

The first question, which is inevitably raised when watertight storm drainage systems are discussed, is; why are they needed? We have functioned for centuries without watertight storm systems. Our current designs have served us well over the years and this is simply an unnecessary expense. In fact, we like to have our joints partially opened to allow for drainage of the backfill around the pipe. All these arguments have been made over the years, but contrary to popular belief watertight systems are not only more economical than standard mortared pipe and connections, but their use is being required for engineering purposes.

When a joint permits the infiltration of water into the structure or pipeline, it carries soil particles with it. The loss of the soil fines around a structure undermines its integrity and will eventually result in a pavement settlement or pipeline collapse.

The Environmental Protection Agency (EPA) is one of many federal, state and municipal governmental bodies concerned with water quality. The pollution of streams or groundwater can result in massive fines and penalties. Stormwater contains contaminants from many sources collected over an entire drainage area. The infiltration or exfiltration of water from a stormwater system may, therefore, result in these contaminants polluting a stream or the groundwater.

When joints leak or permit infiltration, they drain the groundwater or surrounding surface water. When located near or through a wetland, they will, over time, drain the entire wetland and destroy the sensitive ecology of the area.

The expense of constructing a pipeline is time related. The quicker the project is completed, the lower the project costs. Mortaring or field applying wraps, filter fabrics and bands takes a great deal of time and significantly increases the costs of a project over those for gasketed systems.

The cost of most products are material based. Small changes in manufacturing processes do not have a significant impact on the cost of the product and may result in a significant improvement in its performance. It is, therefore, possible to obtain a sanitary pipe at a storm pipe price.

Each of these items makes the case for using watertight storm sewers. They are not all monetary, environmental or safety related. Their benefits are comprehensive and of use to manufacturers, contractors, municipalities and the public.

STRUCTURAL FAILURES

All structural failures of pipelines are a result of inadequate soil performance. The cause of this lack of performance varies, but the ultimate failure mode is the soil. All pipelines and underground structures are soil-structure interaction systems. If the soil component of this system is poor, it will manifest itself in pavement distress, embankment settlement or collapse of the pipe.

When joints in pipelines are not watertight, there is no control over the amount of infiltration into the pipeline. With this inflow of water come fines from the surrounding backfill material. Over time, the continual loss of this material will create voids around the pipe and structures. With flexible pipe, this may undermine the structural integrity of the pipe, resulting in a pipe collapse. With rigid pipe, it would probably first manifest itself as localized pavement failures around the pipe or structures.

These failures may result in the loss of the roadway, but as a minimum, they represent a safety hazard to the traveling public. Potholes, sinkholes and roadway collapse are examples of the type of problems, which can result from leaking stormwater systems. Since these failures are a result of design decisions not to control infiltration, they can lead to liability concerns and costly repairs for the municipality.



<FIGURE 1: Structural Failure From Loss of Fines>

Some municipalities are addressing these structural and liability issues by requiring watertight connections or no infiltration into the pipeline. The Ohio Department of Transportation has recently issued “Supplemental Specification 802,” which requires independent third party inspection of all storm sewer projects for joint integrity and infiltration. If either is found to be a problem, detailed repair and replacement requirements are stipulated prior to the acceptance of the pipeline and payment of the contractor.

The main culprit of infiltration is mortared or mastic joints and non-gasketed coupler or banded connections. All of these types of joints do not provide a watertight seal or control infiltration. The mortared or mastic joints may initially be watertight, but they can not accommodate pipe-to-pipe or pipe-to-structure settlement resulting in cracking of this filler material and subsequent leaking. The bands or couplers are or eventually become plastic-to-plastic or metal-to-metal, which prevents creating a watertight seal. The structural integrity of a system can, therefore, only be assured by preventing infiltration, which requires a silt-tight or watertight system.

ENVIRONMENTAL ISSUES

In 2001, ASCE published a report card on the country’s infrastructure. Two issues, drinking water and wastewater were rated “D”. One of the justifications for drinking water’s poor “D” rating was, “...Non-point-source pollution remains the most significant threat to water quality.” Wastewater’s “D” rating sited, “...More than one-third of the U.S. surface water fails to meet current water quality standards.” Both of these problems are influenced directly by infiltration and exfiltration of contaminates from stormwater systems.

If a stormwater system is not watertight, it has the potential of leaking every 3.8 to 9.5 meters (8 to 20 feet) depending on the pipe used. When placed through an area with

contaminated soils, industrial complexes or farms, pollution-laden waters can leach into the system through one of these many openings. Once in the system, these contaminants can be concentrated with pollutants from other parts of the storm system. The first flush of a storm event with this concentrated elixir can result in a significant shock to the local eco-system of a stream or river. In this case, our leaking stormwater systems can do more damage than even point source polluters.

In this same fashion, the storm drain systems may also function to contaminate groundwater. Once pollutants are in a leaking system, they can exit anywhere along the length of the pipeline. Where the groundwater is below the elevation of the pipe invert, pollutants can leach out of the storm drainage system contaminating the groundwater. Surface drainage pollutants entering the system from catch basins far upstream may also contaminate an area's groundwater by this same process.

The EPA currently allows an infiltration or exfiltration leakage rate of 18.5 liters per millimeter of internal diameter per kilometer (200 gallons per inch of internal diameter per mile) of sewer over 24-hours. This requirement is for sanitary sewers as defined in ASTM C 969. If we were to apply this leakage rate to an average 914-kilometers (3,000-ft) concrete storm sewer with a diameter of 1500-millimeters (60-inches), the rate of contamination would be 25,500 liters (6,750 gallons) per day. Storm sewers, however, are not held to this tight leakage requirement, so the rate of infiltration or exfiltration is much greater, in orders of magnitude. In a relatively short period of time, this rate of pollution can cause irrevocable damage to either the groundwater or natural stream or river.



<FIGURE 2: Typical Joint Infiltration in Non-Gasketed Storm Sewer>

Infiltration of this magnitude causes other problems, in addition to pollution. If such a storm sewer were placed near or in the vicinity of a wetland, pond or other natural water

retention area, it would eventually drain the entire water resource. The de-watering of wetlands has resulted in numerous lawsuits, fines and penalties against developers and contractors over the years. The U.S. Army Corps of Engineers regulates these valuable retention and detention areas for not only their flood mitigation benefits but also for the ecological diversity it provides for the environment. Wetlands contain unique habitat for migrating birds and other wildlife. Providing leaking piping systems in proximity of these resources is equivalent to deliberating draining them.

CONSTRUCTION CONSIDERATIONS

The basic equation for the construction and installation of underground pipelines and structures is: Time = Money. Speed and ease of installation, in many cases, overshadow initial material costs. The profitability of a contractor is directly related to the production rate obtained by his crews. For the laying of underground pipelines, this benchmark is the number of meters (feet) of pipe per crew per day. Gasketed and booted structural connectors greatly reduce installation time and thereby the cost of an installation. Mastic and mortared connections are measured in the hours whereas the use of rubber connectors are measured in the minutes.

A typical mortared 1200-millimeter (48-inch) concrete pipe-to-manhole connection has \$200 in labor per connection. An additional \$85 for mortar and \$48 in brick are required for materials. The \$333 total cost of this infield construction process compares unfavorably to that of a rubber booted connection of \$240. This differential gets multiplied with each additional connection.



<FIGURE 3: Labor Intensive Field Mortaring of Structure Connection>

Infield construction connections also have additional inherent problems. The construction quality is usually poor, as it is difficult to elevate the pipe to properly seal under the invert, which is typically resting on the manhole base. The appearance and integrity of these connections is only as good as the individual's technique at the bottom of the trench. This working environment can not be controlled and is subject to adverse weather conditions, limited working space and numerous construction hazards. All of which effect the quality of the product. Since these connections must also be cured prior to testing, the trench must be kept open for a longer period of time, creating safety problems for the traveling public and others in the vicinity. Gasketed connections, on the other hand, are applied above ground with the pipe simply inserted into place in the trench. These installations can then be immediately backfilled, allowing the contractor's crew to concentrate on another part of the project.

PRODUCT QUALITY

A common axiom is: "You get what you pay for." A more appropriate saying for underground pipelines is: "You get what you specify." The material and product costs for producing a sanitary versus storm sewer pipe are nearly the same. There are some small modifications or enhancements, which may be necessary depending on the pipe material utilized; but if the pipe is capable of being made watertight, there is little difference in overall production costs. Storm and sanitary structures are identical. Essentially, a watertight sanitary system can be obtained for the same price as a culvert's, if specified correctly.

It is the performance and testing criteria that drive the cost of sanitary pipe higher than storm and culvert pipe. The manufacturers install extra costs on the pipe for testing and risk. The risk factor is variable depending on the quality of the producer's equipment, the tolerances they can hold, and their attention to proper material handling and production techniques. For example, sanitary concrete product that is not produced to specification is typically downgraded to storm. The point being all storm pipe can be made to sanitary quality, with proper production controls. With the cost of the rubber gaskets and connectors a relatively insignificant cost of the project with respect to the overall pipe production costs, and as previously mentioned, less expensive than field installations, why not specify a higher quality pipeline?

To obtain sanitary quality pipe at storm prices, one must recognize the level of testing can not be the same. A 90 kPa (13 psi) or 9 meter (30 foot) pressure test is going to require a significant amount of plant and field verification, which will increase project costs. A lower 14 kPa (2 psi) requirement should be considered. Although this requirement is not a high pressure rated joint, it is very easy for all standard storm pipe products to obtain and it insures a silt tight connection, preventing many of the problems previously mentioned in this paper. One can always increase the joint's pressure rating, but this requirement, as a minimum, should be specified to prevent soil infiltration.

Such watertight requirements will also insure structures are properly sized. In many cases, storm structures are poorly sized and not structurally adequate to accommodate the

pipe, it's wall thickness and angle of entry. To properly seal a manhole structure, these product dimensions and field variables must be incorporated into the design. The final manhole is one, which is not only watertight, but functions well structurally. The problem of manholes so poorly constructed that they are falling apart during handling or before they are installed is eliminated.

WATERTIGHT CONNECTIONS

Watertight connections take two forms: rubber gasketed pipe connectors and rubber pipe-to-structure booted-gasketed connectors. The key word with both of these connectors is rubber. Rubber is a resilient material that is capable of maintaining high pressure seals and will permit independent movement of pipe-to-pipe and pipe-to-structures without loss of watertight integrity. Rubber gasketed connections are therefore used on all water and sanitary pipe. These rubber products are covered under ASTM standards C 443, C 923, D 3212 and F 477. All other sealing methods used for storm sewers are not watertight. This group includes mastics, mortar, filter fabric, external wraps, collars, coupler bands and any other non-rubber applications.



<FIGURE 4: Typical Pipe-to-Structure Boot Connection>

In addition to being watertight, these flexible rubber connections accommodate soil consolidation and settlement, do not become brittle or lose their sealing capability, allow for pipe deflection, have high durability, require no maintenance, can be formulated to resistant to any field chemical exposure, and maintain the system's long-term structural integrity. Installation of either a gasket or booted connection can be made in seconds, once installed on the pipe or manhole at the production plant or above ground at the construction site.

CONCLUSIONS

Design concerns are driving the need for watertight storm sewers. The loss of materials around the pipe and structures are resulting in structural failures and liability issues. The in-flow of water and pollutants into the system are endangering downstream wildlife and habitats. Exfiltration of contaminants into the groundwater is polluting drinking water. High project costs and long construction times are necessitating the need for more innovative processes for installation and design of storm water systems. Poor quality and low durability products are draining financial resources with higher maintenance expenses and costly replacements.

Watertight storm sewers address all these problems. They control infiltration into the line eliminating structural and de-watering concerns. Provide water pressure quality connections for infiltration and exfiltration control to eliminate any pollution related problems. They also have field flexibility to accommodate joint deflection at the pipe or structures.

In general, gasketed connections have lower total labor and material costs, provide for faster and less expensive installations, result in higher quality products at no additional cost, and have lower maintenance costs. Another benefit, which will be materializing with the evolving EPA stormwater program, is the elimination of any secondary water treatment costs.

Evolution is a process of change. We can no longer afford to have our storm sewers leak. Watertight storm sewers preserve our environment, finances and infrastructure. It is time they are made watertight.

REFERENCES

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FIGURE 1: Structural Failure From Loss of Fines



FIGURE 2: Typical Joint Infiltration in Non-Gasketed Storm Sewer



FIGURE 3: Labor Intensive Field Mortaring of Structure Connection



FIGURE 4: Typical Pipe-to-Structure Boot Connection