Why Concrete Pipe?

Made of Concrete

Concrete is the world's most commonly used building material. In its simplest form, concrete is a mixture of paste and aggregates. The material (paste) used to manufacture concrete pipe is composed principally of Portland cement and water, and is used to coat the surface of the fine and coarse aggregates. The Portland cement is a closely controlled chemical combination of calcium, silicon, aluminum, iron, and small amounts of other compounds, to which gypsum is added in the final grinding process to regulate the setting time of the concrete. Portland cement's chemistry comes to life in the presence of water. Soon after the cement and water are combined, a chemical reaction called hydration occurs and the paste hardens and gains strength to form the rock-like mass known as concrete. During hydration, a node forms on the surface of each cement particle. The node grows and expands until it links up with nodes from other cement particles or adheres to adjacent aggregates. Within this process lies the key to the remarkable trait of concrete - it's plastic and malleable when newly mixed and strong and durable when hardened.

The character of the concrete is determined by the quality of the paste. The strength of the paste, in turn, depends on the ratio of water to cement. The water-cement ratio is the weight of the mixing water divided by the weight of the cement. High-quality concrete is produced by lowering the water-cement ratio as much as possible without sacrificing the workability of fresh concrete. Generally, using less water produces a higher quality concrete provided the concrete is properly placed, consolidated, and cured. Typically, a mix is about 10 to 15 percent cement, 60 to 75 percent aggregate and 15 to 20 percent water. Entrained air in many concrete mixes may also take up another 5 to 8 percent.

Almost any natural water that is drinkable and has no pronounced taste or odor may be used as mixing water for concrete. However, some waters that are not fit for drinking may be suitable for concrete. Specifications usually set limits on chlorides, sulfates, alkalis, and solids in mixing water unless tests can be performed to determine what effect the impurity has on various properties.

The type and size of the aggregate mixture depends on the thickness and purpose of the final concrete product. A continuous gradation of particle sizes is desirable for efficient use of the paste. In addition, aggregates should be clean and free from any matter that might affect the quality of the concrete.

Curing begins after the exposed surfaces of the concrete have hardened sufficiently to resist marring. Curing ensures the continued hydration of the cement and the strength gain of the concrete. Concrete surfaces are cured by steam or water. The longer the concrete is kept moist, the stronger and more durable it will become. The rate of hardening depends upon the composition and fineness of the cement, the mix proportions, and the moisture and temperature conditions. Most of the hydration and strength gain take place within the first month of concrete's life cycle, but hydration continues at a slower rate for many years. Concrete continues to get stronger as it gets older.

Precast concrete products are cast in a factory setting. These products benefit from tight quality control achieved at a production plant. Precast concrete pipe is produced in highly controlled plant environments under rigid production standards and testing specifications.

Strength

Precast concrete pipe the strongest pipe available. It can be designed and plant tested to resist any load required. Unlike flexible pipe, it has minimal reliance on installation to support loads; it relies primarily on its inherent brute strength manufactured into the pipe. That adds up to a tremendous difference in the design, the installation and the long-term success of a project.

Compressive strengths for concrete pipe normally range from 4,000 psi to 8,000 psi. It is a function of other factors including, aggregates, cementitious material, the manufacturing process, curing process and mix design. Most concrete design strengths refer to 28 day compressive strengths. It is not uncommon for 28 day tests to substantially exceed the specified design strengths.

Concrete pipe strength is standardized by ASTM C76 and AASHTO M170. Pipe is strength-tested in the plant using D-Load standards. Supporting strength of a pipe is determined under three-edge-bearing test conditions. Expressed in pounds per linear foot per foot of inside diameter or horizontal span, D-load tests the pipe under severe loading conditions where there is no bedding, and no lateral support, under three-point loads.

ASTM C76 (standard for four classes of reinforced concrete pipe)

- Class I, II, III, IV, V
- Class III: 1,350 lb/ft/ft
- Class IV: 2,000 lb/ft/ft
- Class V: 3,000 lb/ft/ft
- Gasketed joints are tested to 13 psi

ASTM C14 (non reinforced concrete pipe)

- Class 1, 2, 3
- D/Load expressed in lb/linear foot (to compare to reinforced divide by diameter)

Design Loading (used for determining pipe strength for installations underneath traveled roadways)

- AASHTO HS20 (Standard for vehicle loads on pipes)
    - 16,000 lbs Axle Load
    - 10" x 20" Tire Footprint
    - 0 - 30% Impact Load
    - Distributed 1.75H

Wire reinforcement in concrete pipe adds significantly to its inherent strength. Wire reinforcement shaped as cages is a precision-fabricated mesh fabricated by automatic cage welding machines. The cage machines fabricate machine formed bells, are dimensionally stable, and have close engineered tolerances. Reinforced concrete pipe have higher load capacities.

Reinforced concrete pipe is a composite structure and specially designed to use the best features of both concrete and reinforcement. The concrete is designed for the compressive force and the reinforcement for the tensile force. Unless the concrete cracks, the reinforcement is not being used to its design capacity. As more tensile forces are carried by the reinforcement, hairline cracks become visible, but these occur at loads well below the design loading of the reinforced member. Hairline cracks are not an indication of danger, distress, or loss of structural integrity. Concrete pipe is generally designed to carry loads well within the engineered load bearing capacity of a pipeline, and hairline cracks do not occur. If hairline cracks do occur, they tend to seal themselves through a process known as autogenous healing. Autogenous healing is the ability of concrete to repair itself in the presence of moisture. Reinforced concrete pipe, unlike reinforced concrete beams and slabs, are buried where moisture conditions are present for autogenous healing to take place.

Durable

Durable is defined in Webster's dictionary as, "able to exist for a long time without significant deterioration." With concrete pipe, durability deals with the life expectancy and enduring characteristics of its materials. There are a variety of products that can meet your specs today, but will they continue to do the job they were intended to do for the long term? The capability of pipe to perform as expected for the design life of a project is a fundamental engineering consideration, especially in today's economic environment, where requirements have been set in place to ensure a sustainable buried infrastructure.

The Army Corp of Engineers recommends a design life of 70-100 years for precast concrete pipe, and there are countless examples of installations that surpass those numbers. This means the expectation for precast concrete's functional life is at least twice as long as lesser materials. The reasons for this go far beyond concrete's innate strength. Concrete also won't burn, rust, tear, buckle, deflect, and it's immune to the attack of most elements, whether the pipe is buried or exposed.

Quality concrete pipe densities typically range from 145-155 pounds per cubic foot. Usually the higher the density, the greater the durability of the concrete pipe.

Dependable

Technology is now in place for making concrete pipe more reliable than it has ever been before. Decades of research and development of many aspects of concrete pipe has enabled concrete pipe producers to change concrete mixes, pipe design, and improve manufacturing processes to provide products that can withstand a complete range of underground environments and effluent profiles.

Dependability is not just a matter of how a product performs on its own. It also has a lot to do with how well it is understood by the people who plan, design, construct and install a project. How well does the engineer know its properties? How adept is the project team at spotting and correcting potential problems before they happen? How experienced are the crews when it comes to flawless installation and execution?

In this vital area, no material is better understood and more commonly used in the field than concrete pipe. That adds up to fewer mistakes and a greater level of comfort and confidence.

Both Structure and Conduit

Concrete pipe is a rigid pipe that provides both structure and conduit when it arrives on site. Concrete pipe is a rigid pipe system that is over 85% dependent on the pipe strength and only 15% dependent on the strength derived from the soil envelope. The inherent strength of concrete pipe compensates for construction shortcomings and higher fill heights and trench depths. Flexible pipe is at least 95% dependent on soil support and the installation expertise of the contractor. Backfill must be properly engineered and applied to provide structure. Imported fill is usually required for flexible pipe systems. Concrete pipe is less susceptible to damage during construction, and maintains its shape, by not deflecting as does flexible pipe.

As a rigid pipe, concrete pipe has high beam strength and can be pushed to proper grade. Only concrete pipe can bridge over uneven bedding without affecting the pipe hydraulics. Flexible pipe has a low beam stiffness and deflects with uneven bedding, thereby inducing strain along the pipe axis.

Deflection testing of flexible pipe is critical to measure the strain and any circumferential deflection. Allowable deflection of flexible pipe is 3% initial and 5% long term. Deflection testing should not end, or be taken when backfilling has been completed. Installation problems that may be associated with flexible pipe are deflection, deformation or buckling, wall strain or crush, and buckling. When installation or manufacturing failures occur with flexible pipe, there is often reduced hydraulic capacity of the drainage system and leaking joints. Mandrel testing of flexible pipe is mandatory in many jurisdictions.

Non Flammable

Unlike thermoplastic conduits, concrete pipe will not burn. This is important for the planning of road and highway cross drains in urban areas and remote locations that are heavily forested. Concrete pipe is a wise choice for construction site safety, public safety (fire and toxic fumes hazard), and homeland security.

Thermoplastic conduits are also sensitive to extremes in temperature that may cause joint separation, an impact on wall stiffness, and strains on the corrugations of some

Value

The infrastructure maintained and managed by any public or private organization must first and foremost be handled as an asset, much like the assets of large corporations. When building, the taxpayers, users or owners make an investment and that investment is carried on the balance sheet for a certain period of time, most likely the design life of the project.

The full value of a project, or asset, must absorb all of the costs of initial design, material cost, installation and maintenance over the projected life of that asset. An asset that will steadily depreciate over time and one that requires additional investment (repairs, maintenance and/or replacement) to maintain its “book” value actually costs the owner more during its lifetime.

Understanding the true value of an asset over time is critical in making the initial decision of the choice of infrastructure materials. The design (including required soil sampling), installation and inspection costs of flexible plastic and metal pipes are greater than comparable costs for concrete pipe. Additionally, the asset value of concrete pipe will not drop during the design life of the project.

Local Availability

Concrete is one of the most widely used construction materials in existence. In virtually every major market, there is a local manufacturer that produces concrete pipe from local suppliers.

Local availability gives you better convenience, and also helps minimize shipping time and costs related to trucking. Having a local manufacturing resource also means that the materials are designed and produced to meet local/state standards. If any issues or changes arise, you also have access to local engineering and support personnel who can respond quickly. In addition, local producers support the local economy by hiring local people and paying local taxes.

Costs

A common misuse of the concept of least cost is the adoption of that analysis when choosing underground drainage pipe material. Least cost variables, including material cost, material life, inflation rates, replacement cost and residual values are vital in the design of roadway pavements. These same criteria, however, just don't work when attempting to predict the service life for pavements and underground utilities working together as a system. The underground material service life must, in all cases, exceed the design life of the entire roadway system. It would be inconceivable to replace a concrete roadway surface one year and reach the material service life of an underground culvert the next, necessitating an early re-replacement of the road.

For this reason, Life Design should be used to evaluate all underground drainage culverts and storm sewers. The Life Design concept encompasses all factors that could potentially lead to the premature repair or replacement of a roadway surface. Basically, materials are chosen for use based on their ability to remain in service for, at a minimum, of the design life of the roadway system.

Life Design takes into consideration material service life, defined as the long term structural strength of either the pipe itself or of the soil/pipe interaction system insuring that required design strength will not decline during the life of the system. Additionally, the pipe itself must maintain its hydraulic capacity, not experiencing losses due to changes in the pipe wall (rippling) or as a result of deflection.

The ability of a pipe material to survive unanticipated external events including fires, flashovers and flooding is also a major design element of Life Design. Finally, protecting the environment by insuring that pipe materials do not leach toxic substances into our nations estuaries will help maintain our fragile natural resources.

The Life Design “costs” of a system are inclusive of all of the elements of Life Design and provide for a more accurate gage of the fully absorbed cost of the asset. Initial material cost, design costs, soil testing (in the case of flexible materials), installation costs and post installation costs are all evaluated using the Life Design parameters as a minimum. Repair and maintenance costs should be minimal at best and replacement during the life of the system should not be an option.

Concrete pipe will easily meet all of the demands of Life Design as it remains the strongest, most hydraulically efficient, durable and environmentally friendly pipe available today.

Installation

Concrete pipe far out performs plastic or metal. Concrete’s rigidity and mass allow for easy and secure placement in the ditch, without disrupting line or grade. Plus, precast concrete pipe joints are easily assembled, which helps minimize the time needs for installation. When installation time matters, or when the soil poses challenges to installation, precast concrete pipe is quite simply the most logical and responsible option. Since Concrete pipe is a rigid pipe system that is over 85% dependent on the pipe strength and only 15% dependent on the strength derived from the soil envelope, installation is made easy. In many situations, the installation of plastic or metal pipes can take longer than precast concrete pipe. That’s because the structural and hydraulic integrity of flexible pipes rely heavily on how well you prep the surrounding soil at installation, rather than on their own inherent brute strength. Making sure all conditions are right and installing per national specifications can be a costly and time-consuming proposition when installing flexible pipe.

Concrete pipe has an unlimited range of pipe strengths from which to choose, and strength is demonstrated prior to installation. By specifying concrete pipe:

- The designer has more control over pipe strength than any other facet of the project
- There is less reliance on quality installation by the installer
- There is lower embedment material cost
- There is less compaction required
- It is easier to maintain grade and alignment
- There are no excess deflection concerns
- There is a lower life cycle cost of the project
- There is a lower maintenance cost over the design life of the project
- There is a reduced likelihood of failure
- A lower risk for the specifier, designer and owner of the project, and reduced overall liability to the public after the project has been commissioned

Standard Installations is a term for a technology used for precast concrete pipe beddings. Design of the pipe wall - its thickness and amount of reinforcement - is based on the stresses and strains in the pipe. This approach is more precise and can result in pipes that require less material. In addition, the standard installations approach permits greater choice of backfill materials, from granular materials to clay, and needs less compaction of the backfill.

Standard Installations were adopted by the American Society for Civil Engineers (ASCE) as Specification 15-93-*Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations.* It was adopted later in the 1996 (16th) Edition of the American Association of State Highway and Transportation Officials (AASHTO) *Standard Specification for Highway Bridges, Section 17, Soil-Reinforced Concrete Structure Interaction Systems.*

Standard Installations provide several benefits when using concrete pipe.

- Provides flexibility to meet design requirements and site conditions
- Allows for narrower excavation limits
- Less expensive backfill materials may be used
- Can reduce the level of compaction

- Increases contractor productivity in installing reinforced concrete pipe

There is a choice of Types of Standard Installations that provide versatility to adapt to field conditions.

- Type 1**:** Highest Quality installation using select granular soils with high compaction requirements for haunching and bedding.
- Type 2**:** Allows silty granular soils with less compaction required for haunching and bedding.
- Type 3: Allows use of soils with less stringent compaction requirements for haunching and bedding.
- Type 4: Allows use of onsite native material for haunching and bedding with no compaction required. (6 inches of bedding is required if rock foundation)

The short lengths of concrete pipe make it easier to work with around existing municipal services. Concrete pipe installations using trench boxes do not require special attention to sliding the trench box and disturbing the bedding and backfill in the process, referenced by all installation standards and recommendations of manufacturers. Using standard lengths of concrete pipe, line and grade can be checked frequently for accuracy.

Design and Construction Flexibility

Some projects have design elements that are a little more complex or intricate than others. Precast concrete pipe provides solutions for these projects, whether they are open-cut, deep burials, tunnels, trenchless, shallow burials, or with vertical structures or complex alignment changes. Concrete pipe design is simple to do; the math is sound and easily definable.

Precast concrete pipe gives you strength and flexibility to ensure the success of your most demanding applications. Pipes are manufactured with a variety of sizes, shapes, joints and seal options. There is also an array of linings and coatings that can handle the most aggressive environment.

The main attributes of concrete pipe apply to sanitary, storm sewers and culverts. Many attributes also may be applied to box sections used for storm drainage, roadway culverts, tunnels, bridges, and underground detention systems. Concrete pipe and box sections accommodate great volumes of effluent in a tiny footprint.

Concrete pipe produced in the early twenty-first century is a consequence of

- Computer aided design and analysis
- Advanced concrete mix designs
- Automated and computer controlled batching
- Precision fabricated wire reinforcement
- Quality driven manufacturing techniques
- Improved water tight joints
- New installation standards

Precast concrete box sections also have similar advantages to concrete pipe.

- Better quality control than flexible pipe products
- Ease of installation
- The dangers associated with open trenches are reduced
- Reduced environmental impacts
- Detour time is reduced
- Design time is reduced
- Just-in-time delivery is available from producers' plants to accommodate small construction sites and tight construction schedules
- Crews familiar with concrete pipe installation procedures can install box sections with minimal training
- Mortar Joint.

Concrete Pipe Joints

Concrete pipe offers a variety of joints from soil-tight to pressure. They are not affected by the type of backfill used for the installation. Joint performance must be demonstrated in the plant prior to pipe installation, and joint integrity can be field tested in a variety of ways. With concrete pipe, deflection will not compromise field joint test capability. The cross sectional rigidity of concrete pipe makes joint assembly a simple operation. Rigid joint integrity will minimize the likelihood of embedment intrusion and subsidence of overfill, often referenced as infiltration.

Gasketed leak-resistant RCP joints withstand a minimum hydrostatic internal head of 13 psi equal to 30 feet of water. (ASTM C 443 or C 1628)

Types of concrete pipe joints include:

- O-Ring Gaskets.
- Profile Gaskets.
- Mortar and Mastic Joints.

O Ring gaskets are used on all sanitary and some storm RCP where leak-resistant joints are required. These gaskets may be used in joints following ASTM designations, C 443, C 1628, or C 361 for low-head pressure applications.

Profile gaskets are used on stormwater culverts and RCP storm and sanitary sewers. Pipe is produced with a single offset spigot joint according to ASTM designation C 443 or C 1628.

Mortar or mastic joints are used for storm sewers, culverts, and horizontal elliptical reinforced concrete pipe. Mortar or mastic is applied to the bottom half of the bell end and to the top half of the adjoining spigot.

Mastic and Butyl sealants are applied in accordance with ASTM designation C 990-96.

In some applications, a quality joint may be a wrap applied to the external surface of the joint. These may be specified in accordance with ASTM C 877.

Concrete Pipe Mass

In a low laying or marshy environment, **the buoyancy of buried pipelines depends on the mass of the pipe material, the weight of the volume of water displaced by the pipe, the weight of the liquid load carried by the pipe, and the weight of the backfill material. Whenever the water table level is above the invert of the pipeline, the potential for floatation or buoyancy exists.** Although the trench for a pipe installation in a marshy area is dewatered, the trench area downstream (after initial backfill) may become saturated. This would lead to a buoyant effect on the pipe. The mass of the concrete pipe typically counteracts this buoyant force. Alternate materials such as thermoplastic pipe and corrugated metal pipe may heave vertically or snake horizontally in wetland conditions. During the backfill operation, the fill may accumulate more on one side of the pipe than the other. The mass of the concrete pipe resists lateral forces, and the structure remains true to line and grade.

The mass of concrete pipe allows for:

- Effective compaction of embedment and backfill
- Prevention of movement during backfilling ensures adherence to design grade and alignment
- Unlikely movement of structure following installation
- Reduces likelihood of floatation
- Reduces possibility of damage during subsequent construction or maintenance in phased projects

Hydraulic Efficiency

The key to long-term performance and efficiency lies in a materials ability to retain its original shape and alignment. Precast concrete pipes rigidity and mass allow it to greatly out perform flexible pipe systems in this critical area, which in turn helps to improve hydraulic efficiency by minimizing the resistance to water flow that often occurs when the shape or integrity of a flexible pipe is compromised.

The hydraulic capacity (the amount of water a pipe can convey) of all types of pipe depends on the smoothness of the interior pipe wall. The smoother the wall, the greater is the hydraulic capacity of the pipe. Smoothness of pipe is represented by Manning's Roughness Coefficient commonly called Manning's "*n*." The lower the Manning's "*n*" value, the greater is the volume of water that will flow through pipe.

Hydraulic analysis for drainage systems involves the estimation of the design flow rate based on climatological and watershed characteristics. The hydraulic design of a drainage system always includes an economic evaluation. A wide spectrum of flood flows with associated probabilities will occur at the site during its design life. The benefits of constructing a large capacity system to accommodate all of these storm events with no detrimental flooding effects are normally outweighed by the initial construction costs. An economic analysis of the tradeoffs is performed with varying degrees of effort and thoroughness. Risk analysis balances the drainage system cost with the damages associated with inadequate performance. With concrete pipe, there is no risk. With its long service life and hydraulic efficiency, concrete pipe handles the requirements of a system's hydraulic design.

Two basic values are often cited when discussing the coefficient of roughness of a pipe; laboratory test values and design values. The difference between laboratory test values of Manning's '*n*' and accepted design values is significant. Manning's "*n*" values were obtained using clean water, smooth joints, no loads, and straight pipe lengths without bends, manholes, debris, or other obstructions. The laboratory results indicate only the differences between smooth wall and rough wall pipes. Rough wall, such as unlined corrugated metal pipe have relatively high "*n*" values, which are approximately 2.5 to 3 times those of smooth wall pipe.

Smooth wall pipes were found to have "n" values ranging between 0.009 and 0.010, but historically, engineers familiar with concrete pipe and sewers have used 0.012 or 0.013. This design factor of 20 to 30 percent takes into account the differences between laboratory testing and actual installed conditions of various sizes as well as allowing for a factor of safety. The use of such design factors is good engineering practice, and to be consistent for all pipe materials, the applicable Manning's '*n*" laboratory value should be increased a similar amount to arrive at comparative design values.

Research has concluded that designs using concrete pipe can be downsized by at least one size in most cases when compared to steel, aluminum, and lined corrugated HDPE pipe. For design engineers and owners to select the proper drainage pipe for a specific culvert or sewer application, it is critically important that the applied Manning's "*n*" values are design values rather than laboratory values

Using design values, concrete pipe has superior hydraulic characteristics, and engineers understand and posses proper verification of concrete pipe hydraulics.

Grade and alignment are as important as barrel surface characteristics. In addition, inlet and outlet controls impact the hydraulics of a drainage system. The flow of water the pipe is throttled or limited by the inlet of the pipe. The inlet may have a headwall, flared end, or protruding pipe. This condition exists in most all cross drains, and typical in subdivisions and county roadway crossings. Outlet control occurs when the flow of water through the pipe is controlled by the conditions at the outlet end of the pipe. Outlet control usually does not exist unless the outlet end of the pipe is under water or if the orifice has been damaged and restricted. The outlets of flexible pipe are easily damaged, thereby affecting the hydraulics of the pipeline.

Quality Control and Testing of Concrete Pipe

Batching and mixing operations in the industry's premier plants have been upgraded over the past 10 years. Characteristics of this operation of the pipe production process normally include:

- Computer controlled weighing and proportioning systems
- Computer controlled mixing systems
- Automated recording systems
- Absorption testing

The American Concrete Pipe Association offers an on-going quality assurance program called the "Quality Cast" Plant Certification Program.

This 124-point audit-inspection program covers the inspection of materials, finished products and handling/storage procedures, as well as performance testing and quality control documentation. Plants are certified to provide storm sewer and culvert pipe or under a combined sanitary sewer, storm sewer, and culvert pipe program.

Sustainability

Historically, concrete is the most durable and sustainable material for infrastructure and major construction. It continues to function long after a projects life is reached, by maintaining structural integrity, thus reducing the costs associated with repair and replacement.

Precast concrete pipe's staying power has another benefit; it's not a passing fad. When concrete pipe is specified, the projects you build today are more likely to be compatible with any future expansions or alterations.

Environmentally Friendly

Precast concrete drainage products have a reputation for strength and durability. They will not burn, corrode prematurely, deflect or move off grade to reduce hydraulic performance, or collapse under loads designed into the pipe structure. Comprised of the world's most commonly used building materials, precast concrete infrastructure is quickly integrated into ecosystems. This is clearly demonstrated by the use of three-sided precast boxes used to accommodate the natural channels of streams at road crossings, and precast concrete pipe for storm sewers and outfalls in valleys and shorelines.

Today, being recognized as a green material or product is growing in importance to many specifiers. Concrete pipe is suitable for LEED projects and it fits sustainable development.

Unlike plastic pipe, concrete is produced with benign, natural materials. Manufacturing of concrete consumes less energy than plastic fabrication. It's also recyclable and has little if any environmental impact. And, when you use local resources, concrete can also provide lower fuel cost for delivery.

Pipelines, and in particular culverts, are often used in temporary applications to facilitate drainage during construction. While designers often try to minimize the cost of these facilities, one of the overlooked components is the salvage value of the pipe. Salvage value of pipe is closely related to its inherent strength and ability to survive the abuse of installation and removal.

The rigid nature of concrete pipe makes it ideal for removal and replacement. In terms of life cycle costs, it is prudent to account for the salvage value of the pipe when planning a temporary line for drainage.

The benefit of salvaging concrete pipe does not stop on the construction site. There are projects where concrete pipe has been excavated in industrial areas after decades of use, cleaned and re-installed to continue performing as storm sewer pipe. The pipe was examined in laboratories and tested. It was found to be stronger that originally tested, since concrete gets stronger over time.