CHAPTER 3: CORROSION, SOLVENT-BASED CHEMICALS, ABRASION & HIGH TEMPERATURE APPLICATIONS IN SANITARY SEWERS

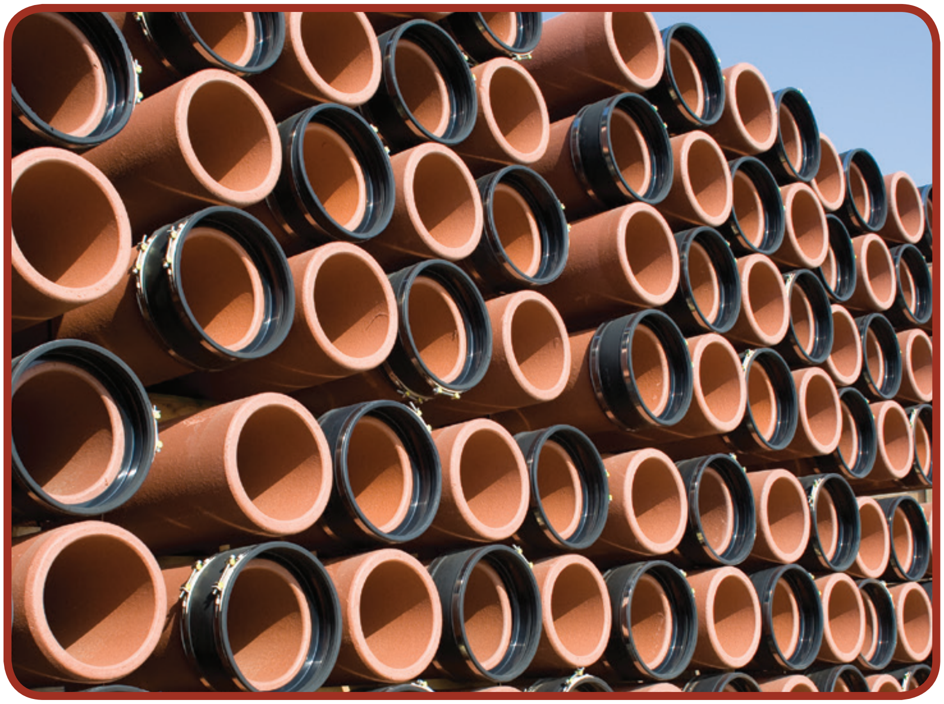

Figure 3-1: Both bell and spigot pipe and plain-end pipe joined with rubber compression couplings (seen here) have demonstrated a superior resistance to all chemicals commonly found in sewers.

Corrosion – Vitrified Clay Pipe is Chemically Inert

Vitrified Clay Pipe is not vulnerable to damage due to domestic sewage, order control chemicals, sulfide attack, most industrial wastes and solvents or aggressive soils. The only known chemicals that may damage clay pipe are Hydrofluoric Acid (used in glass etching) and Caustic Soda at temperatures exceeding 200°F. Vitrified Clay Pipe is the most chemically resistant pipe material available and the only one to have a proven life span in excess of 100 years.

Hydrogen Sulfide

The relationship between the chemistry of sewage to the pipe materials conveying it is of primary concern in the design of sanitary sewer systems. A brief outline of the factors involved in the ever-present generation of hydrogen sulfide gas is provided to point out the variety of conditions, which can exist and must therefore be anticipated in sanitary sewers. The protection of the sewer system from the ravages of sewer gas attack is of fundamental importance in designing and providing permanent, trouble-free lines. Failure to fully and properly evaluate any of the contributing factors may lead to subsequent failure of the sewer line.

Factors contributing to sulfide generation and evolution are:

1. Temperature of sewage
2. Strength of sewage
3. Velocity of flow
4. Age of sewage
5. pH of sewage
6. Sulfate concentration

Sulfides are generated in the slime layer which forms between the sewer pipe and the flowing sewage. The sulfides form hydrogen sulfide gas which first diffuses into the sewage and then, unless destroyed or neutralized, escapes into the sewer atmosphere.

The sulfuric acid collects on the exposed arch of the pipe and begins a chemical attack unless the pipe material is chemically inert and invulnerable to corrosive acid action. See Figure 3-2 showing the results of chemical attack on an exposed arch in a sanitary environment on a pipe susceptible to corrosion.

Figure 3-2: *Concrete pipe degraded over years in the corrosive environment of a sanitary sewer.*

High velocity may also be damaging if any hydrogen sulfide is present in a stream of sewage. The rate of sulfide release increases with increased flow rate. Turbulence, due to junctions, changes of pipe size, drops, etc. will cause a relatively rapid release of hydrogen sulfide gas. One of the major causes for the increasing sulfide damage in modern sewer systems is the dumping of vast quantities of organic matter from household garbage disposals. This condition increases deposits in sewer lines, thus retarding the flow and providing a source of increased sulfide generation. It also substantially increases the Biochemical Oxygen Demand (BOD) which increases the difficulty of meeting the oxygen required to limit sulfide build-up.

Force mains are a cause of sulfide problems in sewers, particularly if the sewage is retained for any appreciable length of time. High sulfide concentrations will not damage the interior of the filled pipe, but may cause odor nuisances and damage to downstream structures.

When corrodible pipe materials are attacked by sulfuric acid, disintegration begins on the upper surface of the pipe leaving a soft residue. Sometimes the soft or pasty material is washed away by high water exposing new surfaces to corrosive attack. Even when this does not occur, acid formed at the exposed surface continues to diffuse through this residue and attacks the underlying pipe material. When the pipe is too weak to support the earth load, it collapses and the sewer becomes inoperable.

Acid Resistance

Vitrified Clay Pipe is commonly tested with 1 N solutions of sulfuric (H2SO4), hydrochloric (HCl), nitric (HNO3), or acetic (CH3COOH) acids and allowed zero weight loss. Test procedures to determine the acid resistant qualities and other properties of vitrified clay pipe are outlined in ASTM C301 *Standard Test Methods for Vitrified Clay Pipe.*

Aggressive Soils and Other Hostile Environments

Some sanitary sewers are subject to constant attack by a multitude of wastes from industry, homes and businesses. Ordinary domestic sewage includes detergents, drain cleaners, scouring powders, bleaches and other household chemicals. From business and industry come other and more aggressive chemicals, solvents, acids and alkalis.

Sanitary sewer pipe may also be subject to corrosion from acidic or alkaline soils, electrolytic decomposition attack and temperature induced damage. Different pipe materials display various levels of resistance to these factors. Cement bonded and metallic pipe materials normally require special protection.

Temperature and solvent sensitive plastic materials should be avoided where the potential exists for these factors to occur.

Former industrial sites, commonly referred to as brownfields, are another area where soil conditions have a high potential for contaminants that may corrode or damage non-clay pipe materials.

Preliminary soils and site investigation should be required if conditions in the area selected for installation are unknown or suspected to cause damage to candidate materials.

Abrasion

Ceramics are among the most abrasion-resistant materials known. As a ceramic, VCP is the most abrasion-resistant commonly-used sanitary sewer pipe material. This abrasion resistance has always been an important material property of VCP, but it has become essential as modern cleaning methods intensify the concern. For more on the impact of these methods, see Chapter 12: Operations & Maintenance.

Various 8-in sewer pipe were tested for abrasion resistance. The test accelerated normal abrasion rates. Based on test results, the pipes were ranked in order of highest resistance to abrasion as shown in Table 3-1.

Figure 3-3: NCPI accelerated abrasion testing of various 8-inch pipe materials.

The test results were obtained by rotating pipe sections at 2.5 feet per second for 500 hours. The abrasive charge consisted of 7 pounds #67 crushed stone and 6.6 pounds of water which was changed every 48 hours.

Pipe (All 8-in Diameter)	Wall Thickness Δ (Inches)	Abraded Percent
Vitrified Clay	.003	0.3
Certain-Teed (PVC)	.027	10.5
Carlon Prime (PVC)	.043	19.4
Corrugated (PVC)	.048	100.0[a]
PVC Truss	.059	100.0[a]
ABS Truss	.067	100.0[a]
a - 100% indicates complete abrasion through the pipe body or in the case of Truss pipe through the inner pipe wall.		

Table 3-1: Abrasion test results

Pipe	Pipe Stiffness Test (ASTM D 2412)		
	Min. Req.	After Abrasion	% Decrease
Carlon Prime (ASTM F 789)	46 psi	19.2 psi	58.3%
Certain-Teed (ASTM D 3034)	46 psi	32.1 psi	30.2%
ABS Truss (ASTM D 2680)	200 psi	143.5 psi	28.3%
PVC Truss (ASTM D 2680)	200 psi	152.6 psi	23.7%
A-2000[b]	46 psi	28.6 psi	37.8%
[b] – *Manufacturers' Requirement*			

Table 3-2: Post abrasion testing, pipe stiffness test results

Following the abrasion test, 6-inch sections were cut from each of the plastic pipe. A standard 5% pipe stiffness test was run. The vitrified clay was subjected to a three-edge bearing test Results for the thermoplastic pipe and the vitrified clay are listed in Tables 3-2 and 3-3.

Pipe	ASTM C700 Standard	Actual Bearing Strength After Abrasion	Over ASTM Standard
Vitrified Clay	2,200 lbs /ft.	4,067 lbs /ft.	84.9%

Table 3-3: *Post abrasion testing, three-edge bearing test results*

Abrasion Testing Summary

1. Vitrified clay pipe demonstrated superior abrasion resistant qualities compared to the plastic pipe tested.
2. The most abrasion resistant plastic pipe abraded at a rate which was nine times greater than vitrified clay.
3. Three of the four plastic pipe made of PVC abraded at essentially the same rate whereas the Carlon Prime PVC pipe abraded at a markedly faster rate. The Carlon Prime pipe abraded at a rate nearly 40% faster than the next highest PVC pipe. The Carlon PVC tested contained a substantial amount of filler.
4. All of the plastic pipe demonstrated a substantial decrease in pipe stiffness following abrasion.
5. The loss of plastic pipe stiffness due to abrasion may affect its long-term load supporting capability.
6. All non-solid wall plastic pipe consisting of thin inner and outer walls experienced total abrasion of the inner wall within the 500 hour test time.
7. The bearing strength of vitrified clay pipe after abrasion greatly exceeded the ASTM minimum requirement of 2,200 lbs per linear foot.

This abrasion test is not intended to duplicate actual field conditions or to predict longevity. It does determine the relative abrasion resistance qualities of each product tested.

Most of the plastic pipe tested have established maximum velocity limits. Vitrified clay should be used where high velocity or water borne abrasive particulate are anticipated.

Solvent Based Chemical Applications

In industrial areas, resistance to solvent-based chemicals can be critical to the long-term performance of the pipe. Certain commonly used pipe materials are susceptible to attack from various chemicals. VCP is resistant to attack from any chemicals legally found in sewers today.

The elastomeric coupling gasket jointing materials have proven to perform well for the vast majority of sanitary sewer applications. However, there are rare occasions where exposure to solvent based chemicals as well as strong oxidizing mineral and organic acids may require the use of elastomeric materials resistant to the anticipated chemicals or other non-elastomeric jointing systems such as specialty mortars.

High Temperature Applications

Vitrified Clay Pipe can withstand extreme temperatures. However, a rapid change of temperature produces thermal gradients in the pipe wall which may damage the pipe. This is commonly referred to as thermal shock. Proper system design should consider, at least, the following factors: temperature of the effluent, rate and depth of flow, wall thickness of the pipe, temperature of the pipe, temperature of the soil, and the volume of the effluent. The number of variables makes it difficult to predict behavior of the pipe under all conditions. The polyester, polyurethane and rubber gasket jointing materials have shown good high-temperature resistance for short time periods. However, long term exposure to high temperatures is likely to affect the sealing capability of these materials. Other jointing systems such as mortars and high temperature couplings are available and will perform better over the long-term for these applications. Pipe and Joint samples may be evaluated for suitability for this application.

With thermoplastic materials, the more times they are heated, the more the physical properties change. Subsequent heat cycles can break the chemical bonds within the polymer chains, changing the physical properties of the pipe.