Comparative Properties and Service Life of Pipes Used as Sanitary Sewers

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Sanitary sewers carry corrosive effluents which result in the additional generation of a corrosive atmosphere within the pipe. Hydrogen sulfide generation and condensation on the pipe wall results formation of sulfuric acid. Industrial waste and chemicals adds indeterminate additional corrosive potential to the natural corrosive sanitary sewerage. Furthermore as water becomes more precious and valuable, the concentrations of the effluent will rise and the historical performance expectations of many pipe materials will be challenged by the higher chemical concentrations. Stresses from external loading and resulting deflection of some materials accelerated the effects of corrosion. Some pipe materials are even deleteriously affected by the presence of water.

Installation of vitrified clay pipes by traditional open cut have a long success in the United States and around the world. It is specified as a required product in four of the seven largest U.S. cities. Confidence from experience and the recognition of the material properties are the leading reasons for continued specification.

The types of pipes can be classified as rigid or flexible. Rigid pipes installation design is based upon adequate pipe strength to support trench loads from backfill above the top of the pipe. Trench loads are increased with increased trench width. Bedding selection can add strength to the combined bedding/ppe system requiring proper selection.

Flexible pipes transfer trench loads to the soil/bedding around the pipe and require good side support to prevent collapse. Flexible pipes installations require careful installation to ensure the shape of the pipe, measured as deflection from a true circle, is maintained within specific limits. Initial deflection limit recommendations by the manufacturers are in some types is a maximum of three percent. Excessive deflections add additional stress to the flexible pipes, result in reduction of corrosion resistance and premature failure.

Inherent differences between rigid and flexible pipes illustrate long term life expectancies. Corrosion effects accelerate when flexible pipes are stressed, reducing life expectancy.

Jointing may be factory designed joints or field installed joints. Field joints require additional scrutiny and inspection in the field to ensure properly made joints.

There have been many pipes introduced over the years that are no longer available due to poor performance. Poor longevity has frequently been the demise of pipes.

Materials used for sewer pipes have other varying advantages and disadvantage. The owner and the installer may have differing perspectives and criteria for selection of pipes. For instance pipe longevity is essential for an owner to amortize long term return on investment and to build residual asset value. An installer is primarily concerned of installation cost over the short term. The installer and owner may often result in the same selection of ideal material but sometimes the selections would not be equal. The owner has the burden for selecting long term performance, financial responsibility and building residual wealth from assets that long exceed amortization requirements of financing.

It is essential for the designer and owner to understand the selection of pipes for ease of installation, maintenance costs and long term life. It is of major economic significance. The selection process is more complicated than in the past. New materials are developed or used in new ways to make pipes. In many cases numerous classifications of cell structure must be understood and specified to achieve expected performance. Various resins can be specified and must be understood. In some cases the materials can be coatings or relatively thin layers that rely on adherence to the main pipe body to reach expected performance. There is no definitive data base that can be accessed to aid in the selection of pipes. The selection process is less a calculation than a subjective judgment. The provided references are provided to give basis to the material selection process as related to life expectancy.

Impact to the public when pipes are installed in new or less developed areas in preparation for future growth and expansion are often low. Utilities are expensive to install and repair, but even more so after growth has occurred. A street that may have been moderately traveled grows to be an essential corridor. Replacement/repair at a later date can still be accomplished, but at a higher impact to the public/social cost than during the original construction and/or with techniques that are less disruptive but more expensive. The desire for less impact to the public is translated through public expression and even voter dissatisfaction.

The best solution to minimize cost and impact to the public in the future is to specify materials that have a high likelihood of long term life. Longevity has become a larger driver in pipe selection. Installations that use designs and require materials that have long term cost advantages should be selected. The oft repeated adage, “If you can’t afford to do it correctly the first time, can you afford to do it twice?”comes to mind.

The following table is generated from assembly of information in manufacturing standards, papers and manufacturer’s product literature:

Sewer Pipe Material for Microtunneling	Strength of Pipe Material at 50 yrs	Initial Internal Corrosion resistance	Initial External Corrosion resistance	Design Basis	Typical Seal Pressure Rating	Longevity, Greater than 100 Years
GRP, glass fibers, sand, polyester	50% of initial, loss of cross linking naturally occurs – accelerated by stress and corrosion elements. Water damage.[1 2 3]	Good, 1 pH – 10 pH (based upon 1.15 yr. extrapolation at 22 deg C. deteriorates with temperature increase	Good, 1 pH – 10 pH (based upon 1.15 yr. extrapolation at 22 deg C. deteriorates with temperature increase[4]	Flexible	>2bar	Poor, extrapolated from 50% strength deterioration at 50 years, corrosion acceleration with stress and molecule linking failures with age.[5 6]
GRP, glass fibers, sand, polyester, vinyl ester interior coating	50% of initial, loss of cross linking naturally occurs – accelerated by stress and corrosion elements.[1 2 3]	Very good, 1 pH – 10 pH (based upon 1.15 yr. extrapolation at 22 deg C. deteriorates with temperature increase	Very Good, 1 pH – 10 pH (based upon 1.15 yr. extrapolation at 22 deg C. deteriorates with temperature increase	Flexible	>2 bar	Poor, extrapolated from 50% strength deterioration at 50 years, corrosion acceleration with stress and molecule linking failures with age.[5 6]

HDPE, high density polyethylene	70% to 80% loss of strength [3]	Very good, subject to deterioration in chemicals or high temperature see reference for list of compatibility [7]	Very good, subject to deterioration in contaminated soils including benzene or high temperature, see list of compatibility [9]	Flexible	Fused or push joints varying pressure ratings	Poor, extrapolated from 70% to 80% strength deterioration at 50 years, corrosion acceleration from stress and molecule linking failure with age. [8, 6]
PVC, polyvinyl chloride	65% to 80% loss of strength [3]	Very good, subject to deterioration in chemicals or high temperature see reference for list of compatibility [9]	Very good, subject to deterioration in contaminated soils including benzene or high temperature, see list of compatibility [9]	Flexible	> 1 bar	Poor, extrapolated from 65% to 80% strength deterioration at 50 years, corrosion acceleration from stress and molecule linking failure with age. [6, 10]
Polymer Concrete, graded sand and gravel, polyester	50% of initial, loss of cross linking naturally occurs – accelerated by stress and corrosion elements. [1, 2, 3, 11]	Good, 1 pH – 10 pH (based upon 1.15 yr. extrapolation at 22 deg C. deteriorates with temperature increase [11]	Good, 1 pH – 10 pH (based upon 1.15 yr. extrapolation at 22 deg C. deteriorates with temperature increase	Rigid	>2 bar	Poor, extrapolated from 50% strength deterioration at 50 years, corrosion acceleration with stress and molecule linking failures with age. [5, 12]
Reinforced Concrete, sand, aggregates and cement	100%, less corrosion of concrete & rebar	Poor, in corrosive conditions [13, 14, 15]	Poor, in corrosive conditions [15]	Rigid	>1 bar	Poor, in applications with internal or external corrosion environment [13]
Reinforced Concrete with Plastic Liner, concrete, sand, aggregates and cement with a cast plastic liner	100%, less corrosion of concrete & rebar	Moderate, liners have shown short and moderate life <50 years. [16]	Poor, in corrosive conditions [15, 17]	Rigid	>1 bar	Poor, in applications with internal or external corrosion environment
Steel, when used as carrier pipe	100% where there are no corrosion effects	Very poor	Very poor	Flexible	Welded	Poor, if corrosion possible Good, if no corrosion present [17]
Vitrified Clay, high temperature fired structural ceramic	100% [18, 19, 20]	Excellent, ph 0 to pH 14 [19]	Excellent, 0 pH to 14 pH [19]	Rigid	>> 2bar 10 psi, >17 psi depending upon manufacturer and joint type [21, 22, 23]	Excellent, demonstrated long life [24]

Conclusion:

The considered selection of pipe materials is an essential element in project design and development of specifications. Pipe selection is essential to long life cycle installations that build asset value and provide economical service.

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Figure H 211.41 A - Long Term (50 year) Tensile Strength & Modulus of Elasticity of Structural Plastics for Piping

RESIN/BRAND	INTENDED USE	CELL CLASSIF.	F_t INITIAL TENS. STR.	CREEP RED. FACT.	F_t 50-YEAR STRENGTH	E_S, INITIAL MODULUS	CREEP RED. FACT.	E, 50-YEAR MODULUS
EPOXY (Shell Epon 9215/ Insituform)	Sewer/Storm Dr.	NA	4,000(27.6)	75%*	1,000(6.9)*	300,000(2068)	75%*	75,000F(517)*
EPOXY VINYLESTER (Dow Derakane 411/ Inliner)	Sewer/Storm Dr.	NA	4,000(27.6)	50%	2,000(13.8)	300,000(2068)	50%	150,000F(1034)F
EPOXY VINYLESTER (******Chemtron B9220/Generic*)	Sewer/Storm Dr.	NA	0	0	0	0	0	0
HDPE	Storm Drain Only	335434C	3,000(20.7)	52%	1,440(9.9)	110,000(758)	80%	22,000(152)T
HDPE	Storm Drain Only	315412C	3,000(20.7)	70%	900(6.2)	110,000(758)	80%	22,000(152)T
HDPE	Storm Drain Only	334433C	3,000(20.7)	62.5%	1,125(7.8)	80,000(552)	75%	20,000(138)T
HDPE (Driscopipe, Plexco & Spirolite)	Sewer/Storm Dr.	345434C	3,200(22.1)	70%	960(6.6)	120,000(827)	70%	36,000(248)T
HDPE (******Nova HD-2007H/U-Liner*)	Sewer/Storm Dr.	345434D	3,100(21.4)	70%	885(6.1)	90,000(621)	70%	27,000(186)T
POLYESTER (Hobas)	Sewer/Storm Dr.	NA	2,500(17.2)	65%	490(3.4)	1,000,000(6895)	65%	350,000(2413)F
POLYESTER (******Chemtron B-3005/ Insituform*)	Storm Drain Only	NA	3,000(20.7)	80%*	600(4.1)*	250,000(1723)	80%*	50,000(345)*
POLYESTER (******Polycrete*)	Sewer/Storm Dr.	NA	NA	75%*	NA	NA	75%*	NA
PVC (AmLiner)	Sewer/Storm Dr.	12111C	3,500(24.1)	80%*	700(4.8)*	155,000(1069)	80%*	31,000T(214)*
PVC (Contech or PW - DIRECT BURIAL)	Sewer/Storm Dr.	12454C	7,000(48.3)	47%	3,700(25.5)	400,000(2758)	65%	140,000(963)T
PVC (Danby & ******PVC-500*)	Sewer/Storm Dr.	13354B	6,000(41.4)	80%*	1,200(8.3)*	400,000(2758)	80%*	80,000(552)*
PVC (Danby Wound)	Sewer/Storm Dr.	12344C	6,000(41.4)	80%*	1,200(8.3)*	360,000(2482)	80%*	72,000(497)*
PVC (******EX Pipe*)	Sewer/Storm Dr.	12334B	6,000(41.4)	80%*	1,200(8.3)	340,000(2344)	80%*	68,000(462)*
PVC (NuPipe)	Sewer/Storm Dr.	13223B	5,000(34.5)	80%*	1,000(6.9)*	280,000(1931)	80%*	56,000(386)*
PVC (******RibLoc*)	Sewer/Storm Dr.	13454C	7,000(48.3)	80%*	1,400(9.7)*	400,000(2758)	80%*	80,000T(552)*
PVC (******Ultraliner*)	Sewer/Storm Dr.	16223B	6,000(41.4)	80%*	1,200(8.3)*	280,000(1931)	80%*	56,000(386)*
PVC (******Uponor- DIRECT BURIAL*)	Sewer/Storm Dr.	12454B	0	0	0	0	0	0
PVC (Vylon)	Sewer/Storm Dr.	12364B	6,000(41.4)	57%	2,600(17.9)	440,000(3034)	64%	158,400(1092)T
VINYLESTER (******Interplastic VE8319/ Insituform*)	Sewer/Storm Dr.	NA	4,000(27.6)	75%*	1,000(6.9)*	250,000(1723)	75%*	62,500(431)*
HDPE (ULiner - Discontinued 1998)	Sewer/Storm Dr.	345434C	3,200(22.1)	70%	960(6.6)	120,000(827)	70%	36,000(248)T
PVC (Danby - Discontinued 1995)	Sewer/Storm Dr.	12454C	7,000(48.3)	47%	3,700(25.5)	400,000(2758)	65%	140,000(963)T
PVC (NuPipe - Discontinued 1996)	Sewer/Storm Dr.	12344B	6,000(41.4)	80%*	1,200(8.3)*	360,000(2482)	80%*	72,000(496)*

Legend:

E : Long Term (50-year) Elastic Modulus [psi/ (MPa)]
F: Flexural Modulus; T: Tensile Modulus

E_S : Initial Elastic Modulus [psi/(MPa)]

F_t : Tensile Strength [psi/(MPa)]

NA : Not applicable

*****: Trial Demonstration Product - Restricted Use

Notes:

1. (*) If this value is inadequately justified by the manufacturer, the arbitrary creep correction factor will be at least 75% for thermosetting resins and 80% for PVC. Many materials are unsuitable for long-term, load-carrying use and will require concrete encasement (Standard Plan S-251 Case 5).
2. This figure is periodically updated by the Engineer of Design.