STRUCTURED WALL HDPE PIPE COMPARISON TO OTHER PIPE MATERIALS

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FLEXIBLE PIPE VS. RIGID PIPE (GENERAL)

Rigid pipes

"Rigid pipes" are sufficiently strong (both within the pipe wall and joints) to withstand most anticipated live and dead loads. A pipe's ability to resist imposed loads is improved by "better" embedment conditions.

Flexible pipes

"Flexible pipes" rely on the deformation of the pipe from imposed loads to mobilise the support of embedment materials on both sides of the pipe. Their primary structural function is distributing the imposed vertical loads to the surrounding soil. Some standards define a flexible pipe as one that can deflect more than 2% without cracking.

Only a small portion of imposed loads are actually carried by the flexible pipe itself. Instead, load is transferred to the surrounding bedding material. A pipe system's load carrying capacity increases significantly with an increase in the stiffness of embedment materials.

Evaluating pipe performance

If all design factors are well understood, a suitable piping system can be created using either "rigid" or "flexible" pipe design methodology. Both methods are supported by academic review and industry standards (SABS, ISO, EN, CEN, SFS) for pipe testing, qualification, and installation. However, design factors and assumptions are often not well known, incorrect, or they may change over time.

Let's examine a few scenarios:

Inadequate/improper bedding and backfill

A rigid piping system's carrying capacity is the total load that can be supported by the pipe itself. For concrete pipe, this is determined by a three-edge bearing test multiplied by a bedding factor (between 1.5 and 4.42). Bedding factors between 1.5 and 2.3 apply to the four standard installation types in a trench application.

When the bedding is improperly installed, and the backfill is not properly compacted, the pipe's strength will initially support the imposed dead and live loads.

The trench walls will support the weight of the backfill (Marston effect). But any theoretical increase in pipe strength resulting from a properly bedded and backfilled installation is compromised. Over time, the pipe will experience more and more of the trench load. Eventually, the pipe's capacity will be exceeded and it may fail. Cracks exceeding the design limits will develop and the pipe's steel reinforcement will be exposed to its internal medium. In sanitary sewer and industrial applications, this may be corrosive to the reinforcing steel. This failure is most likely to occur well after the installation period, when the system is not being monitored as carefully as it is during construction. (Flexible pipes confirm the quality of installation).

Flexible pipe, on the other hand, relies on initial bedding, which conforms to the project's standard requirements. For most sewer applications, this would be well-graded, granular materials that are appropriately compacted.

Limiting pipe deflection is the main factor in the design of a flexible piping system. Even when it isn't, the expected pipe deflection is calculated. This anticipated deflection increases substantially when the project-specified bedding is not provided. Monitoring pipe deflection during the construction process will effectively ensure compliance with project requirements. Installation problems are readily apparent and can be corrected before the pipe is put into service.

Unstable trench bottom

If localised loads exceed the rigid pipe's structural limit, wall failures (cracking) may occur. Either infiltration or ex-filtration will result (flow direction will be from the higher to lower pressure area). If cracking continues, the rigid pipe may collapse.

By contrast, flexible (especially plastic) pipes will deform when the trench bottom is unstable. As such, joint area movement is minimised, reducing occurrences of seal loss. Generally, flexible pipes come in longer lengths than rigid pipes, so there are fewer joints "at risk". Plus, fused or welded HDPE pipe systems are jointless and are therefore not subject to this problem.

Structure and scope

Concrete pipe is formed by encasing reinforcing steel inside a concrete pipe wall. The steel can be optimally located to provide resistance to the anticipated loads. The concrete is produced from different source materials to take advantage of local conditions and/or to obtain the desirable strength or chemical resistance properties.

This product can be designed to limit small crack formation in tensile sections of the pipe to less than 0.3 mm. The 0.3 mm crack classifications are 25-D, 50-D, 75-D, or 100-D. alternatively, concrete pipe can be designed to support an ultimate anticipated load, with appropriate factors of safety. The D load classifications using this method are 60, 75, 100, 150, and 175. The specifications covering this design are SANS 676 and SANS 677.

Fabricating the pipe with a profile allows for desirable stiffness properties at overall weights that are > 40% less than solid-wall HDPE pipe. The structured wall HDPE pipe typically weighs less than 10% of an equivalent concrete pipe. The pipe's structural capacity is classified in accordance with SANS 21138. The Ring Stiffness Constant (RSC) rating for the pipe is an empirical measurement of its load carrying capacity.

Joining systems

Concrete pipe joints are gasketed bell and spigot connections. The pipes are supplied in 2.44 m lengths, to limit the weight of large diameter individual pipe sections. The structured wall HDPE pipe is also available with bell and gasket connections (in sizes up to 800 mm in 12 mm lengths). However, a welded (fused) connection may also be performed for all structured wall HDPE pipes in sewer (storm or sanitary) applications.

Chemical resistance

Generally, concrete is more chemically resistant than carbon steel pipe, but much less so than HDPE. Concrete is vulnerable to hydrogen sulphide, which forms when solids in sanitary wastewater are unable to stay in suspension. This often occurs in collector sanitary sewers during periods of low flow.

Concrete pipe gaskets conform to the requirements of the relevant standards. Gaskets for structured wall HDPE pipes conform to the requirements of EN 681-1. Both piping systems can offer gaskets in a variety of materials. Generally, gaskets are more vulnerable than the pipe material to chemical attack. This is a significant concern for concrete pipe systems, which have a gasket every 2.44 m.

Extrusion welded structured wall HDPE pipe systems are not subject to gasket degradation. HDPE has excellent chemical resistance to most industrial and domestic wastes. With the exception of exposure to apolar solvents (such as some alcohols, halogens and aromatics), the chemical resistance of HDPE is superior to concrete.

Abrasion comparison

Abrasion resistance is a material's ability to withstand mechanical erosion. Pipes used in sanitary, storm water sewer and culvert applications require significant abrasion resistance, since grit and suspended solids continuously impact on the pipe wall. As flow velocity increases, so does abrasion.

The abrasion resistance of concrete pipe may be adversely affected by corrosion. As such, the specific application must be evaluated. Plastic pipe is highly resistant to abrasion. This is because its molecular composition creates a "trampoline" response when impacted by tumbling aggregate (such as grit and solids).

HDPE is three to five times more abrasion resistant than concrete pipe when tested in a Darmstadt abrasion test. In fact, HDPE often ranks first in wear resistance among pipe materials. Dr Louis Gabriel conducted a widely recognised comparison of abrasion resistance in 1990 at California State University.

TABLE 1

	Concrete	Structured Wall HDPE Pipe
Standards (USA)	ASTM C507M	SANS/ISO 21138/EN 13476 - 1
Standards (Canada)	CSA A257. ½	CSA B182.6
Size	110 mm - 900 mm non reinforced	280 mm - 3 500 mm
Size	300 mm - 3 600 mm reinforced	
Structural type	Walls A, B, C	Smooth inner and outer
Unit length/weight	2.44 m/5.3 t	12 m/2.1 t
Burial design method	Rigid	Flexible
Shape	Circular, Elliptical	Circular
Installation	ASTM C1479-01	ASTM D2321/SABS 1 200 Flexible bedding/class C bedding for rigid pipes/ ENV 1 046
Manning's n	0.013	0.01

STRUCTURED WALL HDPE PIPE VS. CONCRETE

Hydraulic comparison

Manning's "n" value for new concrete pipe is 0.010 – 0.009. The concrete pipe industry promotes the use of 0.012 – 0.013 as appropriate long-term values. This 20-30% difference accounts for a long-term deterioration in "n" value due to corrosion and abrasion.

The reduction in flow capacity is anticipated, particularly in hostile environments. Manning's tested "n" value for the structured wall HDPE pipe is between 0.0097 and 0.0092. For pipe exceeding 900 mm ID, this will approach the 0.09 value associated with solid wall HDPE pipe.

A design value of 0.010 is recommended to provide for limited deterioration while recognising the structured wall HDPE pipe's excellent corrosion and abrasion resistance. Still, even by conservative estimates, the structured wall HDPE pipe's flow capacity in a gravity sewer application is 30% greater than comparably sized concrete pipe.

Installation

According to ASTM C1479-01 ("Standard Practice for the Installation of Pre-cast Concrete Sewer, Storm Drain and Culvert Pipe Using Standard Installations"), the clearance between pipe and trench wall must sufficiently allow for the specified compaction. In any case, it must be at least 1/6th of the pipe's outside diameter (OD). ASTM D2321, ("Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity Flow Applications"), on the other hand, specifies a trench width wider than the compaction equipment required plus a minimum clearance of "8 inches" or "1/2 of the pipe's OD times 1.25 plus 6 inches". However, most user specifications, such as the OPS8, require a minimum side clearance of 300 mm — regardless of pipe material. Practically then, there's no difference in trench widths for bedding and initial backfill requirements between concrete and structured wall HDPE pipes. However, standards require that the initial backfill for concrete pipe must extend to the pipe spring-line, while the initial backfill for plastic pipe should extend to a minimum of 150 mm over the top of the pipe. The initial backfill is the zone that must be compacted to achieve the pipe's bedding support.

Where trench settlement isn't a concern, some minor additional effort is needed to meet the initial backfill requirements for structured wall HDPE and other plastic pipes. However, most trench applications in roadway cuts require careful selection and compaction of the trench backfill materials anyway, so there is no additional effort (or cost) involved.

Service life and cost

The popular concrete design software, "PipePac 2000," compares the life-cycle costs between concrete and HDPE (generally presumed to be circular corrugated polyethylene pipe). The software presumes a service life of 100 years for concrete pipe in all storm sewer, sanitary sewer and culvert applications. It presumes a service life value of 70 years for HDPE pipe, despite the material's superior hydraulic, corrosion resistant and abrasion resistant properties.

Concrete pipe failures (due to corrosion or abrasion) often result in a reduced service life. Joint degradation or failure may determine the effective useful life of a pipe system. A welded structured wall HDPE pipe has no joints. In general, its service life will be at least 50% greater than concrete. In corrosive applications, it will be double. Although service life for both pipe materials must be carefully evaluated, concrete should never exceed the service life of a structured wall HDPE pipe.

A fair cost comparison between the two materials will show similar capital costs, where the nominal pipe size is the same. However, in many applications, smaller structured wall HDPE pipes will be used because of its superior Manning's n value. Installation costs will vary. In areas where the trench can be open cut and where longer lengths of pipe can be used, its installation costs should be lower.

STRUCTURED WALL HDPE PIPE VS. CMP (CORRUGATED METAL PIPE)

CMP pipe structure

Corrugated metal pipe comes in a wide range of sizes, corrugation profiles, metal gauges, joint assemblies, and coatings. As a circular pipe, it's available in sizes up to 3 600 mm diameter. When CMP is supplied as structural plate components, spans over 6 m can be accommodated. It is also available in a variety of pipe arch shapes.

Joining systems

CMP joining systems generally feature a coupler with or without a gasket. For most drainage or culvert applications, only a mechanical connection is provided. In situations that require increased soil or water tightness, gaskets (O-rings, sleeve or strip gaskets made from butyl rubber, neoprene or other elastomeric material with or without a mastic surface) are provided.

Chemical resistance comparison

Chemical resistance is the factor most limiting steels use, since unprotected steel will oxidize (rust). The oxidized coating generally has a smaller volume than the base metal and will crack, leaving the base metal unprotected. Unless special protection is provided, oxidization will continue.

Hence, the manufacturer provides various protective coatings.

These coatings range in thickness from 0.05 mm to 0.254 mm. Their effectiveness is limited by durability and can be damaged by shipping and handling, installation, bedding, and backfill placement — as well as internal abrasions from live loads. Commonly in culvert applications, the entire protective coating is removed by abrasion. For example, corrosion and abrasion from highway sand and salt can cause the entire invert of the pipe culvert to wear away, leading to its structural failure and collapse of the roadway.

Abrasion resistance comparison

A Darmstadt abrasion test shows that steel is 5-6 times more susceptible to abrasion than HDPE. This is aggravated by the corrugations in the CMP wall, which increase the turbulence that produces abrasion. Bituminous and zinc coatings are easily removed by abrasion.

Ironically, HDPE coatings on a smooth-walled CMP provide the most effective abrasion and corrosion protection. However, it is limited by the effectiveness of the bond between the coating and base metal. In addition, the lining's thermal characteristics also vary from those of the base metal. HDPE's response to temperature change is approximately ten times that of steel. Even so, the long-term performance of

HDPE-lined CMP is unknown, as it is a relatively complex subject matter.

TABLE 2

	CMP	Structured Wall HDPE Pipe
Standards	ASTM A929	SANS/ISO 21138/ENV 13476
Size range	150 mm-3 600 mm	280 mm to 3 500 mm diameter
	Multi-plate	
Lengths	20', various	12 m, various
Burial Design Method	Flexible	Flexible
Installation	ASTM A798	ASTM D2321/SABS 1200 Flexible bedding/class C bedding for rigid pipes/ ENV 1046
Manning's n	0.012 - 0.025	0.01
Maximum burial depth	> 45 m	12 m
Ph tolerance	5 > ph < 8	Tolerant
Shape	Circular, arch	Circular

Hydraulic comparison

CMP hydraulics cannot match those of HDPE — especially at larger diameters. The National Corrugated Steel Pipe Association recommends Manning's n values of 0.020 for CMP with diameters of 1 219 mm and larger. It recommends Manning's n values as high as 0.025 for CMP of 1 900 mm + diameter and 127 mm x 25.4 mm corrugation. Comparatively, the Manning's "n" value for the structured wall HDPE pipe does not exceed 0.01. This differential means that a smaller pipe size may be used for the same application or that the designer can specify flatter grades than would be possible with CMP.

In culvert applications, the pipe's capacity seldom controls the system's hydraulic capacity. Usually, the flow is inlet-controlled (limited by the ability to get the flow into the pipe) or outlet-controlled (limited by the downstream system's ability to handle the outflow).

The CMP industry has many inlet devices designed to improve a pipe's inlet capacity.

The material's Manning's n value has an impact where the culvert is operating under head, or where the limiting factor is the barrel's capacity when flowing full.

Where inlet control is the limiting hydraulic factor on a square cut culvert pipe end (regardless of which pipe material is being used), the culvert should be mitered to match the embankment slope. An inlet transition structure may also be added to channel the flow into the pipe. Both CMP and HDPE materials are easily adapted for connection to an inlet structure.

Service life and costs

The system designer should select a service life that is consistent with the material's proven track record. A primary application of the structured wall HDPE pipe is the relining of CMP culverts that have been in service for 15-30 years. The 0.05 mm – 0.25 mm thick linings intended to extend the CMP's service life can only be expected to do so by a nominal amount.

CMP with a low-cost bituminous or zinc coating will generally be less expensive on a capital cost basis. The material's bedding and backfill installation requirements are comparable with that of the structured wall HDPE pipe. However, expected service life values for pipes are 2-3 times greater than that of CMP, effectively reducing the lifecycle costs of a structured wall HDPE pipe culvert or pipe system below that of a CMP system.

STRUCTURED WALL HDPE PIPE VS. PVC

Pipe structure and scope

PVC, an extruded plastic pipe, is a close cousin of the HDPE product. It's produced as a straight wall pipe or with one of several profile wall designs (such as concentric straight ribbed or concentric "T" rib). It's also available in sizes from 750 mm – 1 500 mm ID with a "closed" profile design.

PVC up to 355 mm in diameter has become the predominant pipe material for gravity sewer applications. In larger diameters, it has a much smaller market penetration. No recognised industry standards exist for PVC sizes larger than 1 500 mm; a web search did not indicate material availability in that size range.

The profile wall designs give the pipe additional stiffness and its maximum imposed load carrying capacity. PVC is produced in lengths from 6 m – 12 m and is available as a non-pressure (gravity) sewer pipe in a broad range of sizes and configurations.

In general, PVC pipe is more "stiff" than HDPE. Like HDPE pipe, it uses a flexible buried pipe design method. Imposed loads are transferred to the surrounding soil by pipe deflection. PVC's stiffness range makes it suitable for applications with a broad range of dead and live loads. But since PVC is more brittle than HDPE, extra care is required to protect it (particularly the bell and spigot ends) from shipping and handling damage.

The structured wall HDPE pipe is available in a variety of lengths and pipe sizes up to 3 500 mm ID. Standard lengths are up to 12 m, limited solely by shipping logistics. It is the sole practical alternative to concrete pipe in these large sizes, and is the only plastic pipe option available in the 280 mm – 3 500 mm ID range.

Joining systems

PVC pipe is manufactured with an integral bell end. A variety of elastomeric gasket materials are used to make the pipe joint seal. The bell and gasket joints generally meet the requirements of ASTM D3212.

Environmental issues

Chlorine has been identified as a carcinogenic material. And PVC production accounts for 40% of all chlorine use in the United States.

Although opposition to the environmentalist movement's position on PVC use exists, Greenpeace's past success as an advocacy group suggests the PVC industry will have difficulty maintaining its market share.

Chemical resistance comparison

The chemical resistance of PVC and PE are similar for many applications. For example, both are well suited to resisting hydrogen sulphide corrosion. Unlike welded structured wall HDPE pipe or lined concrete pipe systems (where the lining is extended across the gasket), the gasket in a PVC pipe system is exposed to the hostile environment inside the pipe. Hence, the corrosion resistance of the gaskets will generally be a limiting factor of the system and, like all gasketed piping systems, leakage will increase as the system ages — regardless of corrosion.

Abrasion resistance comparison

While PVC has good abrasion resistance compared to steel or concrete, its abrasion resistance is generally half that of HDPE under the conditions experienced in most gravity sewer systems.

Hydraulic comparison

Manning's n value for PVC and the structured wall HDPE pipe are 0.009 and 0.010 respectively.

Installation

Structured wall HDPE pipes and gravity PVC sewer pipes have the same trenching, bedding and backfill requirements. Installation requirements for both pipe-soil systems are specified in ASTM D2321. The primary differences between the two products are the joining systems and pipe flexibility. The structured wall HDPE pipe has a bending radius of 100-200 times the pipe's OD (depending on stiffness). So small alignment changes can be made by deflecting the pipe itself rather than the joint.

Service life

Like HDPE, PVC has a long service life. The pipe and joint assembly's abrasion and corrosion characteristics must be considered when selecting the service life associated with a particular application. It is unrealistic to assign service life values of 50+ years to any pipe with a gasket joint. Only fused or welded HDPE pipe will have an indefinite service life expectancy.

TABLE 3

	PVC	Structured Wall HDPE Pipe
Standards (USA)	ASTM D3034 (4" - 15")	EN 13476/SANS/ISO 21138
	F679 (18" - 27")	
	F794 (8" - 24")	
	F1803 (30" - 60")	
Standards (Canada)	CSA B182.4	CSA B182.6 (18" - 48")
Structural type(s)	Straight wall, profile wall, closed profile wall	Closed profile wall
Size	4" - 60"	280 mm - 3 500 mm
Stiffness	46 psi (PS)	40-400 RSC
Unit length	4-8 m	
Burial design method	flexible	flexible
Shape	Circular	Circular
Installation	ASTM D2321	ASTM D2321
Joints	Gasketed (D3212)	Welded (D3212)/SANS 10268 - 4
Manning's n	0.009	0.010

STRUCTURED WALL HDPE PIPE VS. CPP (CORRUGATED POLYETHYLENE PIPE)

General

Corrugated Polyethylene Pipe (CPP) is intended for surface and subsurface drainage applications. In the United States, it's manufactured to AASHTO M-294 standards. The corresponding specification in Canada is CSA B182.6. Both cover pipe sizes up to 1 200 mm only. M-294 does not include a joint leakage standard.

The structured wall HDPE pipe is manufactured to F894/SANS/ISO 21138/EN 13476 standards. It is intended for low pressure and gravity sewer application in sizes up to 3 500 mm ID. F894 pipes must meet a joint tightness standard (D3212) with an established performance level that is much more demanding than normally specified for gasketed sewer systems. Generally, CPP is made from resins with mechanical properties that are less rigorously controlled than those specified for pipe manufactured to the ASTM F894/SANS/ISO 21138/EN 13476 standards. A comparison of

A structured wall HDPE pipe to the AASHTO M-294 specification, CSA B182.6 specification and ASTM F894 is included in Appendix A, Table 1.

Resin

AASHTO standard M-294 mandates the use of resins that are no longer rated for stress crack growth resistance by the ASTM standard D3350. Similarly, the resin is not rated for compressive or tensile strength by the Hydrostatic Design Basis testing method.

The Canadian standard that applies to CPP (CSA B182.6) permits a lower class of resin (P22) on the waterway wall.

Slow crack growth resistance

According to the old AASHTO M-294 standard, no more than 50% of the stress crack testing samples could fail within the 24-hour testing period (Class 1). Structured wall HDPE pipes adhere to the Class 4 standard (stating that a maximum 20% of samples could fail within a 600-hour testing period). This was the highest class that could be determined by the ESCR test (ASTM D1693) prescribed by D3350, the Standard Specification for Polyethylene Pipe.

Due to a problem with stress induced cracks in installed AASHTO M-294 pipe, CPP manufacturers and AASHTO undertook a systematic evaluation and recommended remedial actions.

The resulting report, published in 1999, was NCHRP Report 42910. This study recommended a modified "Single Point — Notched (sample) Constant Tensile Load" (SP-NCTL) test be used for AASHTO drainage pipe. These recommendations have since been adopted by the current standard (M-294-01).

ASTM D3350 has added a PENT test as a SCR test with classifications 1 through 6. The structured wall HDPE pipe has adopted the more onerous Class 5 definition.

Two significant differences in the AASHTO M-294 and the ASTM F894 standards are the differentiated mechanical testing requirements. These comprise the new test for SCR and the M-294 requirement to undertake brittleness testing (not included in F894 because they are unwarranted by the higher grades of resin). Consequently, it's no longer possible to compare products made to these two very different standards.

Pipe and joint design

CPP pipes are formed in discrete lengths with an integral bell and spigot. A very high corrugation profile in an open profile design gives the pipe a high moment of inertia and high stiffness in the radial direction. However, the pipe's deep exterior corrugations make it difficult to place and compact the bedding materials. As such, significant effort is required to do this properly. Since the pipe has limited stiffness in the axial direction, the placing and compacting of backfill in the haunch zone often results in localized sections of the pipe "lifting" from the desired grade.

The structured wall HDPE pipe's closed profile structure produces high radial moments of inertia and high beam stiffness, along with a high axial moment of inertia. Radial stiffness determines the maximum load a pipe can support. Axial stiffness determines the maximum push or pull load that the pipe can sustain. It also enables the pipe to remain "on grade" during installation. The closed profile design's smooth exterior surface simplifies the placement and compaction of bedding materials essential to the system's performance.

CPP is available with integral bell and gasket joints. Since the standard is silent on joint integrity, CPP manufacturers normally offer a "sand-tight" joint. No objective description or standard on this type of joint exists. But the joint seal may be compromised if suitable stiffness is not achieved in the primary backfill zone (from the bottom of the trench to 300 mm above the top of the pipe). Structured wall HDPE pipes come with a wide assortment of joining methods. Welded joints (all sizes) and bell and spigot joints (15"-36") will produce a watertight joint that meets ASTM D3212 requirements. In most applications, a welded joint will be least costly and it offers the highest performance level (no leaks). The system is completely homogenous — with the same corrosion resistance, abrasion resistance, and mechanical properties across both the joint and pipe. Mechanical joints will produce a sand-tight joint, but not one that is watertight.

TABLE 4

	CPP	Structured Wall HDPE Pipe
Standards (USA)	AASHTO M-294	ASTM F894
Standards (Canada)	CSA B182.6	CSA B182.6
Size range	300 mm-960 mm	280 mm-3 500 mm
Structural type	Open profile	Closed profile
Stiffness range	50 psi (12") to 18 psi (36")	40-400 RSC e.g. 36 RSC 250 = 41 psi. SN2-SN8
Manning's n	0.01	0.01

Longitudinal stiffness and installation issues

Most profile wall HDPE pipe is produced with an "open" rather than a "closed" profile. In general, the open profile is a corrugated exterior surface, usually in a circular (but also in a spiral) pattern. Open profile pipe has a high moment of inertia across the pipe wall (a high resistance to bending in a radial direction). This resists pipe deflection caused by live and dead loads.

However, open profile pipe has a very low moment of inertia in the axial direction. Consequently, axial installation pressures — such as those caused by construction equipment pushing a pipe joint together — easily deform the pipe. In wet soils, joint integrity may be compromised when a pipe section deflects due to buoyancy.

Any flexible pipe's performance is determined by the "soil stiffness" in the trench's primary bedding area. Soil stiffness measures the interlock between adjacent soil or bedding particles. It is highly dependent on the amount of bedding compaction imparted during pipe installation. An open profile pipe requires very careful placement of the bedding materials, especially in the haunch zone. Granular materials must be "sliced" with a shovel to ensure that the voids between corrugations are filled.

"Closed profile" pipe has a smooth interior and exterior surface. Both the radial and axial moments of inertia are high. As a result, it's much easier to place bedding materials properly (and less critical if not properly placed). High axial stiffness allows the use of normal construction equipment to push or pull the pipe into position. The pipe's stiffness will

TABLE 5

		AASHTO M-294-01	CSA B182.6	ASTM F894	Structured wall HDPE pipe F894 & B182.6
Scope	Scope	300-1 200 mm 12"-48"	450-1 200 mm 18"-48"	250-3 050 mm 10"-120"	250-3 050 mm 10"-120"
	Type	Corrugated open or closed profile PE pipe & fittings with or without perforations	Corrugated ID based PE pipe and fittings with a smooth ID for storm & sanitary sewers	ID based, open or closed profile wall pipe for low pressure & gravity sewer flow	ID based closed profile wall pipe for low pressure & gravity sewer flow
	Resin	Virgin PE P335400C	V P324420C (o/s) P221130C (I/s)	Virgin PE P33443C	Virgin PE P345464C
Stiffness	Values	300 mm-345 Kpa 900 mm-150 Kpa	210 & 320 Kpa	40 RSC to 160 RSC	40 to 400 RSC 210 & 320 Kpa
	Spec. Length	1 diameter	1 diameter	Lesser of 2 diameters or 48"	As req'd by Std.
	Rate of Loading	½" per minute	½" per minute	2" per minute	As req'd by Std.
	Conditioning	40 hrs @ 23C	40 hrs @ 23C	40 hrs @ 23C	40 hrs @ 23C
	Deflection Limit	3%	5%	3%	As req'd by Std.
	Stiffness Type	Pipe	Pipe	Ring	As req'd by Std.
	Frequency	As agreed upon by purchaser & seller (Section 10.1)	Once every 24 hrs, 1 per run	Manufacturers discretion (Section 8.3)	As req'd by Std.
Brittleness (impact) test	Activity	ASTM D2444, 4.5 kg tup	13.6 kg tup	None	As req'd by Std.
	Frequency	Unclear, appears to be a qualifying test	Once every 24 hrs, 1 per run		As req'd by Std.
Other tests	Activity	Pipe Flattening Test (Section 7.6)	Compression Test (Section 8.4.1) Air Tight (Section 7.3)		As req'd by Std.
	Frequency	Unclear – 1 set per 'run' implied	Compression – once every 24 hrs/ 1 per run Air Tight – every stick		As req'd by Std.
Slow crack growth resistance testing	Activity	Resin – SP-NCTL per ASTM 5397	Resin – ESCR or PENT Test Level 2	Resin – ESCR or PENT Test Level 3	100 hrs PENT Test Level 6
	Frequency	Resin Qualifying Test, Pipe Section 10.1 – as agreed between purchaser & seller	Resin Qualifying Test	Resin Qualifying Test	Resin Qualifying Test
Resin	Type	V P335400C	V P324420C (o/s) P221130C (I/s)	Virgin PE P334433C	Virgin PE P345464C
	Density (g/cc)	0.945-0.955	0.941-0.955	0.941-0.955	0/941-0.955
	Melt Index (g/10 min)	0.4-.15	1.0-0.4	0.4-0.15	< 0.15
	Flex. Modulus (Mpa)	758-1103	552-758	552-758	758-1103
	Tensile (Mpa)	21-24	21-24	21-24	21-24
	SCGR	SP-NCTL 50% - 24 hrs	Condition B ESCR 50% - 24 hrs or 1 hr PENT	Condition C ESCR 20% - 192 hrs or 3 hrs PENT	100 hrs PENT Test
	HDB (Mpa)	Not required	Not required	8.62 Mpa/1 250 psi	11.03 Mpa/1 600 psi
	Colour & Stabiliser	C < 5%	C > 2%	C > 2%	C > 2%
Other	Wall Thickness	None specified	Min waterway wall 1.27 mm	Min waterway wall varies by size	Min waterway wall varies by size (see note 1)
	Joint Seal	None specified	ASTM D3212 (15psi)	ASTM D3212 (10.8psi)	ASTM D3212 (10.8 psi & 15 psi)
	Marking Reqts	manu/size/Std/manu plant/date/ manu mark	Manu/size/PE class Use/std. no./date	Per Federal standard no. 123	Per Federal standard no. 123

hold the pipe on grade (level) if met with buoyancy forces and the pipe's smooth exterior wall enables easier achievement of the design soil stiffness (E') than with "open profile" pipe.

Corrosion and abrasion resistance

The weight of an open profile CPP pipe may be up to 50% lighter than comparable (in terms of radial stiffness) closed profile structured wall HDPE pipe. Generally, the waterway wall for F894 pipe is 2.5 times that of the M-294 pipe. Long-term abrasion resistance is affected by material thickness.

While both pipes have excellent abrasion resistance (rates of material abrasion exceed that of concrete by 3-5 times), the F894 structured wall HDPE pipe's substantially increased waterway wall thickness will outperform CPP.

Note: Structured wall HDPE pipes are available in all sizes with a waterway wall thickness that meets the minimum wall thickness requirement of ASTM F894. Some of the 'small size – low ring stiffness' items have a waterway wall less than the minimum where it has been possible to obtain the required stiffness with the lighter wall.