

## **MATERIAL AND MANUFACTURING SPECIFICATION FOR PERFECT PIPE**

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FINAL DRAFT

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### **1 SCOPE**

This document provides the minimum requirements for materials, manufacturing, and inspection of PERFECT PIPE. PERFECT PIPE is a hybrid system that combines the strength and structure of reinforced concrete pipe with the chemical resistance of high density polyethylene (HDPE), complete with a water-tight jointing system. PERFECT PIPE is manufactured in various diameters from 600 mm to 1200 mm with the inside surface completely protected by a cast-in HDPE liner. The HDPE liner protects the interior concrete surface from the damaging effects associated with corrosive gases and liquids that can form in the sewer system including Microbial Induced Corrosion (MIC). The HDPE liner has superior abrasion resistance when compared to other pipe materials. PERFECT PIPE has a dual jointing system that seals using a thermoplastic internal connector with dual elastomeric rubber gaskets joining pipe sections; therefore no field welding of the liner is required. PERFECT PIPE is designed for use in open cut and micro tunneling applications as a gravity pipe.

## 2 DEFINITIONS

CPL – Concrete Protective Liner

HDPE – High Density Polyethylene

Liner – Protective layer on the inner surface of the pipe or Concrete Protective Liner

PPP – Plant Prequalification Program

SCC – Self Consolidated Concrete

## 3 REFERENCES

### CSA Standards

A23.1-14	Concrete materials and methods of concrete construction
A23.2-14	Test methods and standard practices of concrete
A23.4-16	Precast Concrete Materials and Construction
A257.0-14	Methods for determining physical properties of circular precast concrete pipe, manhole sections, catch basins, and fittings.
A257.2-14	Reinforced circular concrete culvert, storm drain, sewer pipe, and fittings.
A257.3-14	Joints for circular concrete sewer and culvert pipe, manhole sections, and fittings using rubber gaskets.
G40.20-13	General requirements for rolled or welded structural quality steel / Structural quality steel

### OPSS Standards

.PROV 1350	Material Specification for Concrete – Materials and Production
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### ASTM International

A820	Standard Specification for Steel Fibers for Fiber-Reinforced Concrete
C1064	Standard Test Method for Temperature of Freshly Mixed Hydraulic Cement Concrete
C1765	Standard Specification for Steel Fiber Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
D395	Standard Test Methods for Rubber Property—Compression Set
D412	Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
D573	Standard Test Method for Rubber—Deterioration in an Air Oven
D638	Standard Test Method for Tensile Properties of Plastics
D792	Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D882	Standard Test Method for Tensile Properties of Thin Plastic Sheet
D1238	Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
D1415	Standard Test Method for Rubber Property—International Hardness
D1638	Methods of Testing Urethane Foam Isocyanate Raw Materials

D7853	Standard Test Method for Hydraulic Pullout Resistance of a Geomembrane with Locking Extensions Embedded in Concrete
F477	Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

#### Other Standards

PPP	Plant Prequalification Program
UL-94	Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
DIN 53752	Plastics; Determination of the Coefficient of Linear Thermal Expansion
DIN EN ISO 4624	Paints, varnishes and plastics pull-off test for adhesion
ISO 3384-1	Rubber, Vulcanized or Thermoplastic -- Determination of Stress Relaxation in Compression

## 4 DESIGN AND CONFORMANCE

### 4.1 Design

Structural design testing of the PERFECT PIPE shall be carried out in accordance with CSA A257.0 Section 4. Acceptance of design shall be in accordance with CSA A257.2 Section 3.1. Shorter length test pipe without the liner may be used for design qualification. Full validation testing shall consist of 3 pipe. The class of the pipe shall meet or exceed the required design and ultimate load limits defined in 4.4. Design requirements shall be in accordance with CSA A257.2 Section 7 and Section 8. When steel fiber is used as primary reinforcement, the design of the pipe shall be in accordance with ASTM C1765. Synthetic fiber may be considered upon owner's approval. Full validation shall be conducted using this test when any of the following changed:

- a) Concrete mix design compressive strength reduction
- b) Steel design (except longitudinal reinforcement)

### 4.2 Conformance

Conformance of the PERFECT PIPE to this standard shall be determined by

- a) Strength tests in accordance with Section 9.6;
- b) The hydrostatic test in accordance with Section 9; and
- c) Dimensional variation and tolerance in accordance with Section 6; and
- d) Visual inspection in accordance with Section 9.10; and
- e) Inspection to determine whether the pipe conforms to other requirements stipulated in this standards.

### 4.3 Certification

Manufacturing facility shall have the following certification:

- a) Plant Pre-qualification Program (PPP)
- b) Canadian Standard Association (CSA A23.4)
- c) International Standard Organization (ISO 9001-2008)

### 4.4 Classification

The PERFECT PIPE is classified based on the strength test in accordance with CSA A257.0. The standard class is 65-D, 100-D, 140-D. Higher class designs may be validated in accordance with Section 9.6.

### 4.5 Certificate of Conformance

The certificate of conformance shall be issued for each job by a qualified and licensed plant engineer based on the general conformance to this standard.

## 5 MATERIALS

### 5.1 Concrete Materials

Concrete materials including Portland cement, blended hydraulic cement, supplementary cementing materials, aggregate, mixing water and admixtures shall conform to CSA A23.1 and OPSS.PROV 1350.

### 5.2 HDPE Liner

#### 5.2.1 Physical specification

The inside concrete surface of the PERFECT PIPE is protected with a minimum 1.6 mm thick cast-in HDPE concrete protective liner. The liner shall be manufactured from the same resins and meet the properties shown in Table 1. The anchor distribution shall be evenly spaced with maximum distance of 40 mm. The height of the anchor shall be no more than 8 mm.

#### 5.2.2 Performance

The liner shall be tested to 206 kPa in accordance with ASTM D7853 for pull out resistance.

#### 5.2.3 Design Life

The expected design life will exceeded 100 years under normal ground working condition in terms of abrasion and constant working temperature:

- a) 50 years with a constant working temperature of 35°C
- b) Short term temperature can exceed 60 °C

#### 5.2.4 Appearance

The line shall have a bright yellow colour for ease of visual inspection after installation.

### 5.3 Reinforcement

Reinforcement shall consist of one of the following:

- a) cold drawn wire conforming to ASTM 1064/A1064M yield strength 450 MPa minimum; or
- b) welded wire fabric conforming to ASTM 1064/A1064M yield strength 450 MPa minimum; or
- c) deformed bar conforming to CSA G30.18 Grade 400W; or
- d) steel fiber conforming to ASTM A820 / A820M.

### 5.4 Thermoplastic coupler

The coupler shall be made of polypropylene or fiber reinforced polypropylene and shall be injection molded in one piece. The thermoplastic coupler shall be installed at the manufacturer's facility prior to delivery.

### 5.5 Elastomeric rubber gasket

The double tilting-edge elastomeric rubber gasket shall conform to ASTM F477. The physical property of the gasket is shown in Table 2.

### 5.6 Steel end ring for Micro-tunneling pipe

Steel end ring used for Micro-tunneling pipe shall conform to CSA G40.20 Grade 300W.

## 6 DIMENSIONS AND PERMISSIBLE VARIATION

### 6.1 Designated Dimensions

The designated internal diameters and wall thickness of PERFECT PIPE shall be as prescribed in Table 3.

### 6.2 Wall Thickness

The wall thickness may be greater than that specified in Table 3 but shall not be less than the design thickness by more than 5% or 5 mm, whichever is greater. Localized variations in wall thickness exceeding these limits may be acceptable if the three-edge-bearing strength and minimum steel cover requirements are met.

### 6.3 Length of Pipe

Standard lay length of the PERFECT PIPE is 3000 mm. The underrun in length of any section of pipe shall be not more than 10 mm / m or 13 mm, whichever is less. Shorter length of the pipe section is permitted.

### 6.4 Length of two opposite sides

The lengths of two opposite sides of any section of pipe shall vary by not more than 1% of designated pipe diameter or 6 mm whichever is smaller.

## 7 GENERAL REQUIREMENTS

### 7.1 Quality of work and finish

General requirements shall be in accordance with CSA A257.2 Section 6.1

### 7.2 Joints

Joints are composed of a thermoplastic coupler with two double tilting-edge elastomeric rubber gaskets and concrete pipe joint profiles, after being properly homed, shall meet the required hydrostatic test pressure in Section 0 and in compliance of CSA A257.3. The joint profiles of concrete pipe shall be constructed within the manufacturing tolerance of the original design of the PERFECT PIPE. No field welding is required.

### 7.3 Lifting and Handling

Cast-in lifting systems on the outside face of the pipe may be used as a primary method for handling. Use of forklift to handle through direct contact with the pipe is permitted only when using an appropriate protection device for the liner of the pipe.

### 7.4 Storage and Transportation

Storage and transportation of PERFECT PIPE shall conform to CSA A23.4 Section 30 and 31.

### 7.5 Identification and Marking

PERFECT PIPE shall be identified based on the class defined in Section 4.4. with a waterproof paint or ink, by indentation or adhesive waterproof label at the time the pipe is manufactured. The following information shall be marked on each pipe.

#### 7.5.1 Marking on outside face of the pipe

- a) the pipe strength classification and the designation of this Standard (CSA A257.2);
- b) the pipe designated internal diameter
- c) the date of manufacture;
- d) the manufacturer's name and PERFECT trademark;
- e) the plant identification;
- f) the marking of micro-tunneling pipe with a "J";
- g) the PPP stamp; and
- h) other markings as specified by the owner.

#### 7.5.2 Marking on inside face of the pipe

- a) the pipe strength classification;
- b) the pipe designated internal diameter; and
- c) the date of manufacture;

## 8 MANUFACTURING

### 8.1.1 Facility

Manufacturing shall be carried out in a dedicated production assembly line for steel, liner, pipe mold, curing environment, inspection and storage.

### 8.1.2 Liner

The liner is welded in accordance with the manufacturers and by manufacturer certified operator. The completion of welding shall provide a one piece homogeneous concrete protective liner system using the following acceptable techniques:

- a) Extrusion welding
- b) Butt welding
- c) Hot gas welding

### 8.1.3 Concrete Pipe

Manufacturing of the concrete pipe shall be according to CSA A257.2. When the PERFECT PIPE is used as a micro-tunneling pipe, a steel band is cast at the bell end of the pipe.

### 8.1.4 Concrete Pipe Fitting

Fabricated branches for wyes and tees shall be securely attached to the wall of the pipe in such a manner as not to restrict or otherwise interfere with the flow characteristics of the pipe.

## 9 SAMPLING, TESTING AND INSPECTION

### 9.1 Testing

Sampling and testing of slump, air content and temperature of plastic concrete shall be carried out by a person holding either of the following certifications:

- a) CCIL Certified Concrete Testing Technician; or
- b) ACI Concrete Field Testing Technician – Grade 1

### 9.2 Testing Frequency

Testing frequency shall be in accordance with Table 4.

### 9.3 Production Lot

Production lot is defined as the same size and class manufactured in 7 consecutive days or no more than 50 pieces consecutively whichever comes first.

### 9.4 Plastic Concrete Testing

The plastic concrete shall be tested for slump, slump flow (when SCC is used), air content and temperature according with CSA A23.2 and the results of these tests shall be recorded. Testing shall be conducted on the first batch and at the minimum frequency of every fifth batch following.

### 9.5 Concrete Compressive Strength

Compressive strength shall be determined for each production day in accordance with CSA A23.2-9C. Samples shall be prepared for 1 (1cylinder), 7 (1cylinder), and 28-day testing (2 cylinders).

### 9.6 PERFECT PIPE Three-Edge Bearing Test

Three-edge-bearing testing shall be conducted in accordance with CSA A257.0.

Should a Product fail to meet the requirement of the three edge-bearing test, the Manufacturer shall:

- a) Test three (3) additional pipe from the same production lot, if the pipe passes, the run is pre-qualified;
- b) If any of the above does not pass, the production lot shall be reclassified to the load determined from the three edge-bearing tests conducted.

### 9.7 Hydrostatic Test

#### 9.7.1 Test Procedures

Hydrostatic testing shall be conducted in accordance with CSA A257.0 Section 7. The pipe shall be tested in proper alignment. The internal hydrostatic pressure shall be held for 10 minutes with no sign of leakage. The pressure increase beyond the required pressure shall be in 20 kPa intervals. Each

increase shall be held for 2 minutes with no sign of leakage until failure or 120% of the required pressure whichever is reached. The hydrostatic pressure shall also be tested for the following setting presented in Table 5:

- a) Pipes in maximum deflected position
- b) Joints under differential load

#### 9.7.2 One Pipe Failure

If one out of the three pipes in a hydrostatic test fails then two of the three pipes must be replaced, including the failed pieces. The replacement pipes must be from the same day production and pass all of the tests. For each failure, there must be two tests which pass for the run of pipe. If the hydrostatic tests continue to fail, all of the pipes in that run are considered to have failed. If this occurs, only the pipe passing the test may be stamped as Pre-qualified (i.e.: the plant may test the entire pipe in a run to determine which is acceptable).

#### 9.7.3 Two Pipe Failure

If two or more pipes fail, the test is considered a failure. For each failure, there must be two tests which pass for the run of pipe. If the hydrostatic tests continue to fail, then all of the pipes in that run are considered to have failed. If this occurs, only the pipe passing the test may be stamped as Prequalified (i.e. the plant may test the entire pipe in a run to determine which is acceptable).

### 9.8 Liner Pullout Test

The liner shall be tested to 206 kPa in accordance with ASTM D7853 for pull out resistance.

### 9.9 Dimension

The internal dimension shall meet the dimensional tolerance in Table 3 in accordance with PPP Section 9.2. The inspection shall be conducted at both ends of each pipe.

### 9.10 Product finish

The concrete finish shall be free of surface defects such as honeycombing, voids, cavities, spalls, and delamination.

## 10 QUALITY ASSURANCE

### 10.1 Document Control

Document control in regards to quality records include but not limited to raw materials, finished product inspections, testing results, etc. shall be retained in accordance with ISO 9001-2008.

### 10.2 Acceptance Criteria

Product shall be accepted when all of the following conditions are met:

- a) Validate design and strength test records
- b) Validate hydrostatic test records
- c) Meet all dimensional tolerance
- d) Pass the liner pullout test
- e) Product finish
- f) Pipe is clearly marked

### 10.3 Rejection Criteria

#### 10.3.1 Entire lot

The entire lot of the pipe shall be subject to rejection or reclassification if one of the following condition is met.

- a) Failed to meet the three edge bearing test
- b) Failed to meet the hydrostatic test
- c) Failed to meet the liner pullout test

#### 10.3.2 Pipe made on the same day

All pipe of the same size and class shall be rejected if the product failed to meet compressive strength requirement.

#### 10.3.3 Individual pipe

Individual pipe shall be rejected if one of the following conditions is met.

- a) Failed to meet the dimensional tolerance
- b) Unsound concrete beyond repair
- c) Crack greater than 0.3 mm

### 10.4 Disposition

When the pipe failed to meet the acceptance criteria and beyond repair, the entire lot shall be disposed based on the following condition:

- a) When the strength is not met, re-class the lot to a lower class. Strength test is required for the next lot.
- b) When the working pressure target is not met but CSA A257.2 requirement is met, the entire lot shall be segregated. The PERFECT trademark shall be removed from the pipe. The lot can only be supplied to the project with CSA A257.2 requirement specified. If CSA A257.2 requirement is not met, the entire lot shall be disposed. The hydrostatic test shall be conducted to qualify the next lot.
- c) The entire lot shall be disposed if the pipe failed to meet the liner pullout test.
- d) Any failure with the pipe to meet the internal diameter or the joint profile tolerance shall require all other pipes made in the same lot to be inspected for conformance. All non-conformed pipes shall be disposed.
- e) The pipe with unsound concrete beyond repair shall be disposed.

### 10.5 Other Defects

Other defects including surface finish, unsound concrete, or any other defects that do not impact the performance of the pipe shall be repaired using the approved standard repair procedure listing in Table 6.



*Table 1: HDPE Liner Physical Properties*

Property	Testing Method	Value
Density	ASTM D792	0.945 g/cm <sup>3</sup>
Melt Flow Index (MFI 190/5)	ASTM D1238	1.6 – 2.0 g/10min
Heat Reversion (Dimensional Stability)	ASTM D1638	< 2%
Yield Stress	ASTM D638	> 16MPa (2320 psi)
Elongation of Yield	ASTM D638	> 12%
Elongation at Break	ASTM D638	> 200%
Fire Classification	UL-94	V2
Linear Coefficient of Thermal Expansion	DIN 53752	K <sup>-1</sup> x 10 <sup>-4</sup>
Maximum Working Temperature		60 C°

*Table 2: Elastomeric Gasket Physical Properties*

Property	Testing Method	Value
Hardness	ASTM D1415	+/- 5 IRHD
Tensile strength	ASTM D412	≥ 9 MPA
Elongation at break	ASTM D412	≥ 375%
Compression set in air	ASTM D395	≤ 20% (24h @ 70° C) ≤ +8/-5 (7d at 70° C)
Aging in air	ASTM D573	≤ -20%(7d at 70° C) ≤ +10/-30 (7d at 70° C)
Stress Relaxation in compression	ISO 3384-1	≤ 14(7d at 23° C)
Volume change in water (7d @ 70° C)	ASTM D882	≤ +8/-1%(7d at 70° C)
Strength of the Joint	ASTM F477	Elongation 100%

*Table 3: PERFECT PIPE Dimension*

Designated Internal Diameter (mm)	Permissible variation in internal diameter of pipe (mm)		Minimum Wall Thickness including liner (mm)
	Minimum	Maximum	
500	490	510	89
600	590	610	95
700	690	710	102
800	790	810	108
900	890	910	120
1000	990	1010	127
1100	1090	1110	133
1200	1190	1210	146

*Table 4: Testing Frequency*

Section	Test	Governing Standard	Frequency
9.9	Dimensional verification	PPP Section 9.2	Each size and class per lot
9.4	Plastic concrete testing	CSA A23.2	Daily
9.5	Compressive strength	CSA A23.2-9C	Daily
9.6	Three-edge bearing	CSA A257.0, PPP Section 9.3	1 test per 200 pieces each size and class.
9.7	Hydrostatic	CSA A257.0, PPP Section 9.5	1 test per 400 pieces each size and class
9.8	Liner pull out	ASTM D7853	As required by the owner

*Table 5: Internal Hydrostatic Test Pressure*

Testing Condition	CSA A257.0 Requirement
Pipes in proper alignment	103 kPa
Pipes in maximum deflected position	90 kPa
Joints under differential load	35 kPa

*Table 6: Defects and Deficiencies Repairable by Standard Methods*

Repairable Defects and Deficiencies	Condition	Repair Method
Honeycombing, Voids, Cavities, Spalls, and Delamination	Any area less than an equivalent area of 300 mm x 300 mm with no steel reinforcement exposed.	<ul style="list-style-type: none"> <li>a) Square all sides of the repair area.</li> <li>b) Remove all loose concrete using a chipping hammer or hand tools.</li> <li>c) Air blast clean all concrete surfaces to be patched</li> <li>d) Remove all dust and loose material from the prepared surface by using compressed air.</li> <li>e) Fill repair area with concrete or a proprietary product patching material.</li> <li>f) Cure proprietary patching material according to the manufacturer's recommendations.</li> </ul>