Flexural Testing of CIPP

Tony Araujo
Vice President - Testing
Paragon Systems

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal
INFRA 2012 INFRASTRUCTURES MUNICIPALES

Routine Quality Assurance of CIPP Installations

- Each CIPP installation is unique
- To ensure the quality of an installation, contractors and their clients:
  - Control input variables
  - Verify outcomes

PARAGON SYSTEMS

ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

Routine Quality Assurance of CIPP Installations

Verify outcomes

- Video inspection
- Dimensional inspection
- Initial Structural Properties

PARAGON SYSTEMS

ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

Testing Process

- Contractor prepares field sample
- Test laboratory:
  - measures wall thickness
  - prepares 5 flexural test specimens
  - tests the samples and prepares report

PARAGON SYSTEMS

ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

What is the Data Used For?

- Confirmation that initial properties are achieved after curing
  - 1st – ASTM F1216 minimums

TABLE 1 CIPP Initial Structural Properties[A]

Property	Test Method	Minimum Value psi	Minimum Value (MPa)
Flexural strength	D 790	4 500	(31)
Flexural modulus	D 790	250 000	(1 724)
Tensile strength (for pressure pipes only)	D 638	3 000	(21)

[A]The values in Table 1 are for field inspection. The purchaser should consult the manufacturer for the long-term structural properties.

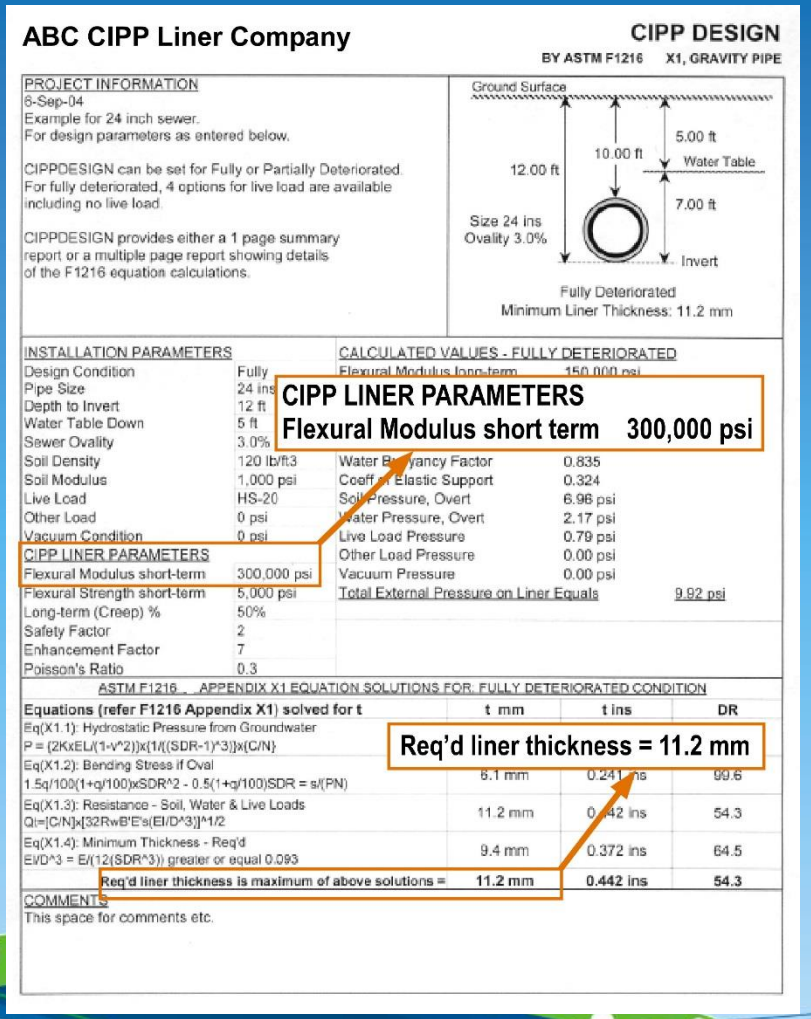
PARAGON SYSTEMS

ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

What is the Data Used For?

- Confirmation that design objectives were achieved after curing
  - 2nd – Design thickness and modulus



ABC CIPP Liner Company — **CIPP DESIGN** — BY ASTM F1216 X1, GRAVITY PIPE

PROJECT INFORMATION
6-Sep-04
Example for 24 inch sewer.
For design parameters as entered below.

CIPPDESIGN can be set for Fully or Partially Deteriorated.
For fully deteriorated, 4 options for live load are available including no live load.

CIPPDESIGN provides either a 1 page summary report or a multiple page report showing details of the F1216 equation calculations.

Ground Surface; 12.00 ft; 10.00 ft; 5.00 ft; Water Table; 7.00 ft; Size 24 ins; Ovality 3.0%; Invert

Fully Deteriorated
Minimum Liner Thickness: 11.2 mm

INSTALLATION PARAMETERS		CALCULATED VALUES - FULLY DETERIORATED	
Design Condition	Fully	Flexural Modulus long-term	150,000 psi
Pipe Size	24 ins		
Depth to Invert	12 ft		
Water Table Down	5 ft		
Sewer Ovality	3.0%		
Soil Density	120 lb/ft3	Water Buoyancy Factor	0.835
Soil Modulus	1,000 psi	Coeff. of Elastic Support	0.324
Live Load	HS-20	Soil Pressure, Overt	6.98 psi
Other Load	0 psi	Water Pressure, Overt	2.17 psi
Vacuum Condition	0 psi	Live Load Pressure	0.79 psi
CIPP LINER PARAMETERS		Other Load Pressure	0.00 psi
Flexural Modulus short-term	300,000 psi	Vacuum Pressure	0.00 psi
Flexural Strength short-term	5,000 psi	Total External Pressure on Liner Equals	9.92 psi
Long-term (Creep) %	50%		
Safety Factor	2		
Enhancement Factor	7		
Poisson's Ratio	0.3		

CIPP LINER PARAMETERS
Flexural Modulus short term 300,000 psi

ASTM F1216 APPENDIX X1 EQUATION SOLUTIONS FOR: FULLY DETERIORATED CONDITION

Equations (refer F1216 Appendix X1) solved for t	t mm	t ins	DR
Eq(X1.1): Hydrostatic Pressure from Groundwater P = (2KxEL/(1-v^2))x(1/((SDR-1)^3))x(C/N)			
Eq(X1.2): Bending Stress if Oval 1.5q/100(1+q/100)xSDR^2 - 0.5(1+q/100)SDR = s/(PN)	6.1 mm	0.241 ins	99.6
Eq(X1.3): Resistance - Soil, Water & Live Loads Qt=[C/N]x[32RwB'E's(EI/D^3)]^1/2	11.2 mm	0.442 ins	54.3
Eq(X1.4): Minimum Thickness - Req'd EI/D^3 = E/(12(SDR^3)) greater or equal 0.093	9.4 mm	0.372 ins	64.5
Req'd liner thickness is maximum of above solutions =	**11.2 mm**	**0.442 ins**	**54.3**

Req'd liner thickness = 11.2 mm

COMMENTS
This space for comments etc.

PARAGON SYSTEMS

ACCREDITED

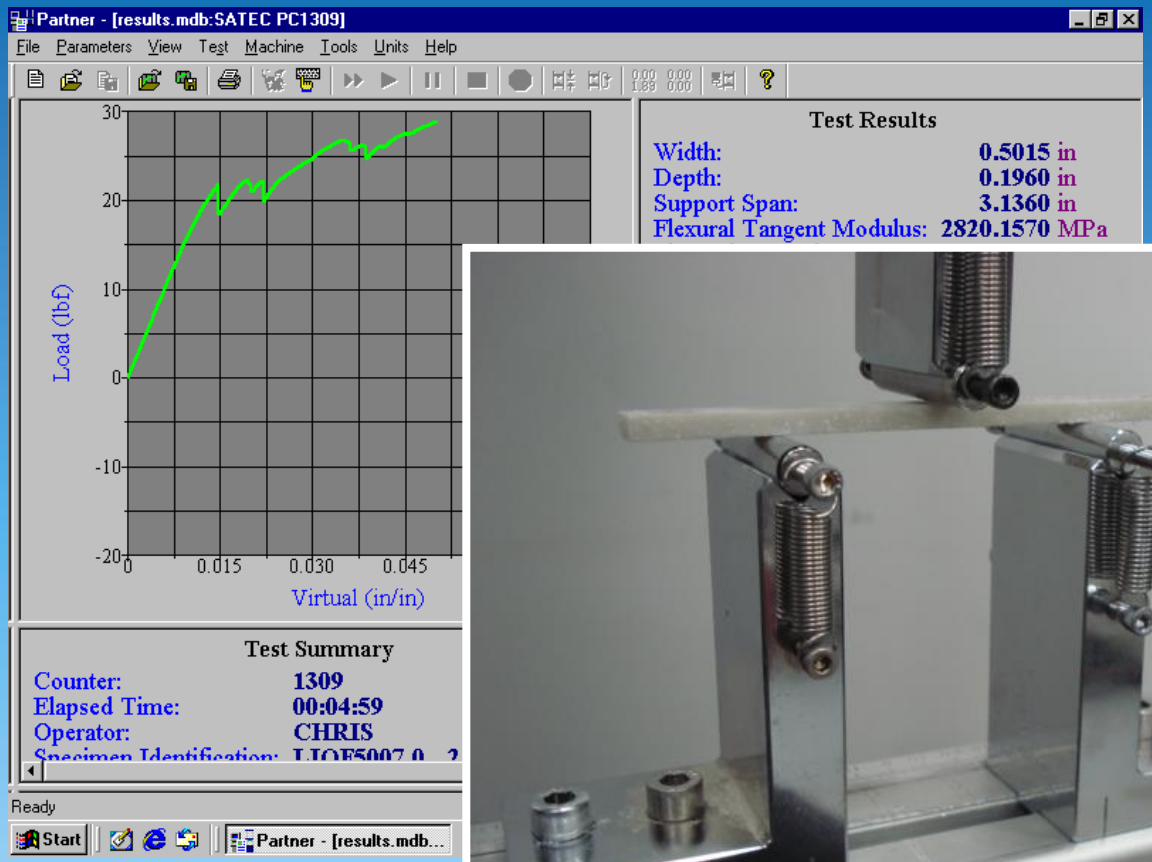
CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

Initial Structural Properties

ASTM F1216-09 specifies:

- Flexural Strength and Flexural Modulus are determined with **ASTM D790**

Initial Structural Properties



PARAGON SYSTEMS

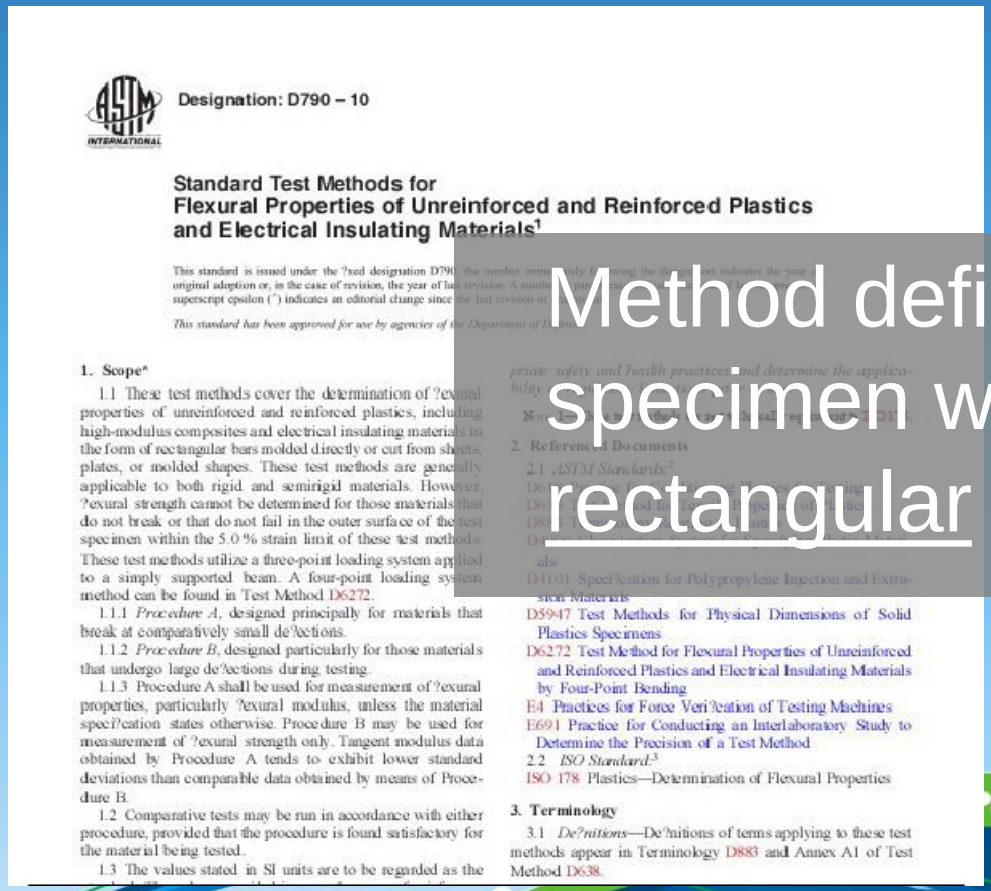
ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal

INFRA 2012 INFRASTRUCTURES MUNICIPALES

ASTM D790

ASTM D790 was not designed for CIPP



Designation: D790 – 10

Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[1]

This standard is issued under the ?xed designation D790; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (′) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 These test methods cover the determination of ?exural properties of unreinforced and reinforced plastics, including high-modulus composites and electrical insulating materials in the form of rectangular bars molded directly or cut from sheets, plates, or molded shapes. These test methods are generally applicable to both rigid and semirigid materials. However, ?exural strength cannot be determined for those materials that do not break or that do not fail in the outer surface of the test specimen within the 5.0 % strain limit of these test methods. These test methods utilize a three-point loading system applied to a simply supported beam. A four-point loading system method can be found in Test Method D6272.

1.1.1 *Procedure A*, designed principally for materials that break at comparatively small de?ections.

1.1.2 *Procedure B*, designed particularly for those materials that undergo large de?ections during testing.

1.1.3 Procedure A shall be used for measurement of ?exural properties, particularly ?exural modulus, unless the material speci?cation states otherwise. Procedure B may be used for measurement of ?exural strength only. Tangent modulus data obtained by Procedure A tends to exhibit lower standard deviations than comparable data obtained by means of Procedure B.

1.2 Comparative tests may be run in accordance with either procedure, provided that the procedure is found satisfactory for the material being tested.

1.3 The values stated in SI units are to be regarded as the

priate safety and health practices and determine the applicability

2. Referenced Documents

2.1 *ASTM Standards*[2]

D4101 Speci?cation for Polypropylene Injection and Extrusion Materials

D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens

D6272 Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials by Four-Point Bending

E4 Practices for Force Veri?cation of Testing Machines

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ISO Standard*[3]

ISO 178 Plastics—Determination of Flexural Properties

3. Terminology

3.1 *De?nitions*—De?nitions of terms applying to these test methods appear in Terminology D883 and Annex A1 of Test Method D638.

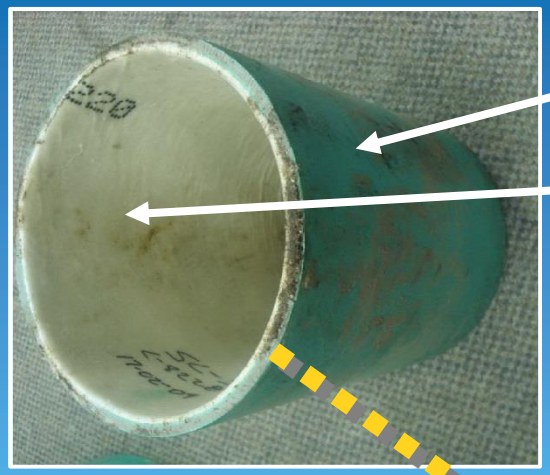
Method defines a test specimen with a rectangular cross section

PARAGON SYSTEMS

ACCREDITED

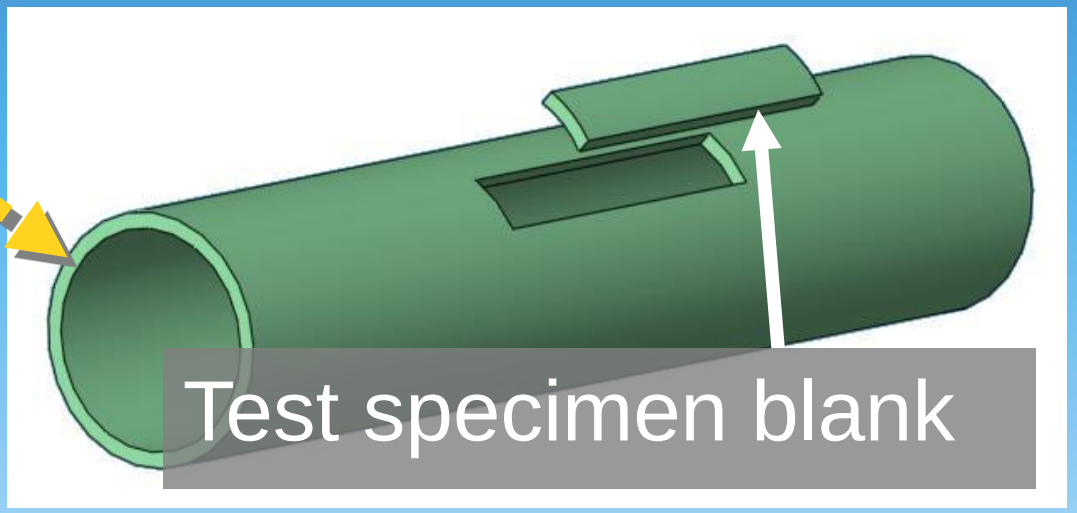
CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

ASTM D790



PVC Pipe Form

CIPP Field Sample



PARAGON SYSTEMS

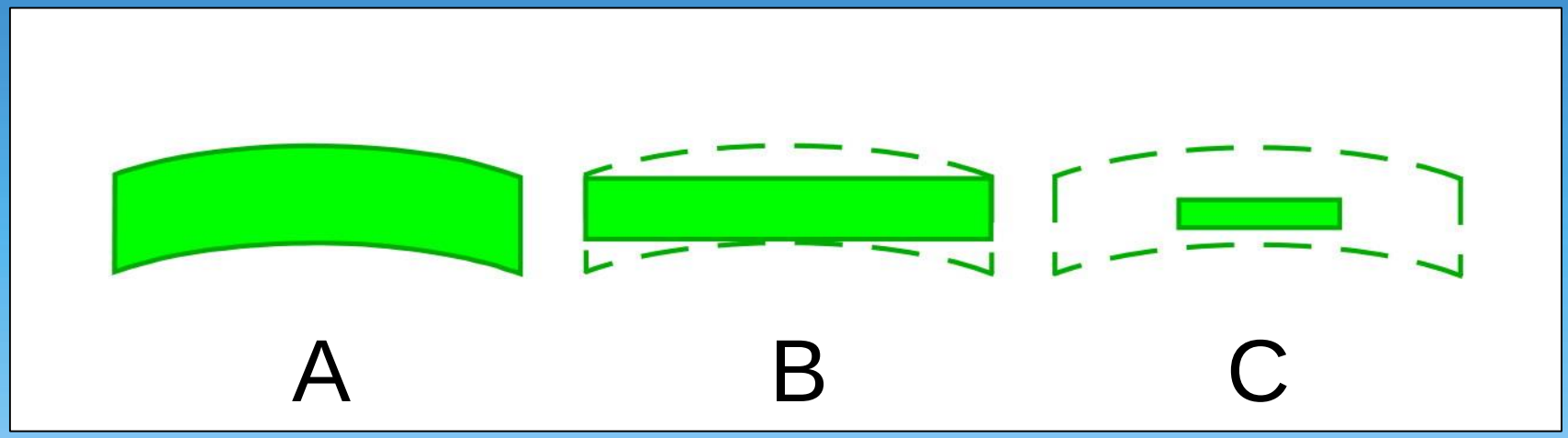
ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal

INFRA 2012 INFRASTRUCTURES MUNICIPALES

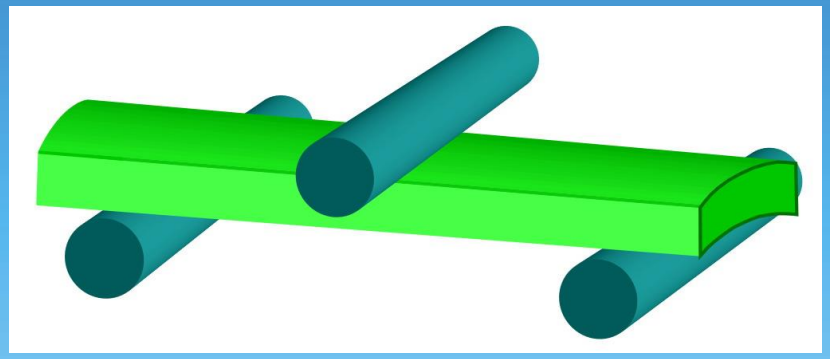
ASTM D790

3 types of test specimen permissible

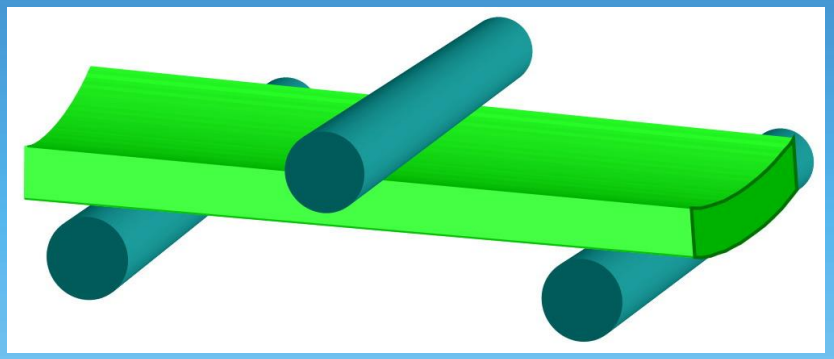


ASTM D790

2 test orientations permissible



ID in Tension



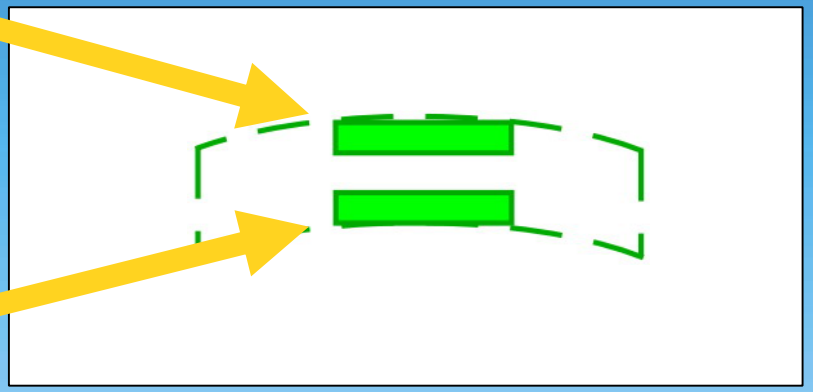
ID in Compression

ASTM D790

Through thickness location can vary

Outside Diameter

Inside Diameter



PARAGON SYSTEMS

ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

2010 Study of 9 CIPP Materials

Tested:

Specimen type, orientation, test location

Results:

All three factors predictably & significantly influence flexural test results

PARAGON SYSTEMS

ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

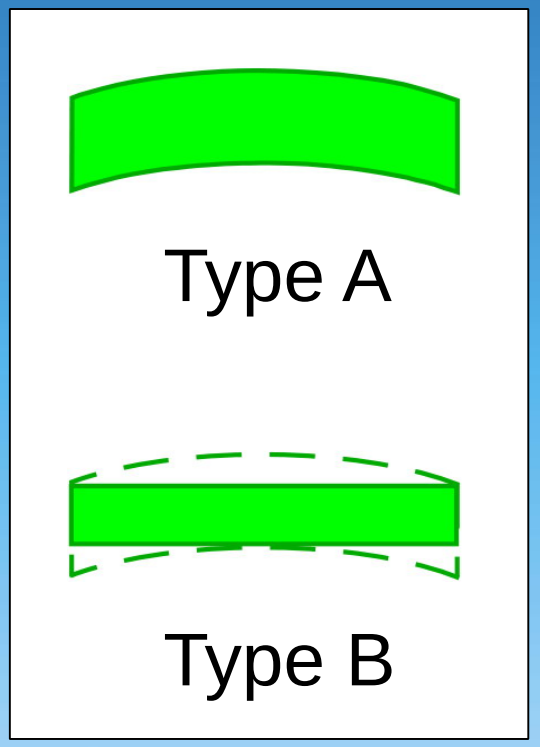
Study Results
Specimen Type

Flexural Strength

Type B as much as 39% higher than Type A

Flexural Modulus

Type B as much as 54% higher than Type A



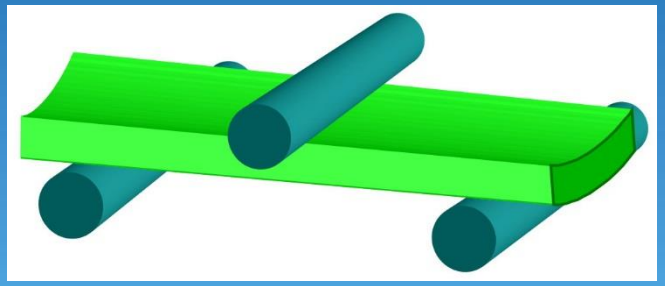
PARAGON SYSTEMS

ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

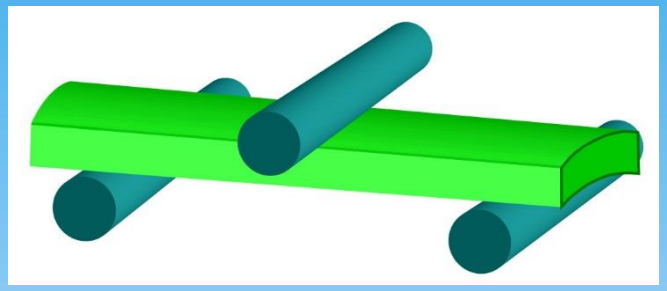
Study Results
Test Orientation

Flexural Strength
ID in tension as much as 44% higher



ID in Compression

Flexural Modulus
ID in tension as much as 57% higher



ID in Tension

PARAGON SYSTEMS

ACCREDITED

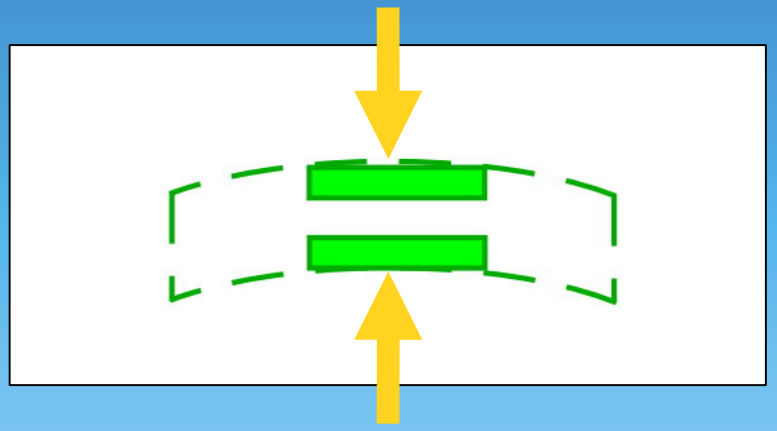
CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

Study Results
Test Location

Flexural Strength
ID location as much as 51% higher

Flexural Modulus
ID location as much as 58% higher

Outside Diameter Location



Inside Diameter Location

PARAGON SYSTEMS

ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

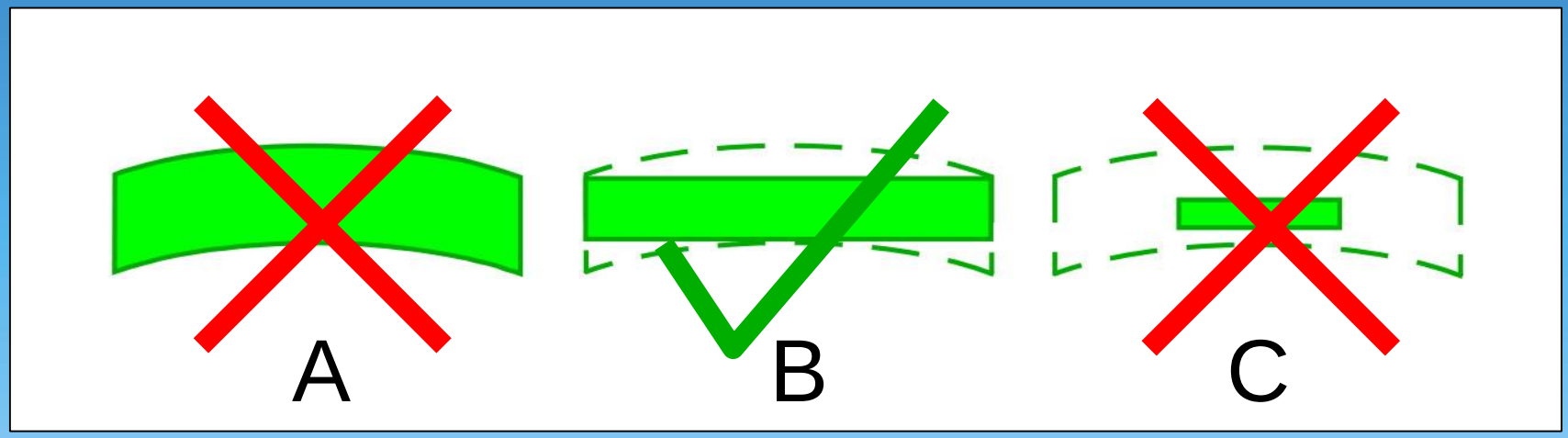
Possible Causes

- Difficult to measure non-machined original surfaces accurately.
- During curing, inside diameter of CIPP achieves higher temperature for longer time than outside diameter

Issues That Arise

- Large variation in test data between labs
- Difficult to confidently use data to confirm contract compliance
  - 1st – ASTM F1216 minimums
  - 2nd – Design modulus

Higher Flexural Properties + Lower Variation



PARAGON SYSTEMS

ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES

Questions?

tonya@paragonsystems.ca

www.paragonsystems.ca

PARAGON SYSTEMS

ACCREDITED

CERIU 18e édition 19 au 21 novembre 2012 Omni Mont-Royal Montréal INFRA 2012 INFRASTRUCTURES MUNICIPALES