Submittal

General Contractor	North American Pipeline Services, LLC
Job Name:	SEWER & MANHOLE REHABILITATION
Contract Number:	SR-01-15-15B
Submitted to:	North American Pipeline Services, LLC 210 Bennett Road, Freehold, NJ 07728
Engineer:	Maser Consulting, P.A. 331 Newman Springs Road, Suite 203, Red Bank, NJ 07701 Project No. 15001124A
Allstate Submittal #:	1
Item Submitted:	CIPP Liner Designs
Manufacturer:	N/A
Date Submitted:	March 17, 2016
Specification Section:	02607
Item is as specified in contract documents:	Yes

Certification Statement:

By this submittal, I hereby represent that I have determined and verified all field measurements, field construction criteria, materials, dimensions, catalog numbers and similar data and I have checked and coordinated each item with other applicable approved shop drawings and contract requirements.

Submitted By:

Al Hickson
Allstate Power Vac, Inc

Allstate power-vac

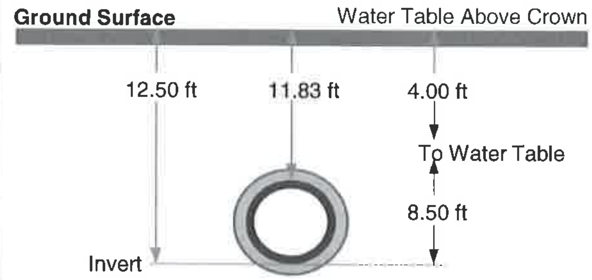
CIPP-DESIGN

CIPP Liner Thickness for Non-Pressure Pipes
By ASTM F1216-09 Appendix X1 Design Method

PROJECT INFORMATION

11-Mar-16
TOMS RIVER MUNICIPAL UTILITIES AUTHORITY
CONTRACT NO. SR-01-15B
SEWER AND MANHOLE REHABILITATION

8-inch



Size: 8 in Ovality: 2%
Fully Deteriorated Design
Required Liner Thickness: 4 mm

BY ASTM F1216 VERSION	F1216-09	CIPP liner design by Appendix X1 method of ASTM F1216-09		
EXISTING PIPE PARAMETERS	ENTERED	**FACTOR SUMMARY - FULLY DETERIORATED**		
Design Condition	Fully Det.	Flexural Modulus Design	125,000 psi	50% of Short-term
Inside Dia. of Existing Pipe	8 in	Flexural Strength Design	2,250 psi	50% of Short-term
Depth to Invert	12.5 ft	Minimum Dia for host pipe	7.84 in	For 2% ovality
Water Table Below Surface	4 ft	Maximum Dia for host pipe	8.16 in	For 2% ovality
Ovality, Δ	2%	Ovality Reduction Factor, C	0.836	
Soil Density	120 lb/ft3	Water Buoyancy Factor, Rw	0.782	
Soil Modulus	1,000 psi	Coeff of Elastic Support, B'	0.3504	
Live Load	HS-20	Water Pressure, Invert	3.68 psi	8.50 ft Head
Other Load	0 psi	Vacuum Pressure, Invert	0.00 psi	
Vacuum Condition	0 psi	Total Design Pressure, Invert	0.00 psi	For X1.1 & X1.2
CIPP LINER PARAMETERS	ENTERED	Water Pressure, Overt	3.39 psi	7.83 ft Head
Flexural Modulus short-term	250,000 psi	Soil Pressure, Overt	7.71 psi	11.83 ft Cover
Flexural Strength short-term	4,500 psi	Live Load Pressure, Overt	0.61 psi	Note 1
Long-term Retention	50%	Other Load Pressure, Overt	0.00 psi	
Enhancement Factor	7	Total Design Pressure, Overt	11.71 psi	For Eq X1.3
Poisson's Ratio	0.3	Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.		
Safety Factor	2			

FULLY DETERIORATED DESIGN REQUIRES SATISFYING F1216-X1 EQUATIONS X1.1, X1.2, X1.3 & X1.4

Equations X1.1, X1.2, X1.3 & X1.4 solved for liner thickness t		t mm	t in	DR
X1.1: $P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$ For load due to groundwater at invert		3.4 mm	0.13 in	59.8
X1.2: $(1.5\Delta/100)(1+\Delta/100)DR^2-0.5(1+\Delta/100)DR=\sigma_L/(PN)$ For minimum thickness for ovality		1.9 mm	0.07 in	106.9
X1.3: qt=[1/N]x[32xRwxB'xE'sxCx(ELxI/D^3)]^(1/2) For hydraulic, soil & live loads at overt	Governs	4.0 mm	0.16 in	50.8
X1.4: EI/D^3 = E/[12(DR^3)] ≥ 0.093 For minimum thickness fully deteriorated		3.4 mm	0.13 in	59.8
Required Liner Thickness - Fully Deteriorated		**4.0 mm**	**0.16 in**	**50.8**

t mm is rounded-up to 1 decimal place; t in = t mm/25.4; DR = (Inside Diameter in)/(t mm/25.4)   NA - Not Available/Applicable

FLOW COMPARISON PARAMETERS		**FLOW COMPARISON FOR: ENTERED LINER THICKNESS**		
Liner Thickness - Entered	6.0 mm	Inside Diameter before Lining	8.00 in	
Before Lining Manning n	0.0130	Inside Diameter after Lining	7.53 in	6.0 mm liner
After Lining Manning n	0.0100	Flow Capacity after Lining	111%	Of before Lining

COMMENTS

MUST ADD 10% TO THICKNESS FOR RESIN MIGRATION (4MM X 10% = 4.4MM)
WILL INSTALL LINER WITH A THICKNESS OF 6MM

3/15/16

ASTM F1216 APPENDIX X1 CALCULATION DETAILS: FULLY DETERIORATED DESIGN **F1216-09**

Fully deteriorated design requires satisfying 4 equations: X1.1, X1.2, X1.3 and X1.4

Check Equation X1.1

$P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$

P is the maximum allowed external pressure on the liner, with safety factor, from groundwater and any vacuum
Determine P for liner thickness of .... t = 4.0 mm   t is from summary page
K = Enhancement factor = 7
E_L = Flexural Modulus Long-term = (Flexural Modulus Short-term) x (Long-term Retention)
= 250000 x 50% = 125000 psi
v = Poisson's ratio = 0.3
DR = D/t = 8/(4/25.4) = 50.8 where D = inside diameter of existing pipe as entered
C = Ovality Reduction Factor = $([1-\Delta/100]/[1+\Delta/100]^2)^3$, where Δ is ovality of host pipe as entered.   Δ = 2
C = ([1- 2/100]/[1+2/100]^2)^3 = 0.836
N = Safety Factor = 2 As entered.
P = [(2 x 7 x 125000)/(1-0.3^2)] x [1/(50.8-1)^3] x [0.836/2] = 6.51 psi
Determine actual external pressure on liner, Pa
Pa = Ground water pressure, Pgw, + Vacuum pressure, Pv, (if any vacuum)
Pgw = 0.433 x H = 0.433 x 8.5 ft = 3.68 psi.   Where H is height of water over invert.
Pv = 0 psi As entered.
Pa = Pgw + Pv = 3.68 + 0 = 3.68 psi
Compare Pa to P
Actual external pressure on liner, Pa = 3.68 psi
Allowed external pressure for 4 mm liner, P = 6.51 psi
Is P ≥ Pa?   Yes. Equation X1.1 is satisfied by 4 mm liner rhickness
Check for DR ≤ 100 as per F1216 Appendix X1 Note X1.2
DR = 50.8 as calculated above
Is DR ≤ 100?   Yes. Note X1.2 is satisfied by liner DR of 50.8

Check Equation X1.2

X1.2: $[(1.5 \times \Delta/100) \times (1+\Delta/100) \times DR^2] - [0.5 \times (1+\Delta/100) \times DR] = (\sigma_L)/(P \times N)$
Δ = 2 As shown above in determination of C, Ovality Reduction Factor, above.
DR, calculated above = 50.8
σL = Flex Strength Long-term = (Flex Strength Short-term) x (Long-term Retention) =4500 x 50% = 2250 psi
P = External pressure on liner = Pa = 3.68 psi See above
N = safety factor = 2
Solve Eq. X1.2 for liner thickness, t. Where DR = (Liner OD)/(t)
$t = [3 \times (\Delta/100) \times Do)]/[0.5 + \{0.25 + (6 \times (\Delta/100) \times (\sigma_L/(P \times N \times (1+(\Delta/100))\}^{\wedge}.5]$
t = [3 x (2/100) x 8)]/[0.5 + {0.25 + (6 x (2/100) x (2250/(3.68 x 2 x (1+(2/100))}^0.5] = 1.9 mm
Compare liner t to t required by Equation X1.2

Liner t:	4.0 mm	t is from summary page
Required t:	1.9 mm	
Is Liner t ≥ Required t?		Yes. Equation X1.2 is satisfied by 4 mm liner thicknes.

Fully Deteriorated calculation details continued on next page

FULL FLOW CAPACITY COMPARISON BEFORE & AFTER LINING - For Entered t

Flow = Q = Area x Velocity =$[(Pi \times D^2)/4] \times [(1.486/n) \times R^{2/3} \times S^{1/2}]$ Manning formula, imperial units   t = 6 mm
S = Slope = same before & after lining; R = Hydraulic Radius = D/4 for full flow (D in ft)   D1 = 8 in = 0.667 ft
$Q2/Q1 = \{[(Pi \times (D_2^2)/4] \times [(1.486/n_2)] \times (D_2/4)^{2/3}\} / \{[(Pi \times (D_1^2)/4] \times [(1.486/n_1)] \times (D_1/4)^{2/3}\}$ D2 = 7.53 in = 0.627 ft
= {[(3.142 x (0.627^2)/4] x [(1.486/0.01)] x (0.627/4)^(2/3)} / {[(3.142 x (0.667)^2)/4] x [(1.486/0.013)] x (0.667/4)^(2/3) = 1.11
Q1 is existing (before lining). Q2 is after lining. Lined capacity is 111% of existing capacity.

ASTM F1216 APPENDIX X1 FULLY DETERIORATED CALCULATION DETAILS CONT'D **F1216-09**

Check Equation X1.3

If F1216-07a, Equation X1.3 is: $q_t=[C/N] \times [32R_wB'E'_s(E_LI/D^3)]^{1/2}$ Not using this equation

If F1216-09, Equation X1.3 is: $q_t=[1/N] \times [32R_wB'E'_sC(E_LI/D^3)]^{1/2}$ Using this equation

Where qt is the maximum allowed external pressure on the liner from cover, live loads and other loads
Determine qt for liner thickness of .... t = 4.0 mm t is from summary page
C = Ovality Reduction Factor, calculated on page 1, = 0.836
N = Safety Factor = 2
Rw = Water Bouyancy Factor (0.67 min, 1.0 max) = 1-0.33(Hw/H) = 1-0.33(7.83/11.83) = 0.782
Where Hw and H are height of water and height of soil over top of pipe. See F1216 X1.2.2
B' = Coefficent of elastic support = 1/(1+4e^[-0.665H]) = 0.3504 Where H = 11.83 and e = 2.718
E's = Modulus of soil reaction = 1000 psi. As entered.
EL = Long-term modulus for CIPP, calculated on page 1, = 125000 psi
I = Moment of inertia for liner = (t^3)/12 = (4/25.4)^3)/12 = 0.000325
D = Inside diameter of existing pipe (as entered) = mean OD of liner = 8 in
qt=[1/N]x[32xRwxB'xE'sxCx(ELxI/D^3)]^(1/2)
qt = (1/2 x [32 x 0.782 x 0.3504 x 1000 x 0.836 x ((125000 x 0.000325)/8^3)]^(1/2) = 12.06 psi

Determine actual external pressure on liner, qta

qta = Pw + Ps + Pl + Po
Pw = Water load = 0.433 x Hw = 0.433 x 7.83 = 3.39 psi Hw is water over top of pipe.
Ps = Soil Load = (w x H x Rw)/144 = (120 x 11.83 x 0.782)/144) = 7.71 psi H is soil height over top of pipe
Pl = Live load = 0.61 psi Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.
Po = Other load = 0 psi As entered
qta = 3.39 + 7.71 + 0.61 + 0 = 11.71 psi

Compare qta to qt

qta =	11.71 psi	Actual external pressure on liner
qt =	12.06 psi	Allowed external pressure for 4 mm liner
Is qt ≥ qta?		Yes. Equation X1.3 is satisfied by 4 mm liner thickness.

Check Equation X1.4

(E x I)/D^3 = E/(12 x (DR^3)) ≥ 0.093

Determine for liner thickness .... t = 4.0 mm t is from summary page
E = initial (short-term) modulus = 250000 psi
DR = liner dimension ratio = D/t = 8 / (4 / 25.4) = 50.8
E/(12 x (DR^3)) = 250000/(12 x 50.8^3) = 0.15892
Is E/(12 x (DR^3)) ≥ 0.093? Yes. Equation X1.4 is satisfied by 4 mm liner thickness

Summary for Fully Deteriorated Design

Fully Deteriorated design requires satisfying Eqs X1.1, X1.2, X1.3, X1.4

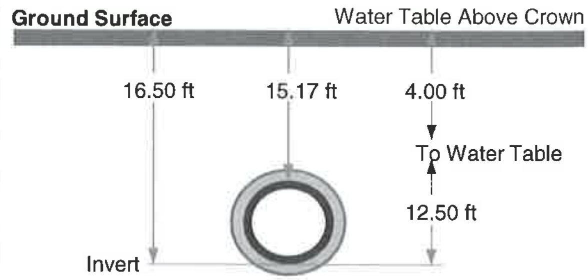
Eq X1.1	Satisfied by 4 mm liner thickness
Eq X1.2	Satisfied by 4 mm liner thickness
Eq X1.3	Satsified by 4 mm liner thickness
Eq X1.4	Satisfied by 4 mm liner thickness

Required liner thickness for fully deteriorated design is............ 4.0 mm

PROJECT INFORMATION

11-Mar-16
TOMS RIVER MUNICIPAL UTILITIES AUTHORITY
CONTRACT NO. SR-01-15B
SEWER AND MANHOLE REHABILITATION

16-INCH



Size: 16 in Ovality: 2%
Fully Deteriorated Design
Required Liner Thickness: 8.9 mm

BY ASTM F1216 VERSION	F1216-09	CIPP liner design by Appendix X1 method of ASTM F1216-09		
EXISTING PIPE PARAMETERS	ENTERED	**FACTOR SUMMARY - FULLY DETERIORATED**		
Design Condition	Fully Det.	Flexural Modulus Design	125,000 psi	50% of Short-term
Inside Dia. of Existing Pipe	16 in	Flexural Strength Design	2,250 psi	50% of Short-term
Depth to Invert	16.5 ft	Minimum Dia for host pipe	15.68 in	For 2% ovality
Water Table Below Surface	4 ft	Maximum Dia for host pipe	16.32 in	For 2% ovality
Ovality, Δ	2%	Ovality Reduction Factor, C	0.836	
Soil Density	120 lb/ft3	Water Buoyancy Factor, Rw	0.757	
Soil Modulus	1,000 psi	Coeff of Elastic Support, B'	0.4012	
Live Load	HS-20	Water Pressure, Invert	5.41 psi	12.50 ft Head
Other Load	0 psi	Vacuum Pressure, Invert	0.00 psi	
Vacuum Condition	0 psi	Total Design Pressure, Invert	0.00 psi	For X1.1 & X1.2
CIPP LINER PARAMETERS	ENTERED	Water Pressure, Overt	4.84 psi	11.17 ft Head
Flexural Modulus short-term	250,000 psi	Soil Pressure, Overt	9.57 psi	15.17 ft Cover
Flexural Strength short-term	4,500 psi	Live Load Pressure, Overt	0.28 psi	Note 1
Long-term Retention	50%	Other Load Pressure, Overt	0.00 psi	
Enhancement Factor	7	Total Design Pressure, Overt	14.69 psi	For Eq X1.3
Poisson's Ratio	0.3	Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.		
Safety Factor	2			

FULLY DETERIORATED DESIGN REQUIRES SATISFYING F1216-X1 EQUATIONS X1.1, X1.2, X1.3 & X1.4

Equations X1.1, X1.2, X1.3 & X1.4 solved for liner thickness t		**t mm**	**t in**	**DR**
X1.1: $P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$ For load due to groundwater at invert		7.6 mm	0.30 in	53.5
X1.2: $(1.5\Delta/100)(1+\Delta/100)DR^2-0.5(1+\Delta/100)DR=\sigma_L/(PN)$ For minimum thickness for ovality		4.5 mm	0.18 in	90.3
X1.3: qt=[1/N]x[32xRwxB'xE'sxCx(ELxI/D^3)]^(1/2) For hydraulic, soil & live loads at overt	Governs	8.9 mm	0.35 in	45.7
X1.4: EI/D^3 = E/[12(DR^3)] ≥ 0.093 For minimum thickness fully deteriorated		6.7 mm	0.26 in	60.7
Required Liner Thickness - Fully Deteriorated		**8.9 mm**	**0.35 in**	**45.7**

t mm is rounded-up to 1 decimal place; t in = t mm/25.4; DR = (Inside Diameter in)/(t mm/25.4) NA - Not Available/Applicable

FLOW COMPARISON PARAMETERS		**FLOW COMPARISON FOR: ENTERED LINER THICKNESS**		
Liner Thickness - Entered	10.5 mm	Inside Diameter before Lining	16.00 in	
Before Lining Manning n	0.0130	Inside Diameter after Lining	15.17 in	10.5 mm liner
After Lining Manning n	0.0100	Flow Capacity after Lining	113%	Of before Lining

COMMENTS

MUST ADD 10% TO THICKNESS FOR RESIN MIGRATION (8.9MM X 10% = 9.79MM)
WILL INSTALL LINER WITH A THICKNESS OF 10.5MM

Tom River B CIPP-DESIGN 2010

3/15/16

ASTM F1216 APPENDIX X1 CALCULATION DETAILS: FULLY DETERIORATED DESIGN — F1216-09

Fully deteriorated design requires satisfying 4 equations: X1.1, X1.2, X1.3 and X1.4

Check Equation X1.1

$P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$

P is the maximum allowed external pressure on the liner, with safety factor, from groundwater and any vacuum

Determine P for liner thickness of .... t = 8.9 mm   t is from summary page

K = Enhancement factor = 7

E_L = Flexural Modulus Long-term = (Flexural Modulus Short-term) x (Long-term Retention)

= 250000 x 50% = 125000 psi

v = Poisson's ratio = 0.3

DR = D/t = 16/(8.9/25.4) = 45.66   where D = inside diameter of existing pipe as entered

C = Ovality Reduction Factor = $([1-\Delta/100]/[1+\Delta/100]^2)^3$, where Δ is ovality of host pipe as entered.   Δ = 2

C = ([1- 2/100]/[1+2/100]^2)^3 = 0.836

N = Safety Factor = 2   As entered.

P = [(2 x 7 x 125000)/(1-0.3^2)] x [1/(45.66-1)^3] x [0.836/2] = 9.02 psi

Determine actual external pressure on liner, Pa

Pa = Ground water pressure, Pgw, + Vacuum pressure, Pv, (if any vacuum)

Pgw = 0.433 x H = 0.433 x 12.5 ft = 5.41 psi.   Where H is height of water over invert.

Pv = 0 psi   As entered.

Pa = Pgw + Pv = 5.41 + 0 = 5.41 psi

Compare Pa to P

Actual external pressure on liner, Pa = 5.41 psi

Allowed external pressure for 8.9 mm liner, P = 9.02 psi

Is P ≥ Pa?   Yes. Equation X1.1 is satisfied by 8.9 mm liner rhickness

Check for DR ≤ 100 as per F1216 Appendix X1 Note X1.2

DR = 45.66 as calculated above

Is DR ≤ 100?   Yes. Note X1.2 is satisfied by liner DR of 45.7

Check Equation X1.2

X1.2: $[(1.5 \times \Delta/100) \times (1+\Delta/100) \times DR^2] - [0.5 \times (1+\Delta/100) \times DR] = (\sigma_L)/(P \times N)$

Δ = 2   As shown above in determination of C, Ovality Reduction Factor, above.

DR, calculated above = 45.66

σL = Flex Strength Long-term = (Flex Strength Short-term) x (Long-term Retention) =4500 x 50% = 2250 psi

P = External pressure on liner = Pa = 5.41 psi   See above

N = safety factor = 2

Solve Eq. X1.2 for liner thickness, t. Where DR = (Liner OD)/(t)

$t = [3 \times (\Delta/100) \times Do)]/[0.5 + \{0.25 + (6 \times (\Delta/100) \times (\sigma_L/(P \times N \times (1+(\Delta/100))\}$^.5]

t = [3 x (2/100) x 16)]/[0.5 + {0.25 + (6 x (2/100) x (2250/(5.41 x 2 x (1+(2/100))}^0.5] = 4.5 mm

Compare liner t to t required by Equation X1.2

Liner t:	8.9 mm	t is from summary page
Required t:	4.5 mm	
Is Liner t ≥ Required t?		Yes. Equation X1.2 is satisfied by 8.9 mm liner thicknes.

Fully Deteriorated calculation details continued on next page

FULL FLOW CAPACITY COMPARISON BEFORE & AFTER LINING - For Entered t

t = 10.5 mm
D1 = 16 in = 1.333 ft
D2 = 15.17 in = 1.264 ft

Flow = Q = Area x Velocity =$[(Pi \times D^2)/4] \times [(1.486/n) \times R^{2/3} \times S^{1/2}]$ Manning formula, imperial units

S = Slope = same before & after lining; R = Hydraulic Radius = D/4 for full flow (D in ft)

$Q2/Q1 = \{[(Pi \times (D_2^2)/4] \times [(1.486/n_2)] \times (D_2/4)^{2/3}\} / \{[(Pi \times (D_1^2)/4] \times [(1.486/n_1)] \times (D_1/4)^{2/3}\}$

= {[(3.142 x (1.264^2)/4] x [(1.486/0.01)] x (1.264/4)^(2/3)} / {[(3.142 x (1.333)^2)/4] x [(1.486/0.013)] x (1.333/4)^(2/3) = 1.13

Q1 is existing (before lining). Q2 is after lining. Lined capacity is 113% of existing capacity.

ASTM F1216 APPENDIX X1 FULLY DETERIORATED CALCULATION DETAILS CONT'D **F1216-09**

Check Equation X1.3

If F1216-07a, Equation X1.3 is: q_t=[C/N] x [$32R_wB'E'_s(E_LI/D^3)$]$^{1/2}$ Not using this equation

If F1216-09, Equation X1.3 is: q_t=[1/N] x [$32R_wB'E'_sC(E_LI/D^3)$]$^{1/2}$ Using this equation

Where qt is the maximum allowed external pressure on the liner from cover, live loads and other loads
Determine qt for liner thickness of .... t = 8.9 mm t is from summary page
C = Ovality Reduction Factor, calculated on page 1, = 0.836
N = Safety Factor = 2
Rw = Water Bouyancy Factor (0.67 min, 1.0 max) = 1-0.33(Hw/H) = 1-0.33(11.17/15.17) = 0.757
Where Hw and H are height of water and height of soil over top of pipe. See F1216 X1.2.2
B' = Coefficent of elastic support = 1/(1+4e^[-0.665H]) = 0.4012 Where H = 15.17 and e = 2.718
E's = Modulus of soil reaction = 1000 psi. As entered.
EL = Long-term modulus for CIPP, calculated on page 1, = 125000 psi
I = Moment of inertia for liner = (t^3)/12 = (8.9/25.4)^3)/12 = 0.003585
D = Inside diameter of existing pipe (as entered) = mean OD of liner = 16 in
qt=[1/N]x[32xRwxB'xE'sxCx(ELxI/D^3)]^(1/2)
qt = (1/2 x [32 x 0.757 x 0.4012 x 1000 x 0.836 x ((125000 x 0.003585)/16^3)]^(1/2) = 14.91 psi

Determine actual external pressure on liner, qta

qta = Pw + Ps + Pl + Po
Pw = Water load = 0.433 x Hw = 0.433 x 11.17 = 4.84 psi Hw is water over top of pipe.
Ps = Soil Load = (w x H x Rw)/144 = (120 x 15.17 x 0.757)/144) = 9.57 psi H is soil height over top of pipe
Pl = Live load = 0.28 psi Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.
Po = Other load = 0 psi As entered
qta = 4.84 + 9.57 + 0.28 + 0 = 14.69 psi

Compare qta to qt

qta =	14.69 psi	Actual external pressure on liner
qt =	14.91 psi	Allowed external pressure for 8.9 mm liner
Is qt ≥ qta?		Yes. Equation X1.3 is satisfied by 8.9 mm liner thickness.

Check Equation X1.4

(E x I)/D^3 = E/(12 x (DR^3)) ≥ 0.093

Determine for liner thickness .... t = 8.9 mm t is from summary page
E = initial (short-term) modulus = 250000 psi
DR = liner dimension ratio = D/t = 16 / (8.9 / 25.4) = 45.66
E/(12 x (DR^3)) = 250000/(12 x 45.66^3) = 0.21885
Is E/(12 x (DR^3)) ≥ 0.093? Yes. Equation X1.4 is satisfied by 8.9 mm liner thickness

Summary for Fully Deteriorated Design

Fully Deteriorated design requires satisfying Eqs X1.1, X1.2, X1.3, X1.4

Eq X1.1	Satisfied by 8.9 mm liner thickness
Eq X1.2	Satisfied by 8.9 mm liner thickness
Eq X1.3	Satsified by 8.9 mm liner thickness
Eq X1.4	Satisfied by 8.9 mm liner thickness

Required liner thickness for fully deteriorated design is............ 8.9 mm

Allstate Power-Vac

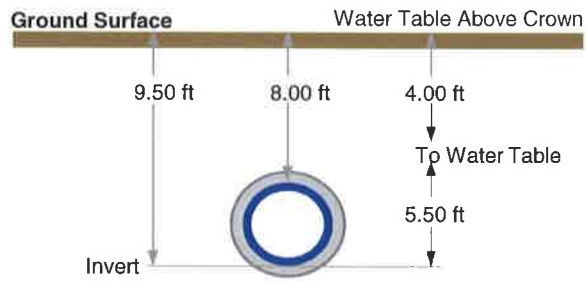
CIPP-DESIGN

CIPP Liner Thickness for Non-Pressure Pipes
By ASTM F1216-09 Appendix X1 Design Method

PROJECT INFORMATION

11-Mar-16
TOMS RIVER MUNICIPAL UTILITIES AUTHORITY
CONTRACT NO. SR-01-15B
SEWER AND MANHOLE REHABILITATION

18-inch



Size: 18 in Ovality: 2%
Fully Deteriorated Design
Required Liner Thickness: 7.6 mm

BY ASTM F1216 VERSION	F1216-09	CIPP liner design by Appendix X1 method of ASTM F1216-09		
EXISTING PIPE PARAMETERS	ENTERED	**FACTOR SUMMARY - FULLY DETERIORATED**		
Design Condition	Fully Det.	Flexural Modulus Design	125,000 psi	50% of Short-term
Inside Dia. of Existing Pipe	18 in	Flexural Strength Design	2,250 psi	50% of Short-term
Depth to Invert	9.5 ft	Minimum Dia for host pipe	17.64 in	For 2% ovality
Water Table Below Surface	4 ft	Maximum Dia for host pipe	18.36 in	For 2% ovality
Ovality, Δ	2%	Ovality Reduction Factor, C	0.836	
Soil Density	120 lb/ft3	Water Buoyancy Factor, Rw	0.835	
Soil Modulus	1,000 psi	Coeff of Elastic Support, B'	0.296	
Live Load	HS-20	Water Pressure, Invert	2.38 psi	5.50 ft Head
Other Load	0 psi	Vacuum Pressure, Invert	0.00 psi	
Vacuum Condition	0 psi	Total Design Pressure, Invert	0.00 psi	For X1.1 & X1.2
CIPP LINER PARAMETERS	ENTERED	Water Pressure, Overt	1.73 psi	4.00 ft Head
Flexural Modulus short-term	250,000 psi	Soil Pressure, Overt	5.57 psi	8.00 ft Cover
Flexural Strength short-term	4,500 psi	Live Load Pressure, Overt	1.05 psi	Note 1
Long-term Retention	50%	Other Load Pressure, Overt	0.00 psi	
Enhancement Factor	7	Total Design Pressure, Overt	8.35 psi	For Eq X1.3
Poisson's Ratio	0.3	Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.		
Safety Factor	2			

FULLY DETERIORATED DESIGN REQUIRES SATISFYING F1216-X1 EQUATIONS X1.1, X1.2, X1.3 & X1.4

Equations X1.1, X1.2, X1.3 & X1.4 solved for liner thickness t		t mm	t in	DR
X1.1: $P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$ For load due to groundwater at invert		6.5 mm	0.26 in	70.3
X1.2: $(1.5\Delta/100)(1+\Delta/100)DR^2-0.5(1+\Delta/100)DR=\sigma_L/(PN)$ For minimum thickness for ovality		3.5 mm	0.14 in	130.6
X1.3: qt=[1/N]x[32xRwxB'xE'sxCx(ELxI/D^3)]^(1/2) For hydraulic, soil & live loads at overt		7.3 mm	0.29 in	62.6
X1.4: EI/D^3 = E/[12(DR^3)] ≥ 0.093 For minimum thickness fully deteriorated	Governs	7.6 mm	0.30 in	60.2
Required Liner Thickness - Fully Deteriorated		**7.6 mm**	**0.30 in**	**60.2**

t mm is rounded-up to 1 decimal place; t in = t mm/25.4; DR = (Inside Diameter in)/(t mm/25.4) NA - Not Available/Applicable

FLOW COMPARISON PARAMETERS		**FLOW COMPARISON FOR: ENTERED LINER THICKNESS**		
Liner Thickness - Entered	9.0 mm	Inside Diameter before Lining	18.00 in	
Before Lining Manning n	0.0130	Inside Diameter after Lining	17.29 in	9.0 mm liner
After Lining Manning n	0.0100	Flow Capacity after Lining	117%	Of before Lining

COMMENTS

MUST ADD 10% TO THICKNESS FOR RESIN MIGRATION (7.6MM X 10% = 8.36MM)
WILL INSTALL LINER WITH A THICKNESS OF 9MM

3/15/16

ASTM F1216 APPENDIX X1 CALCULATION DETAILS: FULLY DETERIORATED DESIGN — F1216-09

Fully deteriorated design requires satisfying 4 equations: X1.1, X1.2, X1.3 and X1.4

Check Equation X1.1

$P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$

P is the maximum allowed external pressure on the liner, with safety factor, from groundwater and any vacuum

Determine P for liner thickness of .... t = 7.6 mm t is from summary page

K = Enhancement factor = 7

E_L = Flexural Modulus Long-term = (Flexural Modulus Short-term) x (Long-term Retention)

= 250000 x 50% = 125000 psi

v = Poisson's ratio = 0.3

DR = D/t = 18/(7.6/25.4) = 60.16 where D = inside diameter of existing pipe as entered

C = Ovality Reduction Factor = $([1-\Delta/100]/[1+\Delta/100]^2)^3$, where Δ is ovality of host pipe as entered. Δ = 2

C = ([1- 2/100]/[1+2/100]^2)^3 = 0.836

N = Safety Factor = 2 As entered.

P = [(2 x 7 x 125000)/(1-0.3^2)] x [1/(60.16-1)^3] x [0.836/2] = 3.88 psi

Determine actual external pressure on liner, Pa

Pa = Ground water pressure, Pgw, + Vacuum pressure, Pv, (if any vacuum)

Pgw = 0.433 x H = 0.433 x 5.5 ft = 2.38 psi. Where H is height of water over invert.

Pv = 0 psi As entered.

Pa = Pgw + Pv = 2.38 + 0 = 2.38 psi

Compare Pa to P

Actual external pressure on liner, Pa = 2.38 psi

Allowed external pressure for 7.6 mm liner, P = 3.88 psi

Is P ≥ Pa? Yes. Equation X1.1 is satisfied by 7.6 mm liner rhickness

Check for DR ≤ 100 as per F1216 Appendix X1 Note X1.2

DR = 60.16 as calculated above

Is DR ≤ 100? Yes. Note X1.2 is satisfied by liner DR of 60.2

Check Equation X1.2

X1.2: $[(1.5 \times \Delta/100) \times (1+\Delta/100) \times DR^2] - [0.5 \times (1+\Delta/100) \times DR] = (\sigma_L)/(P \times N)$

Δ = 2 As shown above in determination of C, Ovality Reduction Factor, above.

DR, calculated above = 60.16

σL = Flex Strength Long-term = (Flex Strength Short-term) x (Long-term Retention) =4500 x 50% = 2250 psi

P = External pressure on liner = Pa = 2.38 psi See above

N = safety factor = 2

Solve Eq. X1.2 for liner thickness, t. Where DR = (Liner OD)/(t)

$t = [3 \times (\Delta/100) \times Do)]/[0.5 + \{0.25 + (6 \times (\Delta/100) \times (\sigma_L/(P \times N \times (1+(\Delta/100))\}^{.5}]$

t = [3 x (2/100) x 18)]/[0.5 + {0.25 + (6 x (2/100) x (2250/(2.38 x 2 x (1+(2/100))}^0.5] = 3.5 mm

Compare liner t to t required by Equation X1.2

Liner t: 7.6 mm t is from summary page

Required t: 3.5 mm

Is Liner t ≥ Required t? Yes. Equation X1.2 is satisfied by 7.6 mm liner thicknes.

Fully Deteriorated calculation details continued on next page

FULL FLOW CAPACITY COMPARISON BEFORE & AFTER LINING - For Entered t

t = 9 mm
D1 = 18 in = 1.5 ft
D2 = 17.29 in = 1.441 ft

Flow = Q = Area x Velocity $=[(Pi \times D^2)/4] \times [(1.486/n) \times R^{2/3} \times S^{1/2}]$ Manning formula, imperial units

S = Slope = same before & after lining; R = Hydraulic Radius = D/4 for full flow (D in ft)

$Q2/Q1 = \{[(Pi \times (D_2^2)/4] \times [(1.486/n_2)] \times (D_2/4)^{2/3}\} / \{[(Pi \times (D_1^2)/4] \times [(1.486/n_1)] \times (D_1/4)^{2/3}\}$

= {[(3.142 x (1.441^2)/4] x [(1.486/0.01)] x (1.441/4)^(2/3)} / {[(3.142 x (1.5)^2)/4] x [(1.486/0.013)] x (1.5/4)^(2/3) = 1.17

Q1 is existing (before lining). Q2 is after lining. Lined capacity is 117% of existing capacity.

ASTM F1216 APPENDIX X1 FULLY DETERIORATED CALCULATION DETAILS CONT'D — F1216-09

Check Equation X1.3

If F1216-07a, Equation X1.3 is: $q_t=[C/N] \times [32R_wB'E'_s(E_LI/D^3)]^{1/2}$ — Not using this equation

If F1216-09, Equation X1.3 is: $q_t=[1/N] \times [32R_wB'E'_sC(E_LI/D^3)]^{1/2}$ — Using this equation

Where qt is the maximum allowed external pressure on the liner from cover, live loads and other loads
Determine qt for liner thickness of .... t = 7.6 mm — t is from summary page
C = Ovality Reduction Factor, calculated on page 1, = 0.836
N = Safety Factor = 2
Rw = Water Bouyancy Factor (0.67 min, 1.0 max) = 1-0.33(Hw/H) = 1-0.33(4/8) = 0.835
Where Hw and H are height of water and height of soil over top of pipe. See F1216 X1.2.2
B' = Coefficent of elastic support = 1/(1+4e^[-0.665H]) = 0.296 Where H = 8 and e = 2.718
E's = Modulus of soil reaction = 1000 psi. As entered.
EL = Long-term modulus for CIPP, calculated on page 1, = 125000 psi
I = Moment of inertia for liner = (t^3)/12 = (7.6/25.4)^3)/12 = 0.002232
D = Inside diameter of existing pipe (as entered) = mean OD of liner = 18 in
qt=[1/N]x[32xRwxB'xE'sxCx(ELxI/D^3)]^(1/2)
qt = (1/2 x [32 x 0.835 x 0.296 x 1000 x 0.836 x ((125000 x 0.002232)/18^3)]^(1/2) = 8.89 psi

Determine actual external pressure on liner, qta

qta = Pw + Ps + Pl + Po
Pw = Water load = 0.433 x Hw = 0.433 x 4 = 1.73 psi — Hw is water over top of pipe.
Ps = Soil Load = (w x H x Rw)/144 = (120 x 8 x 0.835)/144) = 5.57 psi — H is soil height over top of pipe
Pl = Live load = 1.05 psi — Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.
Po = Other load = 0 psi — As entered
qta = 1.73 + 5.57 + 1.05 + 0 = 8.35 psi

Compare qta to qt

qta =	8.35 psi	Actual external pressure on liner
qt =	8.89 psi	Allowed external pressure for 7.6 mm liner
Is qt ≥ qta?		Yes. Equation X1.3 is satisfied by 7.6 mm liner thickness.

Check Equation X1.4

(E x I)/D^3 = E/(12 x (DR^3)) ≥ 0.093

Determine for liner thickness .... t = 7.6 mm — t is from summary page
E = initial (short-term) modulus = 250000 psi
DR = liner dimension ratio = D/t = 18 / (7.6 / 25.4) = 60.16
E/(12 x (DR^3)) = 250000/(12 x 60.16^3) = 0.09568
Is E/(12 x (DR^3)) ≥ 0.093? — Yes. Equation X1.4 is satisfied by 7.6 mm liner thickness

Summary for Fully Deteriorated Design

Fully Deteriorated design requires satisfying Eqs X1.1, X1.2, X1.3, X1.4

Eq X1.1	Satisfied by 7.6 mm liner thickness
Eq X1.2	Satisfied by 7.6 mm liner thickness
Eq X1.3	Satsified by 7.6 mm liner thickness
Eq X1.4	Satsified by 7.6 mm liner thickness

Required liner thickness for fully deteriorated design is............ 7.6 mm

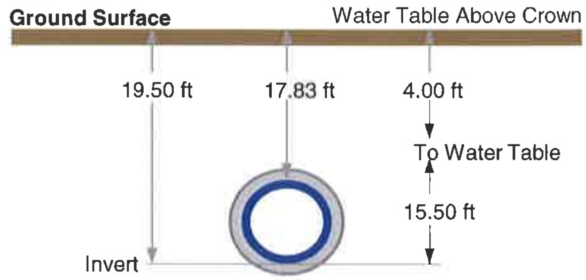
CIPP-DESIGN

CIPP Liner Thickness for Non-Pressure Pipes
By ASTM F1216-09 Appendix X1 Design Method

PROJECT INFORMATION

11-Mar-16
TOMS RIVER MUNICIPAL UTILITIES AUTHORITY
CONTRACT NO. SR-01-15B
SEWER AND MANHOLE REHABILITATION

20-inch



Size: 20 in Ovality: 2%
Fully Deteriorated Design
Required Liner Thickness: 11.9 mm

BY ASTM F1216 VERSION	F1216-09	CIPP liner design by Appendix X1 method of ASTM F1216-09		
EXISTING PIPE PARAMETERS	ENTERED	**FACTOR SUMMARY - FULLY DETERIORATED**		
Design Condition	Fully Det.	Flexural Modulus Design	125,000 psi	50% of Short-term
Inside Dia. of Existing Pipe	20 in	Flexural Strength Design	2,250 psi	50% of Short-term
Depth to Invert	19.5 ft	Minimum Dia for host pipe	19.60 in	For 2% ovality
Water Table Below Surface	4 ft	Maximum Dia for host pipe	20.40 in	For 2% ovality
Ovality, Δ	2%	Ovality Reduction Factor, C	0.836	
Soil Density	120 lb/ft3	Water Buoyancy Factor, Rw	0.744	
Soil Modulus	1,000 psi	Coeff of Elastic Support, B'	0.4434	
Live Load	HS-20	Water Pressure, Invert	6.71 psi	15.50 ft Head
Other Load	0 psi	Vacuum Pressure, Invert	0.00 psi	
Vacuum Condition	0 psi	Total Design Pressure, Invert	0.00 psi	For X1.1 & X1.2
CIPP LINER PARAMETERS	ENTERED	Water Pressure, Overt	5.99 psi	13.83 ft Head
Flexural Modulus short-term	250,000 psi	Soil Pressure, Overt	11.06 psi	17.83 ft Cover
Flexural Strength short-term	4,500 psi	Live Load Pressure, Overt	0.02 psi	Note 1
Long-term Retention	50%	Other Load Pressure, Overt	0.00 psi	
Enhancement Factor	7	Total Design Pressure, Overt	17.06 psi	For Eq X1.3
Poisson's Ratio	0.3	Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.		
Safety Factor	2			

FULLY DETERIORATED DESIGN REQUIRES SATISFYING F1216-X1 EQUATIONS X1.1, X1.2, X1.3 & X1.4

Equations X1.1, X1.2, X1.3 & X1.4 solved for liner thickness t	t mm	t in	DR
X1.1: $P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$ For load due to groundwater at invert	10.2 mm	0.40 in	49.8
X1.2: $(1.5\Delta/100)(1+\Delta/100)DR^2-0.5(1+\Delta/100)DR=\sigma_L/(PN)$ For minimum thickness for ovality	6.2 mm	0.24 in	81.9
X1.3: qt=[1/N]x[32xRwxB'xE'sxCx(ELxl/D^3)]^(1/2) Governs For hydraulic, soil & live loads at overt	11.9 mm	0.47 in	42.7
X1.4: EI/D^3 = E/[12(DR^3)] ≥ 0.093 For minimum thickness fully deteriorated	8.4 mm	0.33 in	60.5
Required Liner Thickness - Fully Deteriorated	**11.9 mm**	**0.47 in**	**42.7**

t mm is rounded-up to 1 decimal place; t in = t mm/25.4; DR = (Inside Diameter in)/(t mm/25.4) NA - Not Available/Applicable

FLOW COMPARISON PARAMETERS		**FLOW COMPARISON FOR: ENTERED LINER THICKNESS**		
Liner Thickness - Entered	13.5 mm	Inside Diameter before Lining	20.00 in	
Before Lining Manning n	0.0130	Inside Diameter after Lining	18.94 in	13.5 mm liner
After Lining Manning n	0.0100	Flow Capacity after Lining	112%	Of before Lining

COMMENTS

MUST ADD 10% TO THICKNESS FOR RESIN MIGRATION (11.9MM X 10% = 13.09MM)
WILL INSTALL LINER WITH A THICKNESS OF 13.5MM

3/15/16

ASTM F1216 APPENDIX X1 CALCULATION DETAILS: FULLY DETERIORATED DESIGN **F1216-09**

Fully deteriorated design requires satisfying 4 equations: X1.1, X1.2, X1.3 and X1.4

Check Equation X1.1

$P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$

P is the maximum allowed external pressure on the liner, with safety factor, from groundwater and any vacuum

Determine P for liner thickness of .... t = 11.9 mm   t is from summary page

K = Enhancement factor = 7

E_L = Flexural Modulus Long-term = (Flexural Modulus Short-term) x (Long-term Retention)

= 250000 x 50% = 125000 psi

v = Poisson's ratio = 0.3

DR = D/t = 20/(11.9/25.4) = 42.69   where D = inside diameter of existing pipe as entered

C = Ovality Reduction Factor = $([1-\Delta/100]/[1+\Delta/100]^2)^3$, where Δ is ovality of host pipe as entered.   Δ = 2

C = ([1- 2/100]/[1+2/100]^2)^3 = 0.836

N = Safety Factor = 2   As entered.

P = [(2 x 7 x 125000)/(1-0.3^2)] x [1/(42.69-1)^3] x [0.836/2] = 11.09 psi

Determine actual external pressure on liner, Pa

Pa = Ground water pressure, Pgw, + Vacuum pressure, Pv, (if any vacuum)

Pgw = 0.433 x H = 0.433 x 15.5 ft = 6.71 psi.   Where H is height of water over invert.

Pv = 0 psi   As entered.

Pa = Pgw + Pv = 6.71 + 0 = 6.71 psi

Compare Pa to P

Actual external pressure on liner, Pa = 6.71 psi

Allowed external pressure for 11.9 mm liner, P = 11.09 psi

Is P ≥ Pa?   Yes. Equation X1.1 is satisfied by 11.9 mm liner rhickness

Check for DR ≤ 100 as per F1216 Appendix X1 Note X1.2

DR = 42.69 as calculated above

Is DR ≤ 100?   Yes. Note X1.2 is satisfied by liner DR of 42.7

Check Equation X1.2

X1.2: $[(1.5 \times \Delta/100) \times (1+\Delta/100) \times DR^2] - [0.5 \times (1+\Delta/100) \times DR] = (\sigma_L)/(P \times N)$

Δ = 2   As shown above in determination of C, Ovality Reduction Factor, above.

DR, calculated above = 42.69

σL = Flex Strength Long-term = (Flex Strength Short-term) x (Long-term Retention) =4500 x 50% = 2250 psi

P = External pressure on liner = Pa = 6.71 psi See above

N = safety factor = 2

Solve Eq. X1.2 for liner thickness, t. Where DR = (Liner OD)/(t)

$t = [3 \times (\Delta/100) \times Do)]/[0.5 + \{0.25 + (6 \times (\Delta/100) \times (\sigma_L/(P \times N \times (1+(\Delta/100))\}^{\wedge}.5]$

t = [3 x (2/100) x 20)]/[0.5 + {0.25 + (6 x (2/100) x (2250/(6.71 x 2 x (1+(2/100))}^0.5] = 6.2 mm

Compare liner t to t required by Equation X1.2

Liner t:	11.9 mm	t is from summary page
Required t:	6.2 mm	
Is Liner t ≥ Required t?		Yes. Equation X1.2 is satisfied by 11.9 mm liner thicknes.

Fully Deteriorated calculation details continued on next page

FULL FLOW CAPACITY COMPARISON BEFORE & AFTER LINING - For Entered t

Flow = Q = Area x Velocity =$[(Pi \times D^2)/4] \times [(1.486/n) \times R^{2/3} \times S^{1/2}]$ Manning formula, imperial units   t = 13.5 mm

S = Slope = same before & after lining; R = Hydraulic Radius = D/4 for full flow (D in ft)   D1 = 20 in = 1.667 ft

$Q2/Q1 = \{[(Pi \times (D_2^2)/4] \times [(1.486/n_2)] \times (D_2/4)^{2/3}\} / \{[(Pi \times (D_1^2)/4] \times [(1.486/n_1)] \times (D_1/4)^{2/3}\}$ D2 = 18.94 in = 1.578 ft

= {[(3.142 x (1.578^2)/4] x [(1.486/0.01)] x (1.578/4)^(2/3)} / {[(3.142 x (1.667)^2)/4] x [(1.486/0.013)] x (1.667/4)^(2/3) = 1.12

Q1 is existing (before lining). Q2 is after lining. Lined capacity is 112% of existing capacity.

ASTM F1216 APPENDIX X1 FULLY DETERIORATED CALCULATION DETAILS CONT'D **F1216-09**

Check Equation X1.3

If F1216-07a, Equation X1.3 is: $q_t=[C/N] \times [32R_wB'E'_s(E_LI/D^3)]^{1/2}$ Not using this equation

If F1216-09, Equation X1.3 is: $q_t=[1/N] \times [32R_wB'E'_sC(E_LI/D^3)]^{1/2}$ Using this equation

Where qt is the maximum allowed external pressure on the liner from cover, live loads and other loads
Determine qt for liner thickness of .... t = 11.9 mm t is from summary page
C = Ovality Reduction Factor, calculated on page 1, = 0.836
N = Safety Factor = 2
Rw = Water Bouyancy Factor (0.67 min, 1.0 max) = 1-0.33(Hw/H) = 1-0.33(13.83/17.83) = 0.744
Where Hw and H are height of water and height of soil over top of pipe. See F1216 X1.2.2
B' = Coefficent of elastic support = 1/(1+4e^[-0.665H]) = 0.4434 Where H = 17.83 and e = 2.718
E's = Modulus of soil reaction = 1000 psi. As entered.
EL = Long-term modulus for CIPP, calculated on page 1, = 125000 psi
I = Moment of inertia for liner = (t^3)/12 = (11.9/25.4)^3)/12 = 0.00857
D = Inside diameter of existing pipe (as entered) = mean OD of liner = 20 in
qt=[1/N]x[32xRwxB'xE'sxCx(ELxI/D^3)]^(1/2)
qt = (1/2 x [32 x 0.744 x 0.4434 x 1000 x 0.836 x ((125000 x 0.00857)/20^3)]^(1/2) = 17.19 psi

Determine actual external pressure on liner, qta

qta = Pw + Ps + Pl + Po
Pw = Water load = 0.433 x Hw = 0.433 x 13.83 = 5.99 psi Hw is water over top of pipe.
Ps = Soil Load = (w x H x Rw)/144 = (120 x 17.83 x 0.744)/144) = 11.06 psi H is soil height over top of pipe
Pl = Live load = 0.02 psi Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.
Po = Other load = 0 psi As entered
qta = 5.99 + 11.06 + 0.02 + 0 = 17.06 psi

Compare qta to qt

qta =	17.06 psi	Actual external pressure on liner
qt =	17.19 psi	Allowed external pressure for 11.9 mm liner
Is qt ≥ qta?		Yes. Equation X1.3 is satisfied by 11.9 mm liner thickness.

Check Equation X1.4

(E x I)/D^3 = E/(12 x (DR^3)) ≥ 0.093

Determine for liner thickness .... t = 11.9 mm t is from summary page
E = initial (short-term) modulus = 250000 psi
DR = liner dimension ratio = D/t = 20 / (11.9 / 25.4) = 42.69
E/(12 x (DR^3)) = 250000/(12 x 42.69^3) = 0.26778
Is E/(12 x (DR^3)) ≥ 0.093? Yes. Equation X1.4 is satisfied by 11.9 mm liner thickness

Summary for Fully Deteriorated Design

Fully Deteriorated design requires satisfying Eqs X1.1, X1.2, X1.3, X1.4

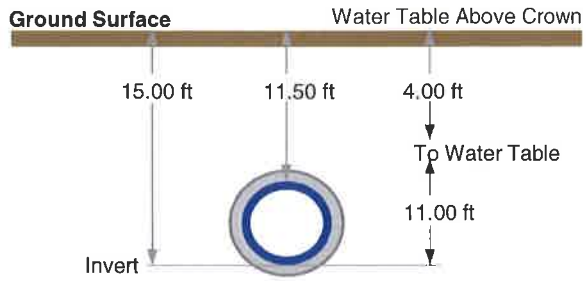
Eq X1.1	Satisfied by 11.9 mm liner thickness
Eq X1.2	Satisfied by 11.9 mm liner thickness
Eq X1.3	Satsified by 11.9 mm liner thickness
Eq X1.4	Satsified by 11.9 mm liner thickness

Required liner thickness for fully deteriorated design is............ 11.9 mm

PROJECT INFORMATION

11-Mar-16
TOMS RIVER MUNICIPAL UTILITIES AUTHORITY
CONTRACT NO. SR-01-15B
SEWER AND MANHOLE REHABILITATION

42-inch



Size: 42 in Ovality: 2%
Fully Deteriorated Design
Required Liner Thickness: 20.4 mm

BY ASTM F1216 VERSION	F1216-09	CIPP liner design by Appendix X1 method of ASTM F1216-09		
EXISTING PIPE PARAMETERS	ENTERED	**FACTOR SUMMARY - FULLY DETERIORATED**		
Design Condition	Fully Det.	Flexural Modulus Design	125,000 psi	50% of Short-term
Inside Dia. of Existing Pipe	42 in	Flexural Strength Design	2,250 psi	50% of Short-term
Depth to Invert	15 ft	Minimum Dia for host pipe	41.16 in	For 2% ovality
Water Table Below Surface	4 ft	Maximum Dia for host pipe	42.84 in	For 2% ovality
Ovality, Δ	2%	Ovality Reduction Factor, C	0.836	
Soil Density	120 lb/ft3	Water Buoyancy Factor, Rw	0.785	
Soil Modulus	1,000 psi	Coeff of Elastic Support, B'	0.3455	
Live Load	HS-20	Water Pressure, Invert	4.76 psi	11.00 ft Head
Other Load	0 psi	Vacuum Pressure, Invert	0.00 psi	
Vacuum Condition	0 psi	Total Design Pressure, Invert	0.00 psi	For X1.1 & X1.2
CIPP LINER PARAMETERS	ENTERED	Water Pressure, Overt	3.25 psi	7.50 ft Head
Flexural Modulus short-term	250,000 psi	Soil Pressure, Overt	7.52 psi	11.50 ft Cover
Flexural Strength short-term	4,500 psi	Live Load Pressure, Overt	0.64 psi	Note 1
Long-term Retention	50%	Other Load Pressure, Overt	0.00 psi	
Enhancement Factor	7	Total Design Pressure, Overt	11.41 psi	For Eq X1.3
Poisson's Ratio	0.3	Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.		
Safety Factor	2			

FULLY DETERIORATED DESIGN REQUIRES SATISFYING F1216-X1 EQUATIONS X1.1, X1.2, X1.3 & X1.4

Equations X1.1, X1.2, X1.3 & X1.4 solved for liner thickness t		**t mm**	**t in**	**DR**
X1.1: $P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$ For load due to groundwater at invert		19.0 mm	0.75 in	56.1
X1.2: $(1.5\Delta/100)(1+\Delta/100)DR^2-0.5(1+\Delta/100)DR=\sigma_L/(PN)$ For minimum thickness for ovality		11.1 mm	0.44 in	96.1
X1.3: qt=[1/N]x[32xRwxB'xE'sxCx(ELxI/D^3)]^(1/2) For hydraulic, soil & live loads at overt	Governs	20.4 mm	0.80 in	52.3
X1.4: EI/D^3 = E/[12(DR^3)] ≥ 0.093 For minimum thickness fully deteriorated		17.6 mm	0.69 in	60.6
Required Liner Thickness - Fully Deteriorated		**20.4 mm**	**0.80 in**	**52.3**

t mm is rounded-up to 1 decimal place; t in = t mm/25.4; DR = (Inside Diameter in)/(t mm/25.4) NA - Not Available/Applicable

FLOW COMPARISON PARAMETERS		**FLOW COMPARISON FOR: ENTERED LINER THICKNESS**		
Liner Thickness - Entered	22.5 mm	Inside Diameter before Lining	42.00 in	
Before Lining Manning n	0.0130	Inside Diameter after Lining	40.23 in	22.5 mm liner
After Lining Manning n	0.0100	Flow Capacity after Lining	116%	Of before Lining

COMMENTS

MUST ADD 10% TO THICKNESS FOR RESIN MIGRATION (20.4MM X 10% = 22.44MM)
WILL INSTALL LINER WITH A THICKNESS OF 22.5MM

3/15/16

ASTM F1216 APPENDIX X1 CALCULATION DETAILS: FULLY DETERIORATED DESIGN **F1216-09**

Fully deteriorated design requires satisfying 4 equations: X1.1, X1.2, X1.3 and X1.4

Check Equation X1.1

$P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$

P is the maximum allowed external pressure on the liner, with safety factor, from groundwater and any vacuum

Determine P for liner thickness of .... t = 20.4 mm t is from summary page

K = Enhancement factor = 7

E_L = Flexural Modulus Long-term = (Flexural Modulus Short-term) x (Long-term Retention)

= 250000 x 50% = 125000 psi

v = Poisson's ratio = 0.3

DR = D/t = 42/(20.4/25.4) = 52.29 where D = inside diameter of existing pipe as entered

C = Ovality Reduction Factor = $([1-\Delta/100]/[1+\Delta/100]^2)^3$, where Δ is ovality of host pipe as entered. Δ = 2

C = ([1- 2/100]/[1+2/100]^2)^3 = 0.836

N = Safety Factor = 2 As entered.

P = [(2 x 7 x 125000)/(1-0.3^2)] x [1/(52.29-1)^3] x [0.836/2] = 5.96 psi

Determine actual external pressure on liner, Pa

Pa = Ground water pressure, Pgw, + Vacuum pressure, Pv, (if any vacuum)

Pgw = 0.433 x H = 0.433 x 11 ft = 4.76 psi. Where H is height of water over invert.

Pv = 0 psi As entered.

Pa = Pgw + Pv = 4.76 + 0 = 4.76 psi

Compare Pa to P

Actual external pressure on liner, Pa = 4.76 psi

Allowed external pressure for 20.4 mm liner, P = 5.96 psi

Is P ≥ Pa? Yes. Equation X1.1 is satisfied by 20.4 mm liner rhickness

Check for DR ≤ 100 as per F1216 Appendix X1 Note X1.2

DR = 52.29 as calculated above

Is DR ≤ 100? Yes. Note X1.2 is satisfied by liner DR of 52.3

Check Equation X1.2

X1.2: $[(1.5 \times \Delta/100) \times (1+\Delta/100) \times DR^2] - [0.5 \times (1+\Delta/100) \times DR] = (\sigma_L)/(P \times N)$

Δ = 2 As shown above in determination of C, Ovality Reduction Factor, above.

DR, calculated above = 52.29

σL = Flex Strength Long-term = (Flex Strength Short-term) x (Long-term Retention) =4500 x 50% = 2250 psi

P = External pressure on liner = Pa = 4.76 psi See above

N = safety factor = 2

Solve Eq. X1.2 for liner thickness, t. Where DR = (Liner OD)/(t)

$t = [3 \times (\Delta/100) \times Do)]/[0.5 + \{0.25 + (6 \times (\Delta/100) \times (\sigma_L/(P \times N \times (1+(\Delta/100))\}\hat{}.5]$

t = [3 x (2/100) x 42)]/[0.5 + {0.25 + (6 x (2/100) x (2250/(4.76 x 2 x (1+(2/100))}^0.5] = 11.1 mm

Compare liner t to t required by Equation X1.2

Liner t:	20.4 mm	t is from summary page
Required t:	11.1 mm	
Is Liner t ≥ Required t?		Yes. Equation X1.2 is satisfied by 20.4 mm liner thicknes.

Fully Deteriorated calculation details continued on next page

FULL FLOW CAPACITY COMPARISON BEFORE & AFTER LINING - For Entered t

Flow = Q = Area x Velocity =$[(Pi \times D^2)/4] \times [(1.486/n) \times R^{2/3} \times S^{1/2}]$ Manning formula, imperial units — t = 22.5 mm

S = Slope = same before & after lining; R = Hydraulic Radius = D/4 for full flow (D in ft) — D1 = 42 in = 3.5 ft

$Q2/Q1 = \{[(Pi \times (D_2^2)/4] \times [(1.486/n_2)] \times (D_2/4)^{2/3}\} / \{[(Pi \times (D_1^2)/4] \times [(1.486/n_1)] \times (D_1/4)^{2/3}\}$ — D2 = 40.23 in = 3.352 ft

= {[(3.142 x (3.352^2)/4] x [(1.486/0.01)] x (3.352/4)^(2/3)} / {[(3.142 x (3.5)^2)/4] x [(1.486/0.013)] x (3.5/4)^(2/3) = 1.16

Q1 is existing (before lining). Q2 is after lining. Lined capacity is 116% of existing capacity.

ASTM F1216 APPENDIX X1 FULLY DETERIORATED CALCULATION DETAILS CONT'D — F1216-09

Check Equation X1.3

If F1216-07a, Equation X1.3 is: $q_t=[C/N] \times [32R_wB'E'_s(E_L I/D^3)]^{1/2}$ — Not using this equation

If F1216-09, Equation X1.3 is: $q_t=[1/N] \times [32R_wB'E'_sC(E_L I/D^3)]^{1/2}$ — Using this equation

Where qt is the maximum allowed external pressure on the liner from cover, live loads and other loads
Determine qt for liner thickness of .... t = 20.4 mm — t is from summary page
C = Ovality Reduction Factor, calculated on page 1, = 0.836
N = Safety Factor = 2
Rw = Water Bouyancy Factor (0.67 min, 1.0 max) = 1-0.33(Hw/H) = 1-0.33(7.5/11.5) = 0.785
Where Hw and H are height of water and height of soil over top of pipe. See F1216 X1.2.2
B' = Coefficent of elastic support = 1/(1+4e^[-0.665H]) = 0.3455 Where H = 11.5 and e = 2.718
E's = Modulus of soil reaction = 1000 psi. As entered.
EL = Long-term modulus for CIPP, calculated on page 1, = 125000 psi
I = Moment of inertia for liner = (t^3)/12 = (20.4/25.4)^3)/12 = 0.043173
D = Inside diameter of existing pipe (as entered) = mean OD of liner = 42 in
qt=[1/N]x[32xRwxB'xE'sxCx(ELxI/D^3)]^(1/2)
qt = (1/2 x [32 x 0.785 x 0.3455 x 1000 x 0.836 x ((125000 x 0.043173)/42^3)]^(1/2) = 11.49 psi

Determine actual external pressure on liner, qta

qta = Pw + Ps + Pl + Po
Pw = Water load = 0.433 x Hw = 0.433 x 7.5 = 3.25 psi — Hw is water over top of pipe.
Ps = Soil Load = (w x H x Rw)/144 = (120 x 11.5 x 0.785)/144) = 7.52 psi — H is soil height over top of pipe
Pl = Live load = 0.64 psi — Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.
Po = Other load = 0 psi As entered
qta = 3.25 + 7.52 + 0.64 + 0 = 11.41 psi

Compare qta to qt

qta =	11.41 psi	Actual external pressure on liner
qt =	11.49 psi	Allowed external pressure for 20.4 mm liner
Is qt ≥ qta?		Yes. Equation X1.3 is satisfied by 20.4 mm liner thickness.

Check Equation X1.4

(E x I)/D^3 = E/(12 x (DR^3)) ≥ 0.093
Determine for liner thickness .... t = 20.4 mm — t is from summary page
E = initial (short-term) modulus = 250000 psi
DR = liner dimension ratio = D/t = 42 / (20.4 / 25.4) = 52.29
E/(12 x (DR^3)) = 250000/(12 x 52.29^3) = 0.14571
Is E/(12 x (DR^3)) ≥ 0.093? — Yes. Equation X1.4 is satisfied by 20.4 mm liner thickness

Summary for Fully Deteriorated Design

Fully Deteriorated design requires satisfying Eqs X1.1, X1.2, X1.3, X1.4

Eq X1.1	Satisfied by 20.4 mm liner thickness
Eq X1.2	Satisfied by 20.4 mm liner thickness
Eq X1.3	Satsified by 20.4 mm liner thickness
Eq X1.4	Satisfied by 20.4 mm liner thickness

Required liner thickness for fully deteriorated design is............ 20.4 mm