2019 TRENCHLESS MIDDLE EAST

International Design Standards for CIPP Liners and their Application in the GCC Region

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Cured In Place Pipe – CIPP

- The leading trenchless sewer rehabilitation method globally
- In use for more than 40 years – first installation London 1971
- More than 12,000 km installed annually worldwide
- Diameter range from 100mm to more than 2000mm

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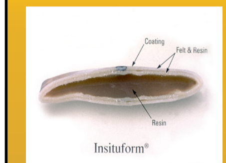

- Inversion – Air
- Inversion - Water
- Pull-in & Inflate
- Polyester Resin
- Epoxy Resin
- Vinyl Ester Resin
- Silicate Resin
- Polyester Felt Tube
- Glass Fibre Tube
- Hot Water Curing
- Steam Curing
- UV Light Curing
- LED Light Curing

96 possible combinations

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Installation Method

Resin Type

Tube Material

Curing Method

Each element can influence performance of the finished liner so must be selected carefully to meet the needs of the project in each case.

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How do we design CIPP liners?

Purpose:

- To provide structural resistance to external loads
- To stop infiltration of groundwater and/or exfiltration of sewage
- To do so for a service life of ≥ 50 years

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How do we design CIPP liners?

Design is structural

- To resist external loads safely for ≥ 50 years

Stopping infiltration/exfiltration is a property of the material

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Internationally recognised liner design methods

- ASTM (USA): Standard F1216-16
  based on Timoshenko theory of plates and shells
  (circular sewers only)
- WRc (UK): Sewer Rehabilitation Manual
- DWA (Germany): Arbeitsblatt DWA-A143-2
  based on Glock theory of rigid pipes under external water pressure
- ASTEE (France): 3R2014
  also based on Glock. For non-circular sewers

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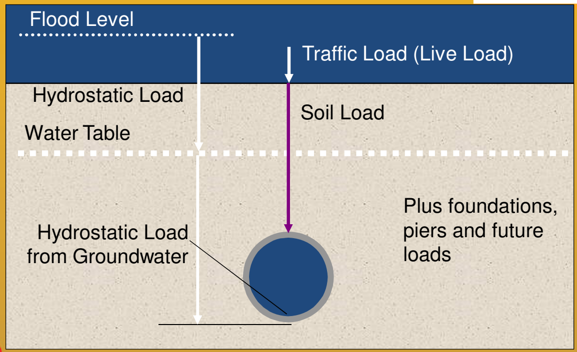

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Parameter	ASTM F1216	DWA-A143-2	Comments
Total external pressure on pipe kN/m²	q_t	q_v	
Water pressure kN/m²	P	p_a	
Live load kN/m²	W_s	pV	
Ovality %	q	Ω_v	DWA uses 2 separate ovality parameters
Ovality reduction factor			
Factor of Safety			roduct of several partial safety tween 1.10 & 1.50
Modulus of soil reaction N/mm²	E_s ʻ	E_2	
Long term elastic modulus N/mm²	E_L	E_L	Modulus of liner
Liner thickness	t	s_L	
Height of soil above top of pipe m	H	h	
Soil unit weight	w	χ_s	
Height of water above pipe invert	H_w	h_w	

DWA-A143-2 has several further input parameters relating to geometry, joint eccentricity, and soil characteristics

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How are these Parameters Measured?

- This is a very important point.
- In order to measure and verify the properties of the liners and component materials where necessary the correct test methods must be used.
- The test methods depend on the materials – different test methods may be required to test the same characteristic of different materials – for example flexural modulus (E) which is the critical characteristic for design.
- Applying the correct test, and doing it correctly, are critical in establishing characteristics for design purposes and also for product testing

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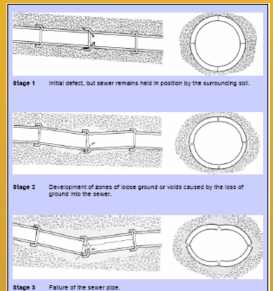
Deteriorated States

1. Leaky sewers, rigid boundary with initial shape.
   ASTM partially deteriorated; DWA state I
2. Broken longitudinally but structurally safe; rigid boundary of four displaced quarters.
   ASTM partially deteriorated; DWA state II
3. Broken and structurally unsafe; flexible boundary of four displaced quarters.
   ASTM fully deteriorated; DWA state III
4. Flexible boundary of granular material without capacity to transfer pressure forces – failed pipe.
   ASTM fully deteriorated; DWA state III


Stage 1 Initial defect, but sewer remains held in position by the surrounding soil.
Stage 2 Development of zones of loose ground or voids caused by the loss of ground into the sewer.
Stage 3 Failure of the sewer pipe.
Figure 1 The Process of Sewer Failure

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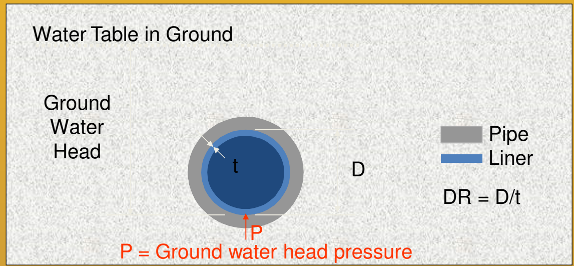
ASTM Partially Deteriorated Design



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Partially Deteriorated Design – solve 2 equations

Equation X1.1:

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

- P = Ground water load rating for liner
- Groundwater pressure must not be more than P
- DR = D/t of liner

Equation X1.2:

$[1.5(q/100)(1+q/100)DR^2] - [0.5(1+q/100)DR] = s/(PxN)$

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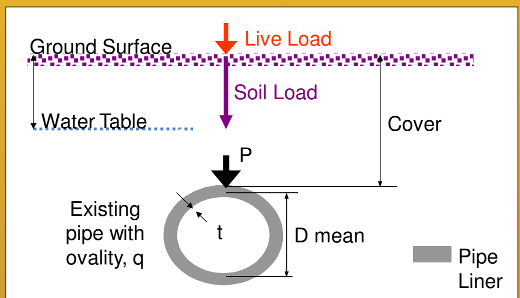
ASTM Fully Deteriorated Design



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Fully Deteriorated Design – solve 4 equations

Equations X1.1 and X1.2 AND

Equation X1.3 estimates the actual pressure acting on the liner

$$q_t = (1/N)[32R_W B' E'_s C (E_L I/D^3)]^{1/2}$$

Equation X1.4

$EI/D^3 = E/(12DR^3) \geq 0.00064$

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Results

Example designs to ASTM F1216-16 and DWA-A143-2 with 1 glass fibre reinforced UV-cured liner:

- 4 depths to invert: 3.0, 5.0, 8.0 & 11.0m
- 4 diameters: 225, 300, 450 & 600mm
- 5% ovality
- Water table at surface
- Main/trunk road traffic loading

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Liner properties

Short term flexural modulus:	10,000 N/mm²
Long term flexural modulus:	6,800 N/mm²
Short term flexural strength:	150 MPa
Long term flexural strength:	105 MPa

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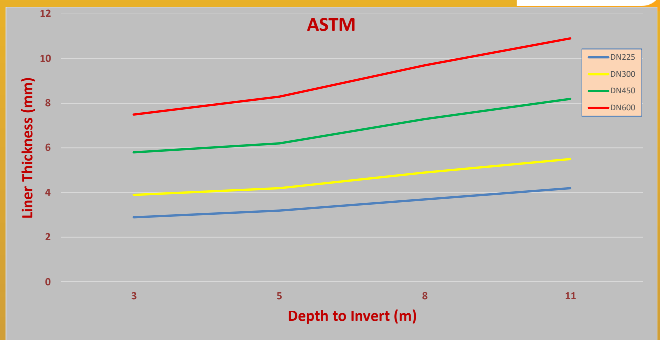

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Higher Strength Liner

Short term flexural modulus:	17,000 N/mm²	(10,000)
Long term flexural modulus:	14,200 N/mm²	(6,800)
Short term flexural strength:	280 MPa	(150)
Long term flexural strength:	235 MPa	(105)

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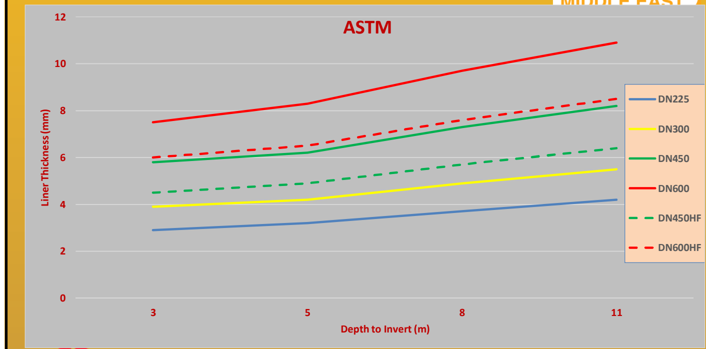

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DWA Method State II

- Uses algorithms to solve several load cases and identify critical case.
- Calculates actual and allowable elastic deformation
- Calculates factor of safety against buckling (stability)
- Checks proof of internal and external stress

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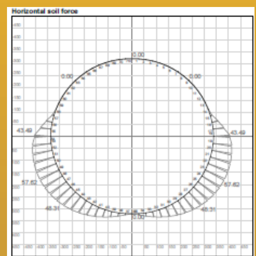
DWA Method State III

- In addition to State II calculations:
- Calculates horizontal force from bedding reaction and lateral pressure



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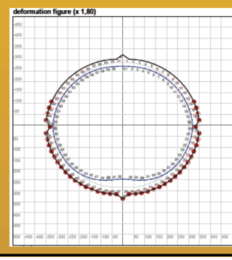
DWA Method State III

- In addition to State II calculations:
- Calculates horizontal force from bedding reaction and lateral pressure
- Calculates strain at springline of host pipe



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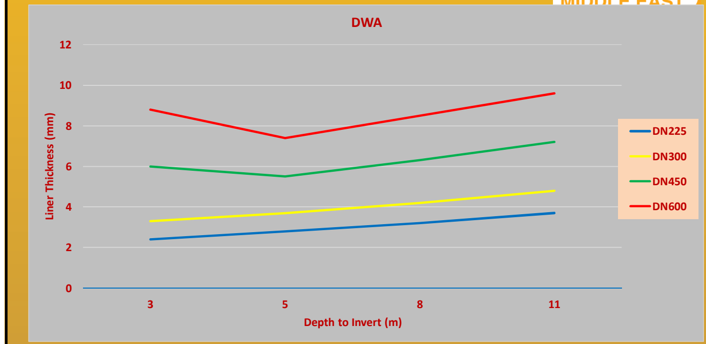

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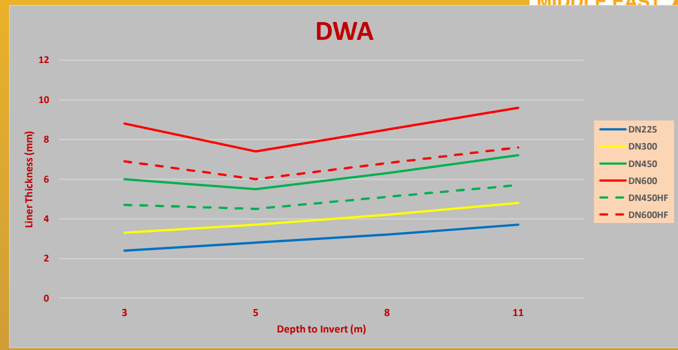

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Theoretical Differences

Parameter	ASTM F1216	DWA-A143-2
Basic theory	Timoshenko	Glock
Critical water pressure	Free ring supported by host pipe (enhancement factor 7)	Ring in a cavity
Critical live load pressure	Fully embedded liner	Ring supported by four quarters of host pipe embedded in soil

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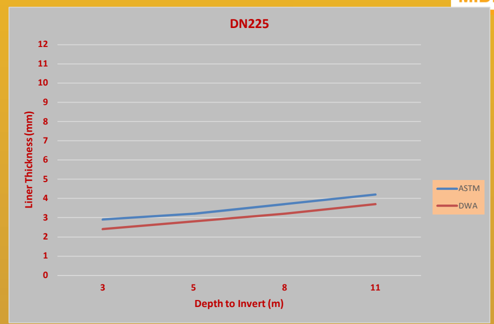

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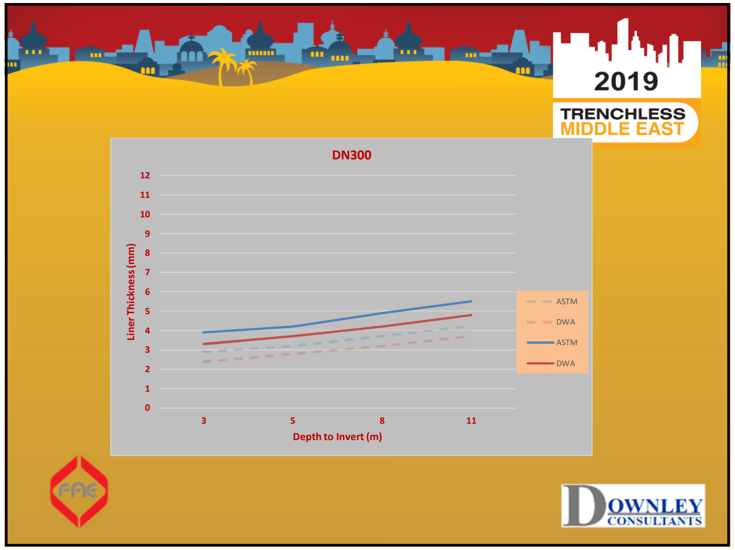
2019
TRENCHLESS
MIDDLE EAST
DN300
Liner Thickness (mm)
Depth to Invert (m)
ASTM
DWA
ASTM
DWA
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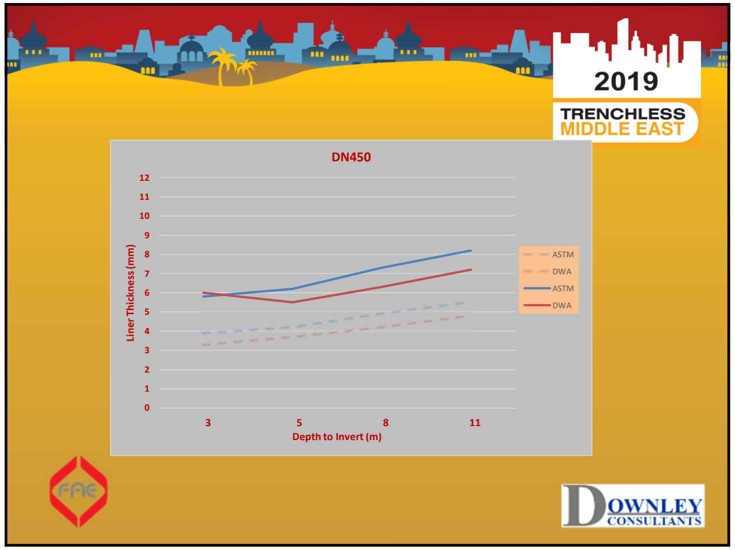
2019
TRENCHLESS
MIDDLE EAST
DN450
Liner Thickness (mm)
Depth to Invert (m)
ASTM
DWA
ASTM
DWA
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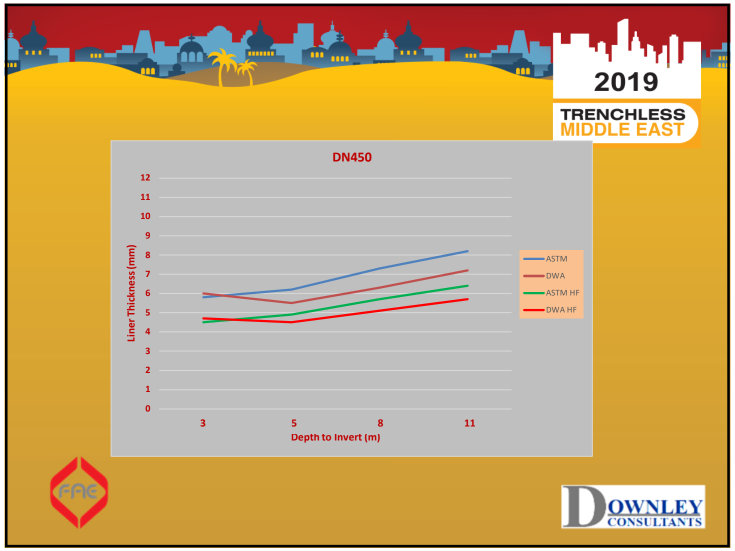
2019
TRENCHLESS
MIDDLE EAST
DN450
Liner Thickness (mm)
Depth to Invert (m)
ASTM
DWA
ASTM HF
DWA HF
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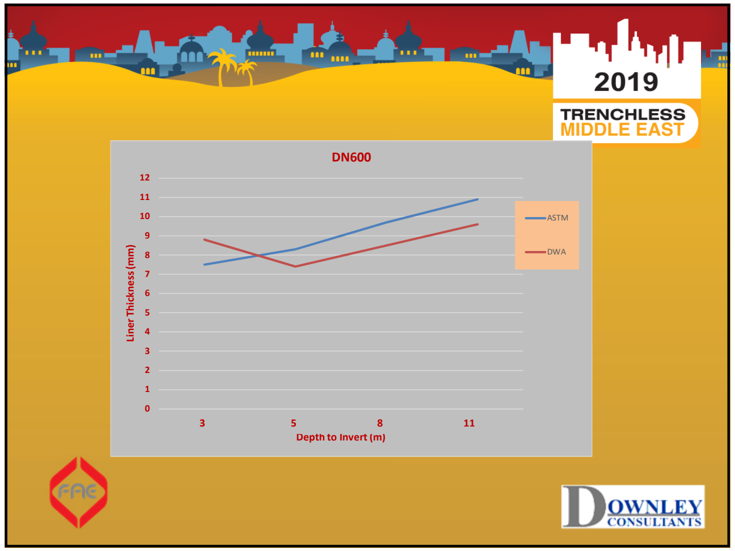
2019
TRENCHLESS
MIDDLE EAST
DN600
Liner Thickness (mm)
Depth to Invert (m)
ASTM
DWA
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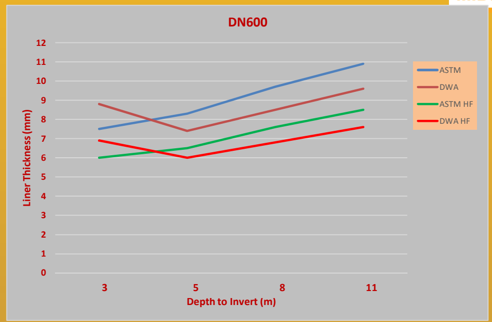

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CONCLUSIONS

- Both design methods are based on well-established structural theory and the basic principles underlying the design methods differ
- The results are similar in most cases - the DWA method generally results in slightly thinner liners for a given load condition
- The ASTM method is simpler and has higher inbuilt safety factor (which explains the thicker liners resulting from this method)
- Both design methods result in safe liner designs
- DWA design is better suited to shallow sewers with high live loading

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Thank you for your attention

Acknowledgement:
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