BASF
The Chemical Company

Project:	Rehabilitación de la Línea Red Matriz de 78" Tibitoc-Casablanca, Colombia
Condition:	FRP Liner for Internal Pressure
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Design Narrative

The objective of the design for the FRP liner is to design the proper number of layers of fiber in the hoop direction and in the longitudinal direction to resist the full internal pressure inside the prestressed concrete cylinder pipe. That is the capacity of the existing tendons and the steel liner is completely neglected.

Known Information about the Existing Structure

Section Dimensions

$R := 39$ Internal Radius of Prestressed Concrete Cylinder Pipe [in]

Loading Requirements

$p := 220$ Internal pressure to be resisted by the FRP Liner [psi]

Required FRP Strengthening System Design Information

FRP Material Properties -- Using MBrace CF 160 Carbon Fiber Reinforcement

$ffu' := 550000$ Ultimate tensile strength of the FRP [psi]

$\varepsilon fu' := 0.0167$ Ultimate rupture strain of the FRP [in/in]

$Ef' := 33000000$ Tensile modulus of elasticity of the FRP [psi]

$tf := 0.0130$ Nominal design thickness of one ply of the FRP [in/ply]

Exposure Design Criteria

$Ce := 0.85$ Reduction factor for environmental exposure (per ACI 440.2R-02 Table 8.1)

Calculate the Number of Layers of FRP to Use

Preliminary calculation of FRP properties

- Design ultimate tensile strength [psi]

$ffu := Ce \cdot ffu'$ [ACI 440.2R-02 Eqn (8-3)]

$ffu = 467500$

- Design rupture strain [in/in]

$\varepsilon fu := Ce \cdot \varepsilon fu'$ [ACI 440.2R-02 Eqn (8-4)]

$\varepsilon fu = 0.014$

- Design tensile modulus of elasticity [psi]

$$Ef := \frac{ffu}{\varepsilon fu}$$ [ACI 440.2R-02 Eqn (8-5)]

$Ef = 32934132$

- Maximum strain in the FRP (per ACI 440.2R-02 Section 11.2)

$\varepsilon fe := \min((0.004 \quad 0.75 \cdot \varepsilon fu))$ [ACI 440.2R-02 Eqn (10-6a)]

$\varepsilon fe = 0.004$

Calculate the Required Number of Layers in the Hoop Direction
(based on mechanics)

- Strength reduction factor for tension-controlled sections

$\phi := 0.90$

- Additional strength reduction factor applied to FRP (completely wrapped section)

$\psi f := 0.95$ [ACI 440.2R-02 Table (10-1)]

- Compute the number of layers required in the hoop direction

$$n_H := \frac{p \cdot R}{\phi \cdot \psi f \cdot \varepsilon fe \cdot Ef \cdot tf}$$

$n_H = 5.86$ **===> Use 6 Layers MBrace CF 160 in the Hoop Direction**

Calculate the Required Number of Layers in the Longitudinal Direction
(based on mechanics)

- Additional strength reduction factor applied to FRP (side bonded)

$\psi f := 0.85$ [ACI 440.2R-02 Table (10-1)]

- Compute the number of layers required in the longitudinal direction

$$n_L := \frac{p \cdot R}{2\phi \cdot \psi f \cdot \varepsilon fe \cdot Ef \cdot tf}$$

$n_L = 3.27$ **===> Use 4 Layers MBrace CF 160 in the Longitudinal Direction**

Note: For Symmetric Ply Layout Use the Following Stacking Sequence:
H H L L H H L L H H