THE Event For The Utility Infrastructure Industry
Underground Construction Technology
International Conference & Exhibition

On-Site Manufactured FRP Pipe for Repair of Pipes and Manholes

Mo Ehsani, Ph.D., P.E., S.E.
President, QuakeWrap Inc., and
Professor Emeritus of Civil Engineering, Univ. of Arizona

February 2, 2017

Pipe Requirements

- **Structural:**
  - **Internal pressure rating**
  - **Thrust loads**
  - **Rigidity & stiffness to resist external loads**
- **Nonstructural:**
  - **Durable (non-corroding)**
  - **Non-leaking joints**
  - **Lighter & safer installation**
  - **Faster delivery**
  - **Easily made in any shape & size**
  - **Easily repaired in the field**
  - **Green & sustainable technology**
  - **Lower cost**

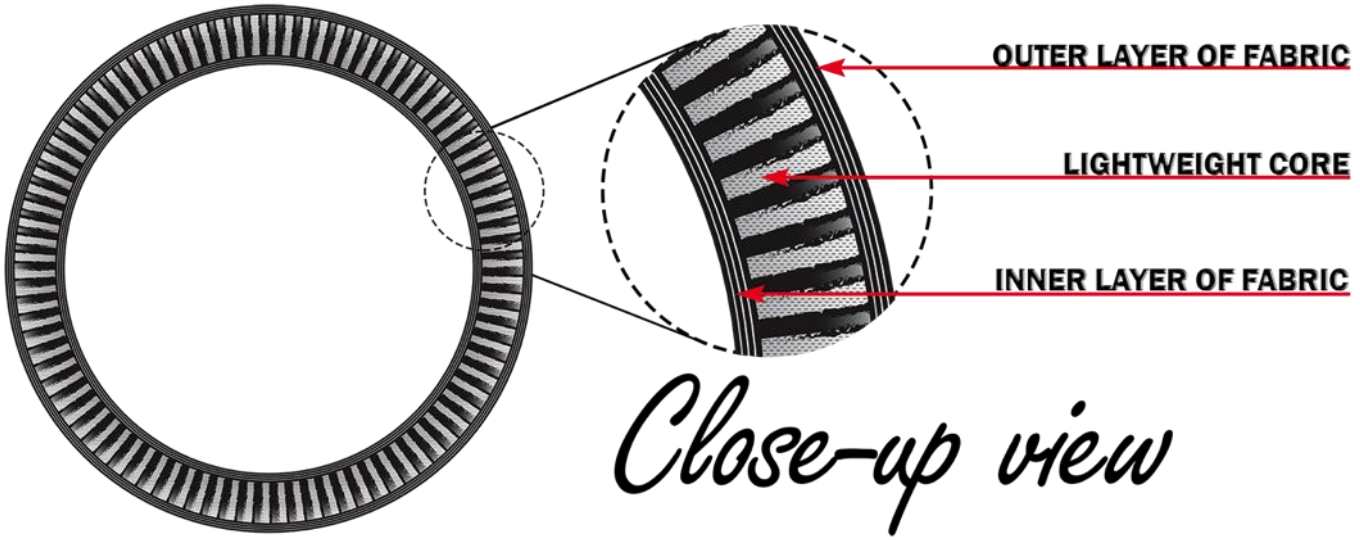
Design for Rigidity & Stiffness

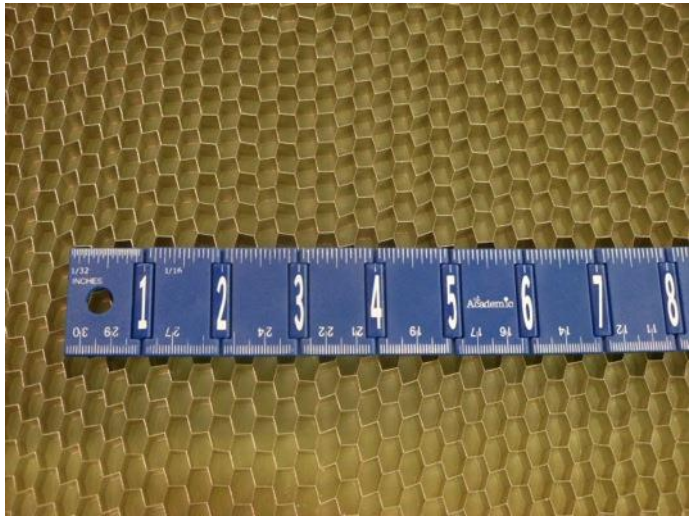
Composite Sandwich Concept

Steel I-beam

RELATIVE STIFFNESS	**1**
WEIGHT (Pounds/ft^2)	**0.910**

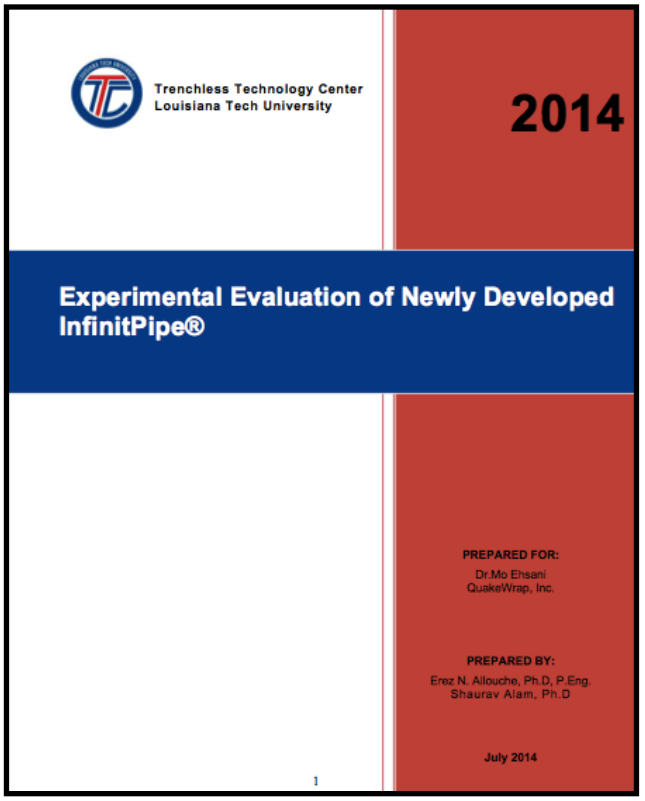
Design for Rigidity & Stiffness



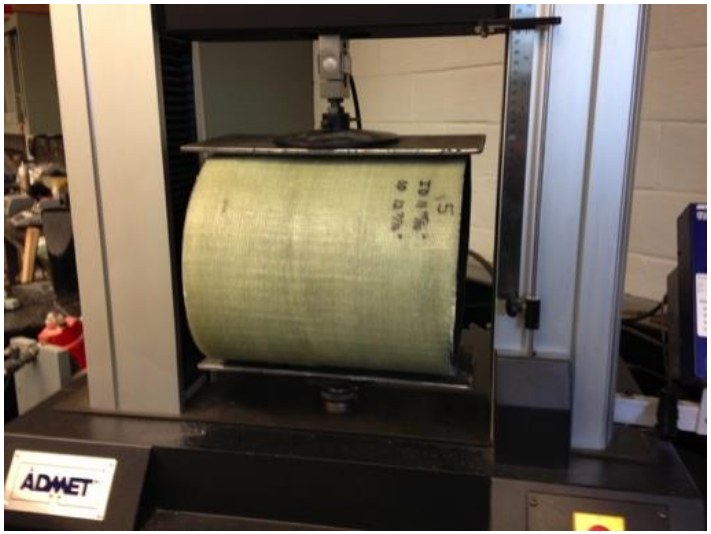


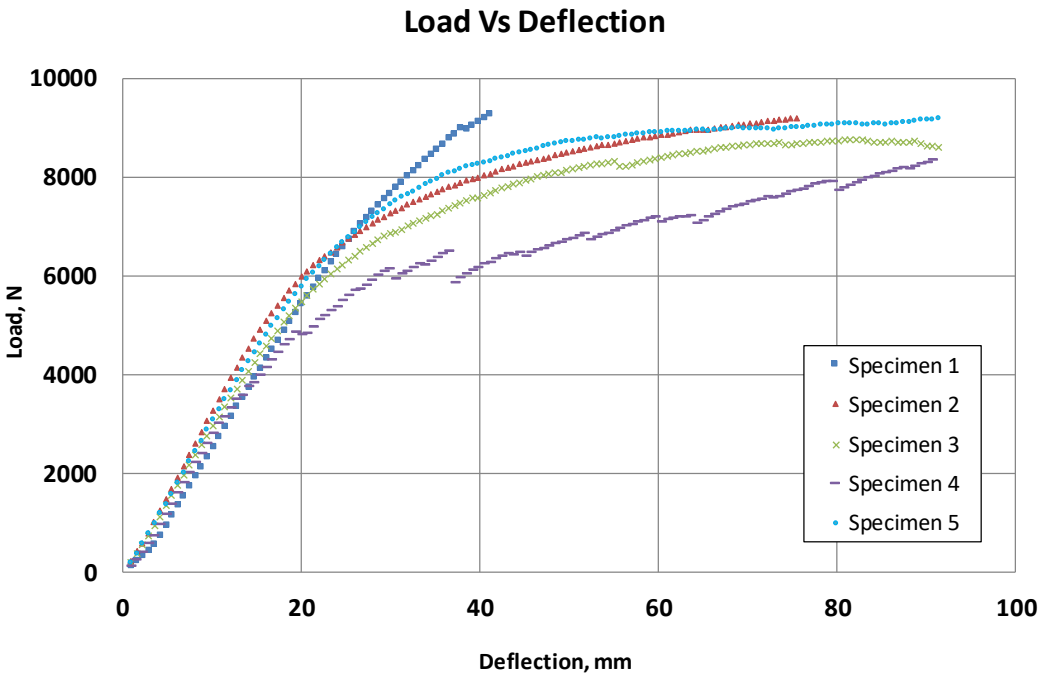
Tests at Trenchless Technology Center (LA Tech Univ.)

- **Funding from the U.S. National Science Foundation**
- **Hand-Made samples tested**



Ring Stiffness
(ASTM D2412)



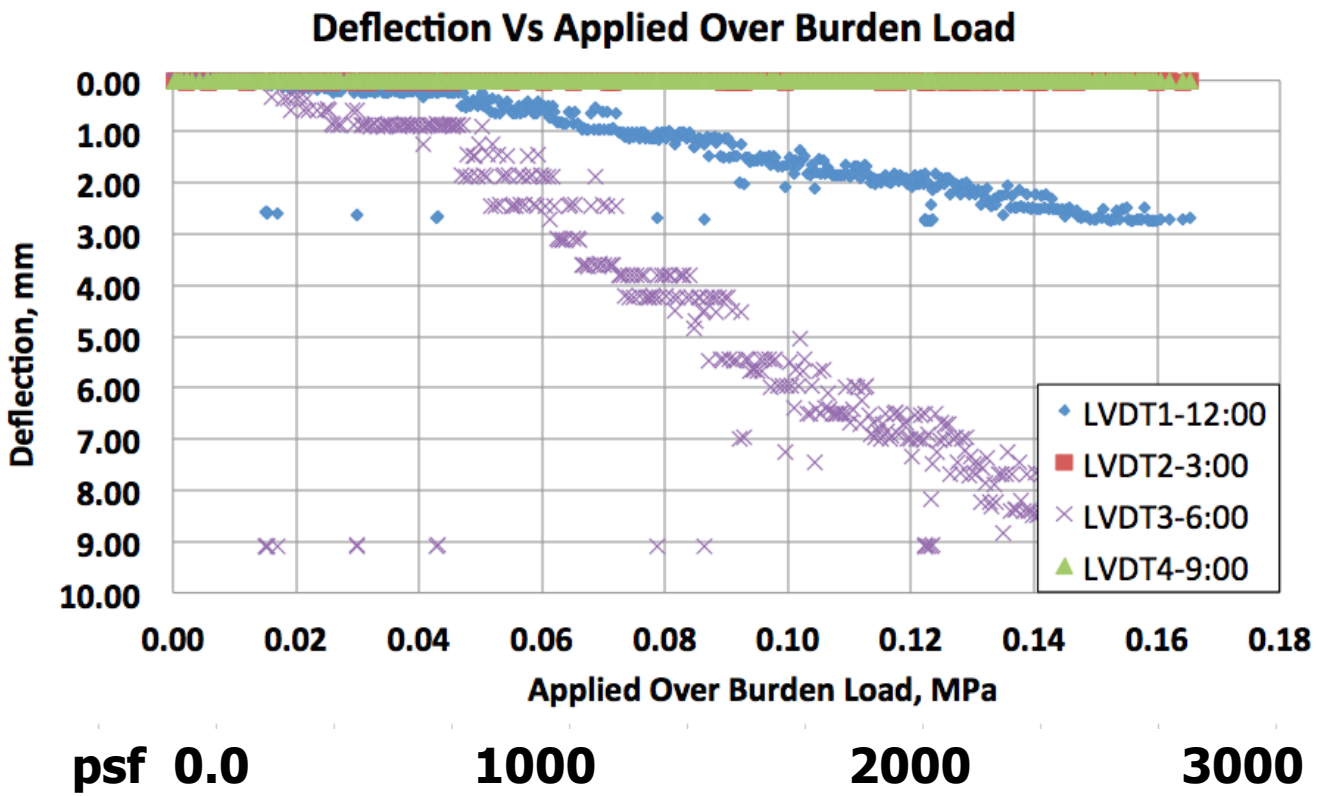


Charpy Impact Test *(ASTM D2444)*

Avg. absorbed energy = 162 N-m

(for annealed steel = 161.3 N-m)

Over Burden Pressure Test



ASCE Innovation Award (2016)

Project Description

- **Puerto Rico Electric Power Authority (PREPA)**
- **3.6M Residents**
- **4.2M Visitors**

- **Aguirre Power Plant:**
  - **900MW thermoelectric diesel oil**
  - **592MW combined cycle**

Project Description

- Pipe network 24-60 in.
- Operating P= 150-200 psi
- Pipe risers throughout
- 2015: One lid dislodged – 100 feet away

Project Description

- 29 Pipe risers
- Repair upper 4-ft internally
- Repair exterior of pipe
- Recoat the lids
- Replace all bolts

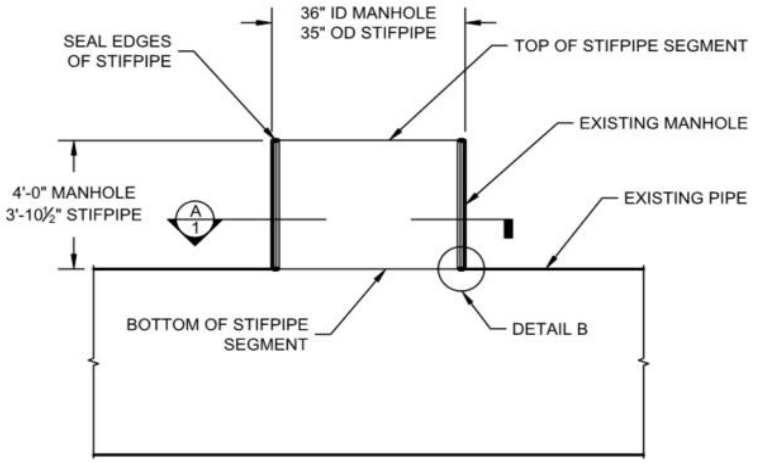
Structural Design Criteria

- **Class IV Structural Liner**
- **External pressure from traffic & soil**
- **Internal design pressure of 400 psi**

Repair Alternatives

- **Replace the upper 4 feet with steel pipe**
- **Repair with wet layup FRP**
- **Repair with Sandwich construction FRP pipe**

Design of the Pipe



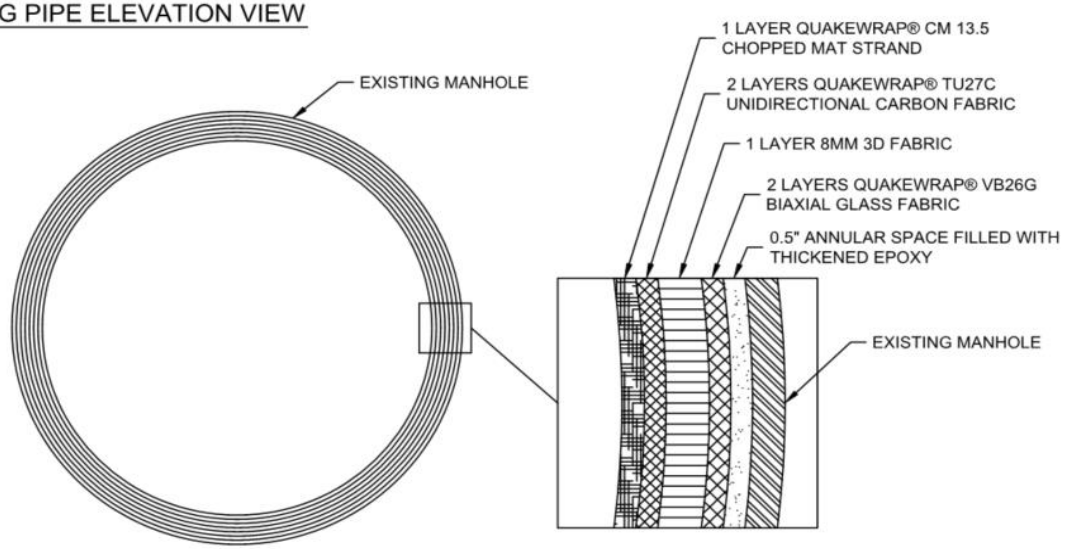
EXISTING PIPE ELEVATION VIEW

INSTALLATION NOTES:

1. PLACE PREFABRICATED STIFPIPE SEGMENT INSIDE OF EXISTING MANHOLE

2. SEAL BOTTOM EDGES BETWEEN STIFPIPE SEGMENT AND EXISTING MANHOLE

3. INJECT THICKENED EPOXY CONSISTING OF QUAKEBOND™ 320LV LOW VISCOSITY RESIN MIXED WITH SAND INTO THE 0.5" ANNULAR SPACE BETWEEN THE STIFPIPE AND THE EXISTING MANHOLE



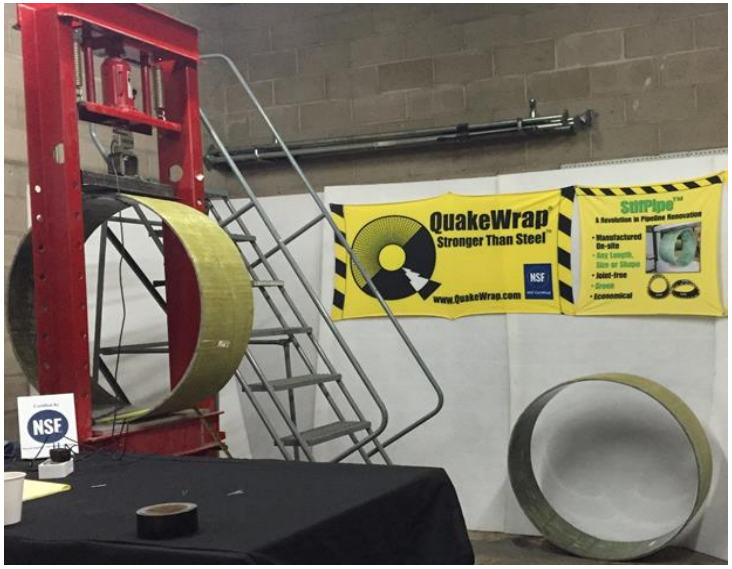
A/1 CROSS SECTION
NTS

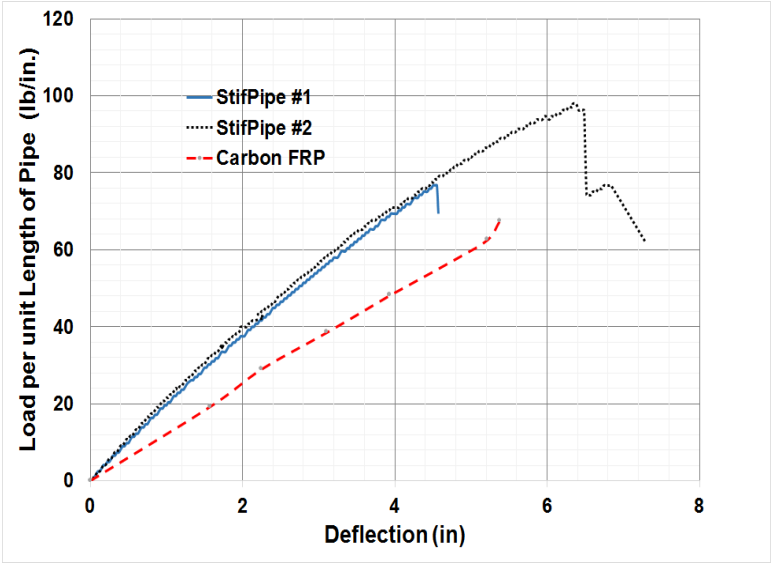
Design of Pipe

- **35” OD pipes to fit into 36” ID host pipes**
- **3’-10½” long to cover 4’-0” section**
- **1 Layer of chopped strand mat**
- **2 Layers of TU27C**
- **1 0.31-inch spacer sheet**
- **2 Layers of VB26G**

Fabric Type	VB26G	TU27C
Aerial Weight Fabric Only	26 oz/yd^2	27.8 oz/yd^2
Ply Thickness	0.04 in.	0.049 in.
Longitudinal (0°) Direction:		
Tensile Strength	54 ksi	135 ksi
Tensile Modulus	3,217 ksi	13,000 ksi
Ultimate Elongation	2.1%	0.98%
Breaking Force	2,170 lb/in	6800 lb/in.
Transverse (90°) Direction:		
Tensile Strength	39 ksi	---
Tensile Modulus	2,700 ksi	---
Ultimate Elongation	1.9%	---
Breaking Force	1,560 lb/in.	---

Testing of Pipe Sample





Pipe Stiffness (psi)				
Percentage of outside diameter	3%	5%	8%	10%
Deflection (inches)	1.12	1.86	2.98	3.73
Pipe Stiffness for Sample # 1 (psi)	19.7	19.3	18.4	17.6
Pipe Stiffness for Sample # 2 (psi)	21.5	20.5	19.2	18.5
Average of two Samples (psi)	20.6	19.9	18.8	18.0

Pipe segments manufactured in Tucson, AZ and shipped to PR

Aguirre Power Plant, PR

Aguirre Power Plant, PR

- **Repair of outside with wet layup glass & carbon FRP**
- **Cleaning and coating of lids**
- **Painted lids installed with new bolts**

Schedule & Cost

- **Pipe segments made in plant and shipped**
- **2 Weeks to install; mostly for lids**
- **Cost of 29 pipe segments $82,000**

Project Location

- Gillies Road Culvert
- 1000 miles N. of Brisbane
- Remote Mountainous Site
- Rainfall 10 ft/yr
- Wet Season Dec-May
- 78 ft long x 59-inch

Structural Design Criteria

- **The Australian Bridge Design Code (Australian Standard AS5100)**
- **DTMR Document "Design Criteria for Rehabilitation of Circular Corrugated Metal Culverts"**

Specific Design Requirements

- **Design life - 50 years (minimum)**
- **Design live loads - SM1600 and HLP400 (per Australian Standard AS5100)**
- **Design fill heights under traffic lanes – 12 feet (min), 13 feet (max) (3.66-3.96 m)**

Design Criteria

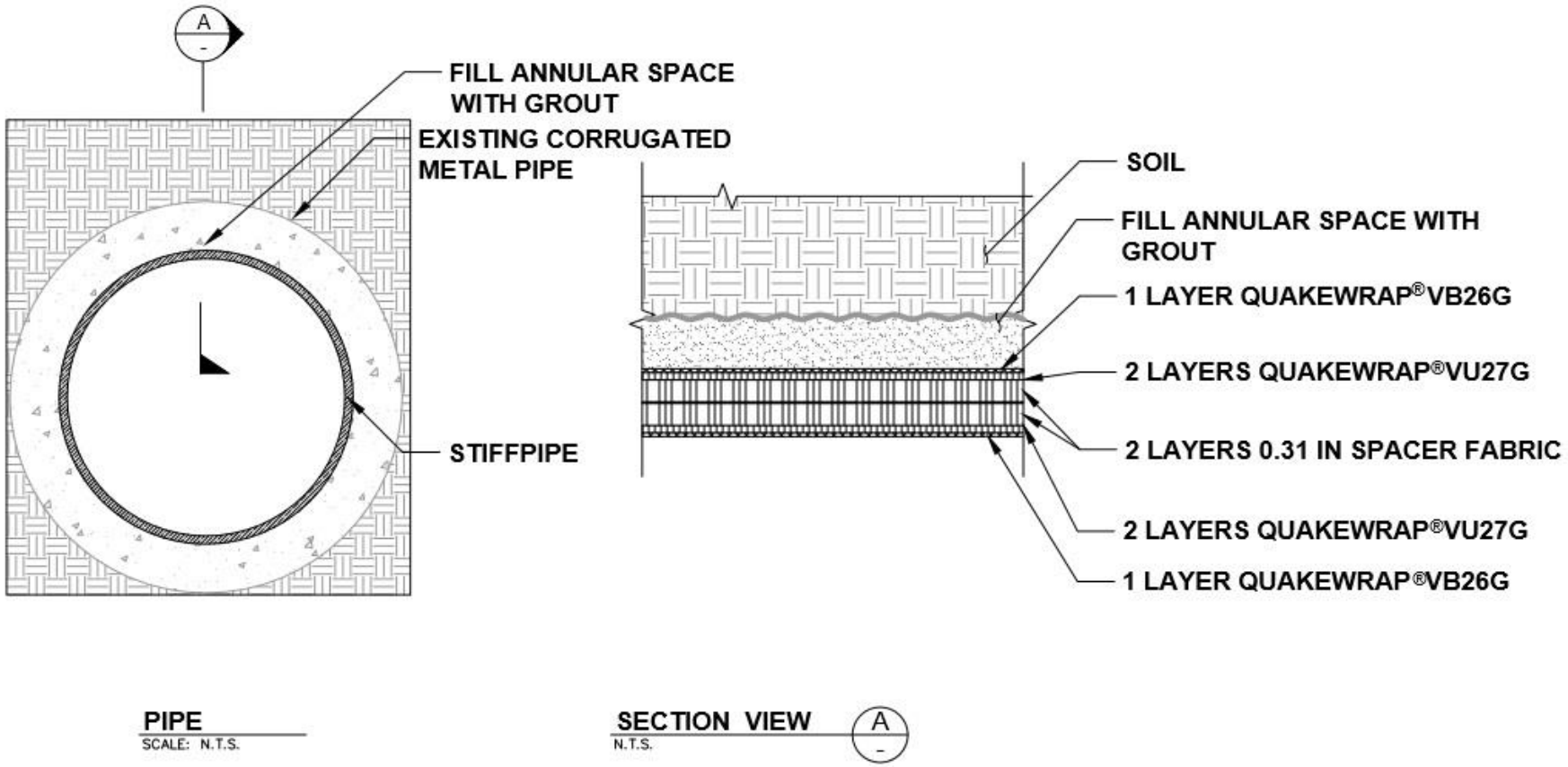
- **Minimized traffic**
- **Fast schedule – before the "wet" season**
- **Minimize waterway loss**
- **Minimize equipment use**

Solutions Considered

- **Concrete in the invert**
- **Reline with R/C pipe**
- **Remove & Replace**
- **Sandwich Construction FRP pipe**

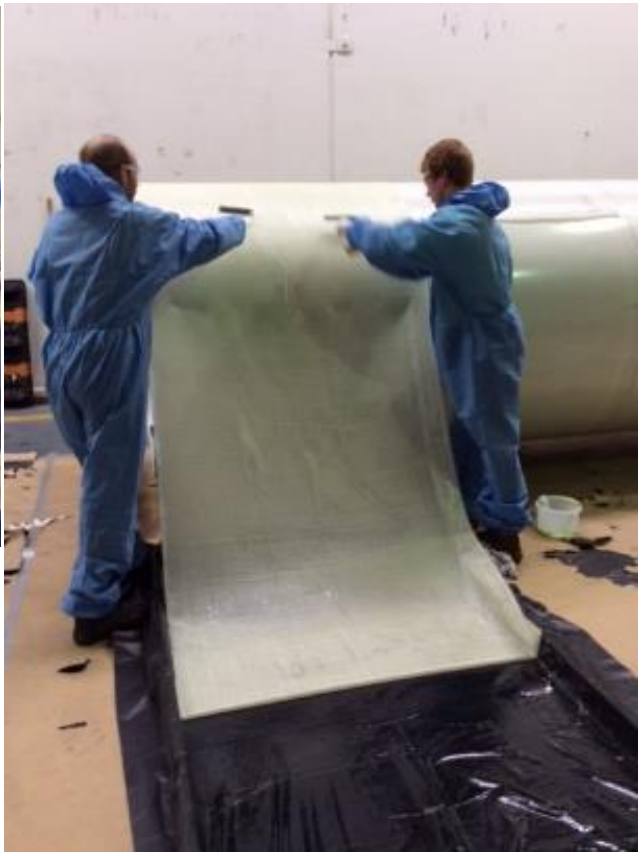
Fabric Type	VB26G	VU27G
Aerial Weight Fabric Only	26 oz/yd^2	27 oz/yd^2
Ply Thickness	0.04 in.	0.05 in.
Longitudinal (0°) Direction:		
Tensile Strength	54 ksi	85 ksi
Tensile Modulus	3,217 ksi	3,980 ksi
Ultimate Elongation	2.1%	2.3%
Breaking Force	2,170 lb/in	3490 lb/in.
Transverse (90°) Direction:		
Tensile Strength	39 ksi	---
Tensile Modulus	2,700 ksi	---
Ultimate Elongation	1.9%	---
Breaking Force	1,560 lb/in.	---

Design of the Pipe



Gillies Road Culvert

Cairns, QLD



Gillies Road Culvert

Cairns, QLD

Gillies Road Culvert

Cairns, QLD

Pipe segments pushed in by hand

Gillies Road Culvert

Cairns, QLD

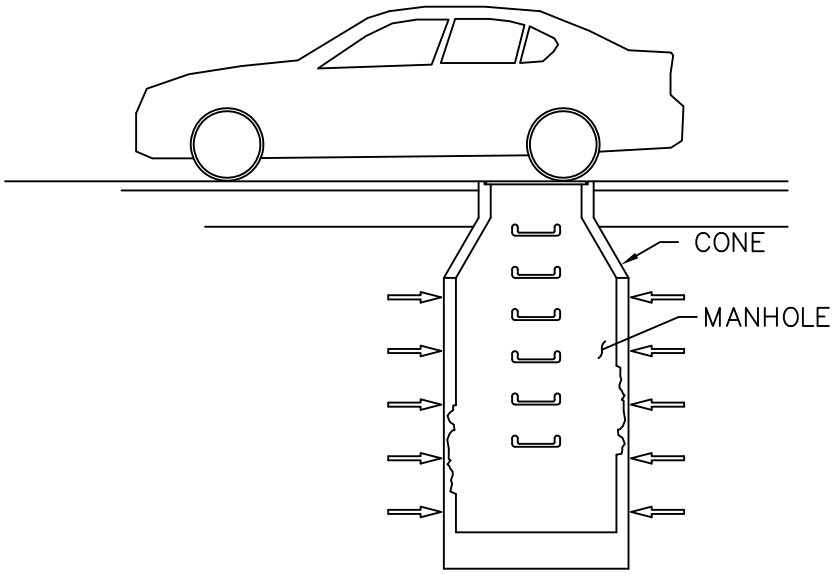
Gillies Road Culvert

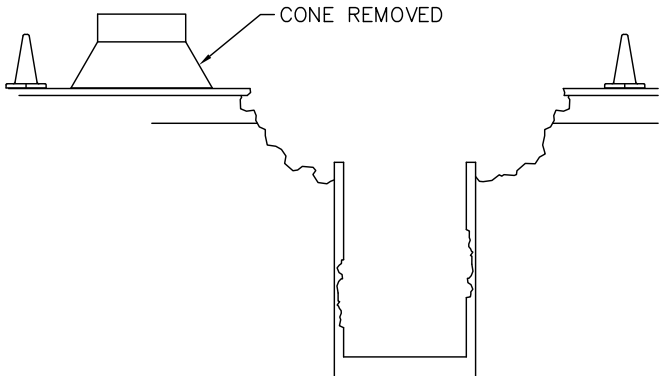
Cairns, QLD

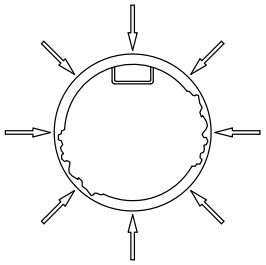
Schedule & Cost

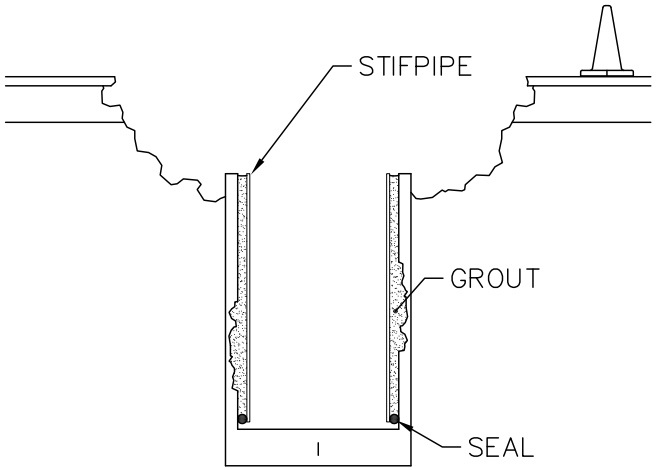
- **2 Weeks to build the pipe segments**
- **5 days to install and grout**
- **Cost $AUS 250k (50/50 for pipe & installation)**

Repair of Manholes with StifPipe®









Thank you for your Attention!

Questions?

Email: Mo@QuakeWrap.com

QuakeWrap.com ***PipeMedic.com*** ***StifPipe®***