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**Fortezza da Basso • FLORENCE (Italy)**

**30<sup>th</sup> September • 2<sup>nd</sup> October 2019**

# ***FRP 101: Taking The Mystery out of Trenchless Repair of Pressure Pipes with Carbon FRP***

***Mo Ehsani, PhD, PE  
Professor Emeritus of Civil Eng., U. of Arizona  
President/CEO QuakeWrap Inc., Tucson, AZ***

# Introduction



- History of Development
- Application to Pipes

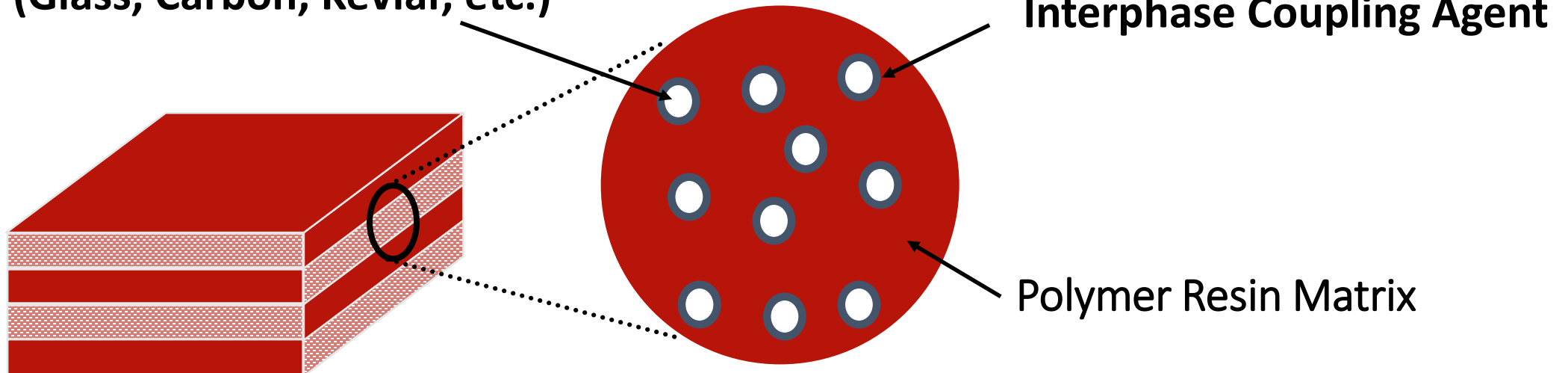
# Fiber Reinforced Polymer (FRP)

Why is it called FRP?

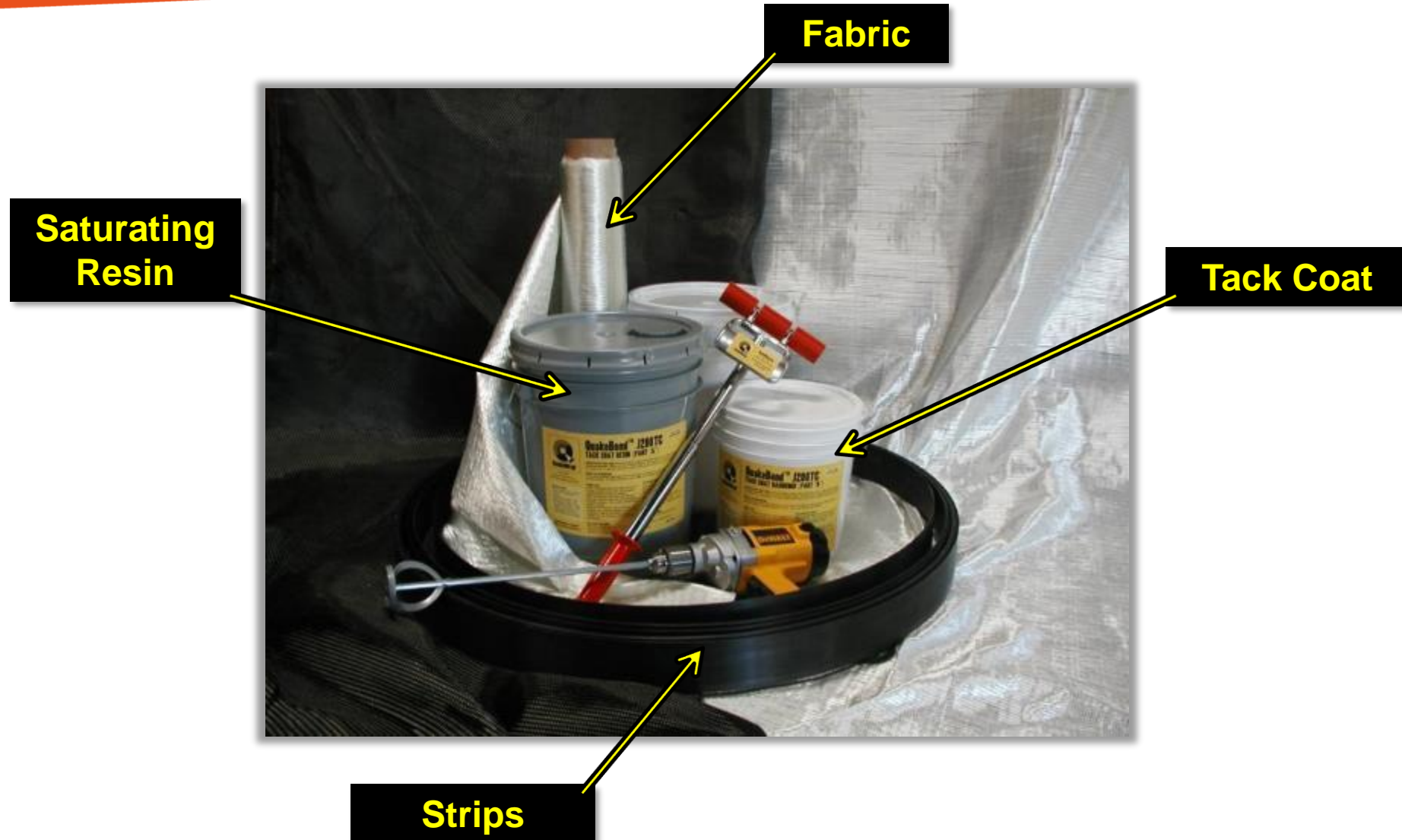
- A Polymer (i.e. epoxy, vinyl ester, etc.) reinforced with a Fiber (e.g. carbon, glass, etc.)
- FRP does not have the same strength in all directions (*anisotropic*)

**Reinforcing Fiber**

**(Glass, Carbon, Kevlar, etc.)**



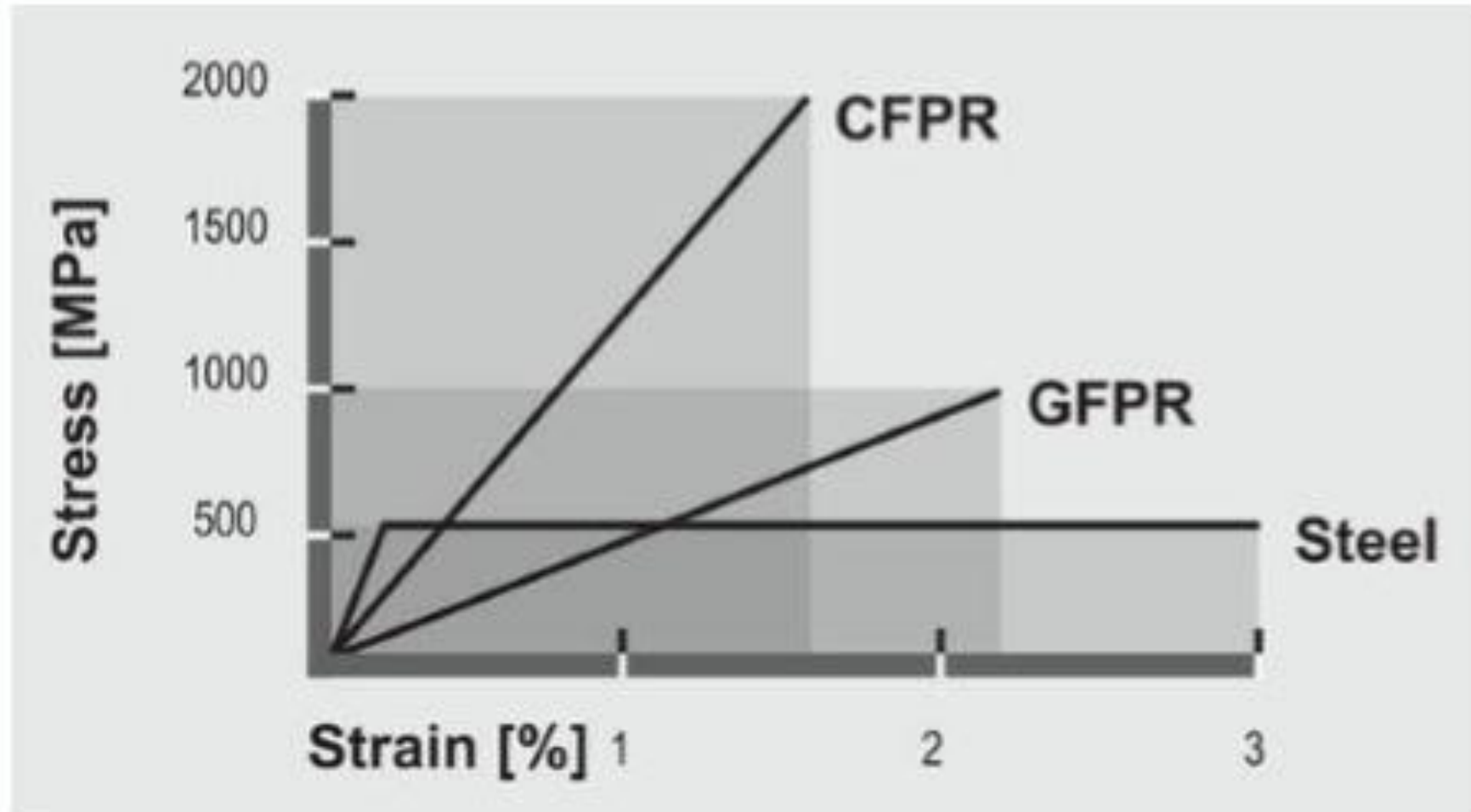
# QuakeWrap® FRP Products



# Comparison of FRP and Steel



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# Advantages of FRP



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- High Tensile Strength *(3-5 times stronger than Steel)*
- Low Weight *(no foundation adjustments required)*
- Corrosion Resistance & Protection
- Chemical Protection
- Waterproof
- Speed of Construction
- Versatility
- Odorless & Non-Toxic (QuakeWrap Products)
- NSF-61 Certified for pipes  $\geq 8$  inches
- Minimal Investment



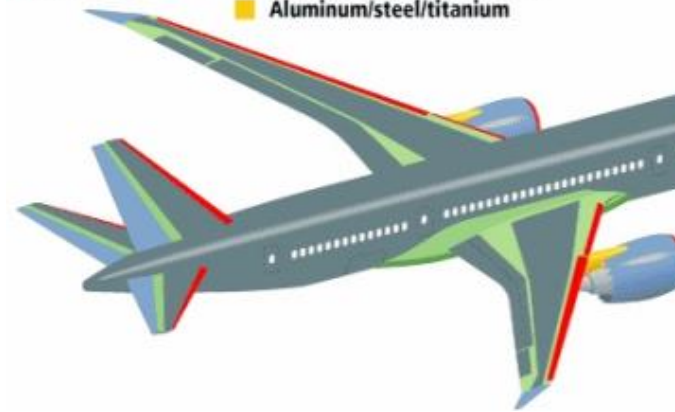
# History of FRP in other Industries

**Corvette C1 - 1953**

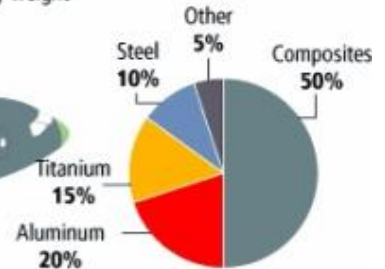


**Materials used in 787 body**

- Fiberglass
- Aluminum
- Carbon laminate composite
- Carbon sandwich composite
- Aluminum/steel/titanium



**Total materials used  
By weight**



**By comparison,** the 777 uses 12 percent composites and 50 percent aluminum.

**100% FRP Hull**



# Original Concept Demonstration (1987)

*Carbon FRP instead of reinforcing steel*



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# Loma Prieta Earthquake Oct 1989

## Failure of R/C Columns



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# Indiana Bridge

*Indiana Project R-27862-A – SR 49*



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# Sample Projects



Testing + R&D



Condo, FL



Statue of Liberty



Bridge, NM



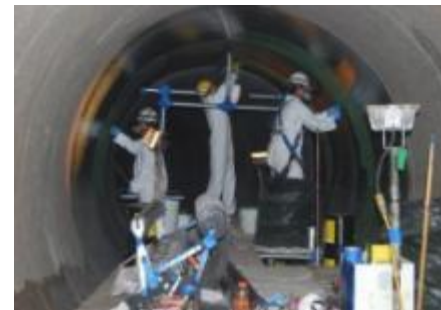
Settling Tank, MX



UN Lebanon



High Rise, AK



Pipe, Costa Rica

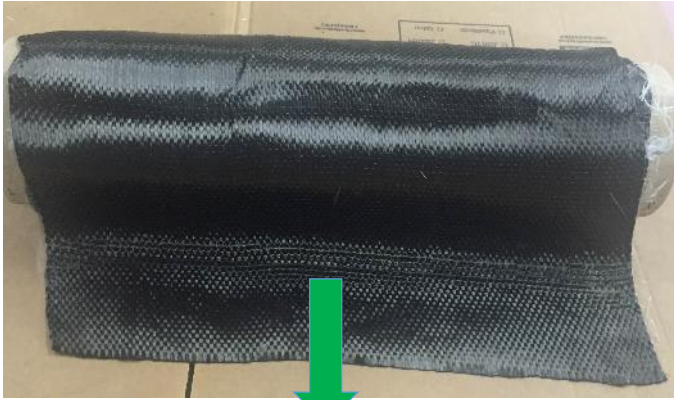


Kazakhstan

# Cell Phone Tower Strengthening

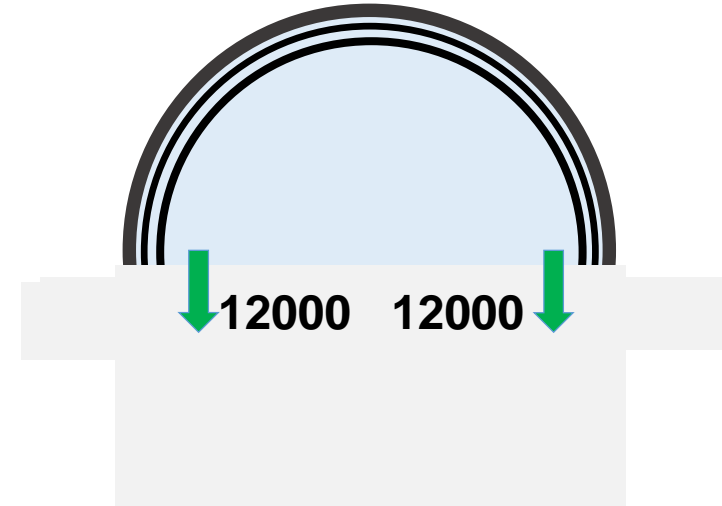


# Design for Internal Pressure



**Carbon  
Fabric**

Thickness: 0.05 in. (1.3 mm)  
Weight: 0.38 lb/ft<sup>2</sup> (1.83 kg/m<sup>2</sup>)  
T = 6000 lb/in. (1050 N/mm)



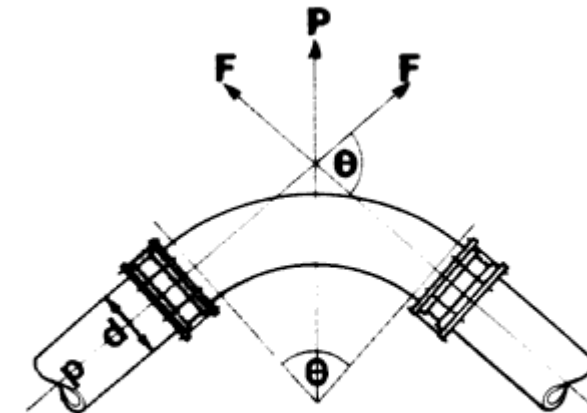
$$P = (6,000 + 6,000) / 24 \text{ in.} = 500 \text{ psi (34.5 bar)}$$

$$P = (12,000 + 12,000) / 24 \text{ in.} = 1,000 \text{ psi (69 bar)}$$

**Note: Little change in weight or thickness**  
**Smooth surface reduces friction & improves flow**

# Design for Thrust

- Align the fibers along the length of pipe
- Increase/decrease number of layers based on the thrust magnitude



where

$$P = \frac{\rho \pi d^2}{2} \sin \frac{\theta}{2}$$

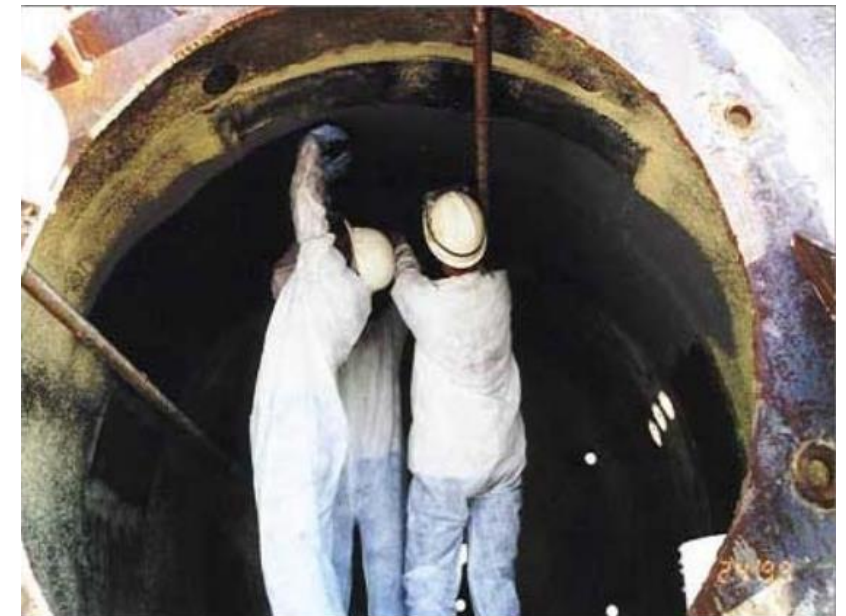
$$F = \frac{\rho \pi d^2}{4} (1 - \cos \theta)$$

# Wet Layup Method

- Carbon fabric saturated with epoxy resin in the field and applied directly to surface of pipe (**Externally** or **Internally**)
- Fabric roll width: 24-48 inch (600-1200mm)
- Fabric thickness: 0.05 inch (1.3 mm)
- For diameters 2 inch (50 mm) and larger
- Applied by packer (small dia.) or by hand
- Used for joint/spot repair or full length
- Creates a pressure vessel inside pipe
- Cures in 24 hours in ambient temperature
- Faster cure is possible by heating
- NSF-61 Approved

# Early Applications in 1998

- Paloverde Nuclear Power Plant, AZ
- Prestressed Concrete Cylinder Pipe (PCCP)
- Corrosion of pre-stressing cables
- High design pressures
- Replacement recommended
- CFRP liner installed
- 108 inch (2700mm) Diameter



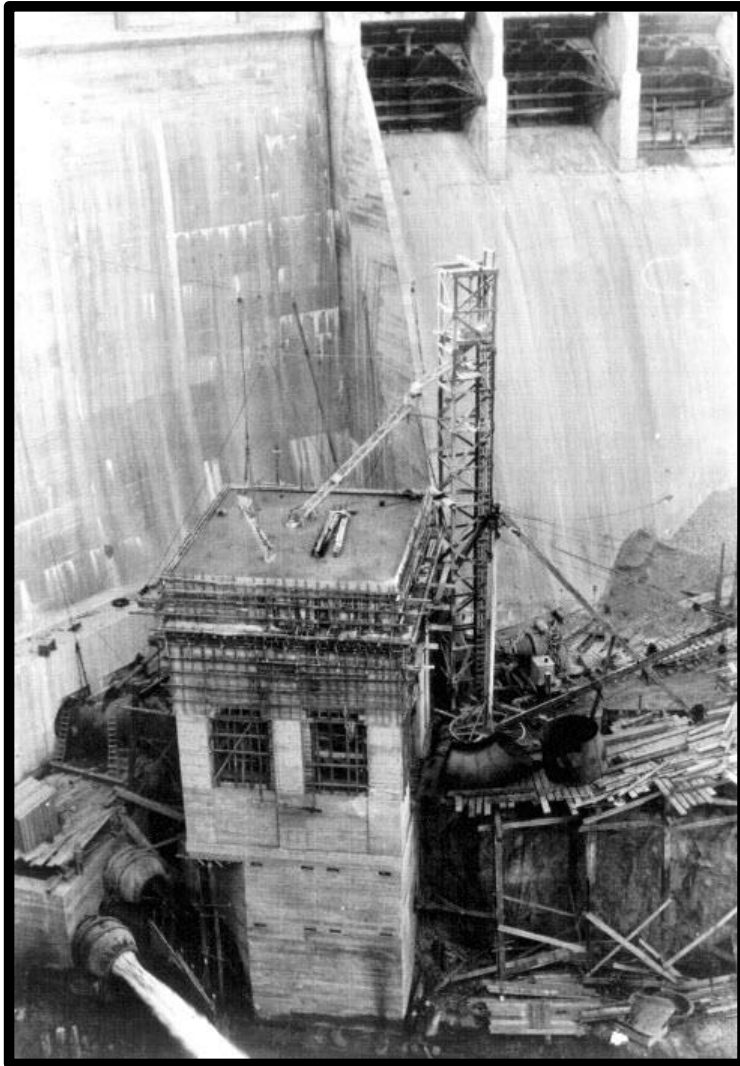
# Wet Layup Process



# DC Water – 96-inch (2400 mm) Sewer Repair



# Salt River Project - Penstock Construction



# Salt River Project – contd.



# El Encanto Hydropower, Costa Rica

*1750m x 2.1m diameter (July 2009)*



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**Sloped Terrain**



**Water seeping into  
pipe**



**Leaks continued after cracks were  
filled**

# El Encanto Hydropower, Costa Rica

*1.1 miles x 84-inch diameter (July 2009)*

- Four 600x600mm Access Ports
- Poor surface conditions req'd much prep



# El Encanto Hydropower, Costa Rica

- Challenge: Not only strengthen but to leak proof
- Total Time: 3 Weeks
- Successful pressurization tests on July 15, 2009



# Steel Pipes for Hot Air, Carlsbad, CA

- 42-inch (1070 mm) curved steel pipe
- Galvanic corrosion
- Use glass fabric as dielectric barrier



# Tests of Steel Pipes (5-inch Dia.) Pertamina Oil Company, Indonesia



# Corroded Steel Pipe in Mine



# Wastewater Facility Pipe Repair

## *City of Atlanta*



# Wastewater facility Pipe Repair *City of Atlanta – cont'd*

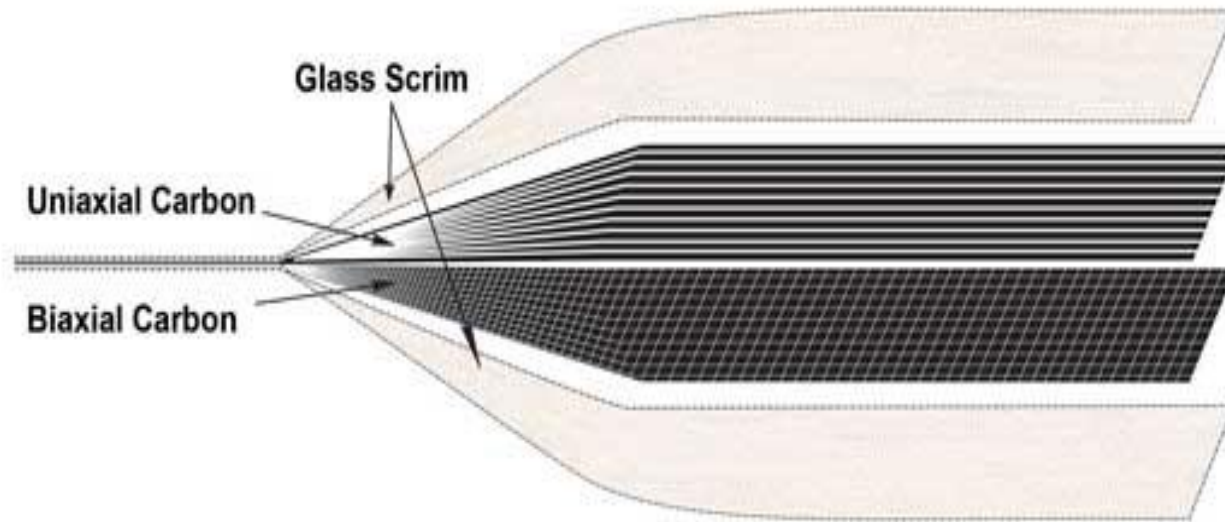


# Quality Control

- Record Lot #
- Adhesion Test (ASTM D7234) (200 psi min.)
- Witness Panel (ASTM D3039); 5 glass and 5 carbon FRP coupons



# Multi-Layered SuperLaminate™ (Patent Pending)



- **Multi-Axial Reinforcement**
- **Thickness  $\approx$  0.01 -0.025 inch (0.25-0.67mm)**
- **Tensile Strength  $\approx$  up to 155,000 psi (1030 MPa)**
- **Infinite combinations of strength & stiffness can be produced**
- **ISO 9000 Certified**

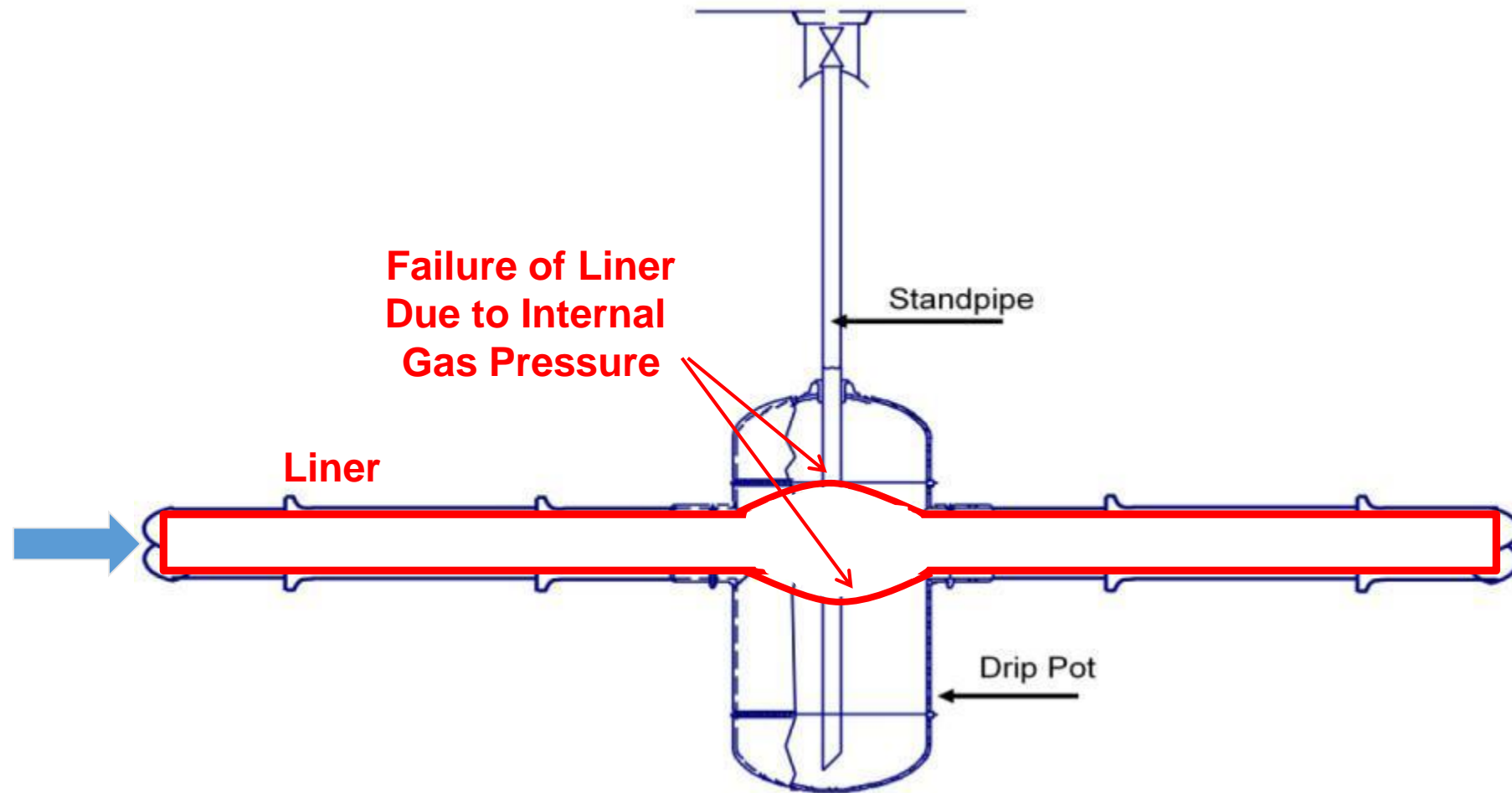


# Bridging a Gap in a Pipeline

*(Gas Technology Institute)*



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How do we create a pressurized pipe?

# Bridging a Gap in a Pipeline

*(600mm Long Gap in 400mm Diam. Pipe)*



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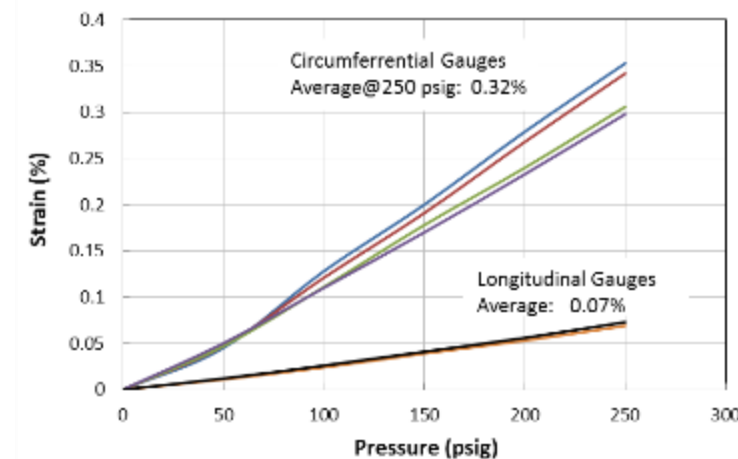
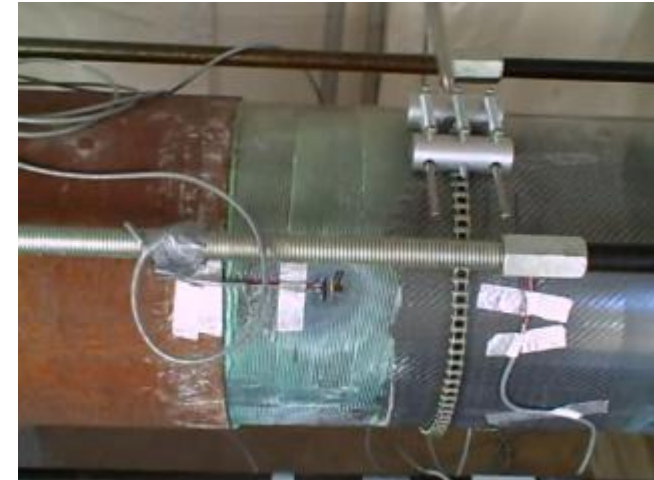
Two 16-in. diameter pipes with a 24-in. gap



# Pressure Testing

*on October 16, 2010*

- Gas Technology Institute
- Max Operating Pressure = 60 psi (4.1bar)
- Tested to 250 psi (17.2 bar)
- Ultimate Capacity = 900 psi (62 bar)



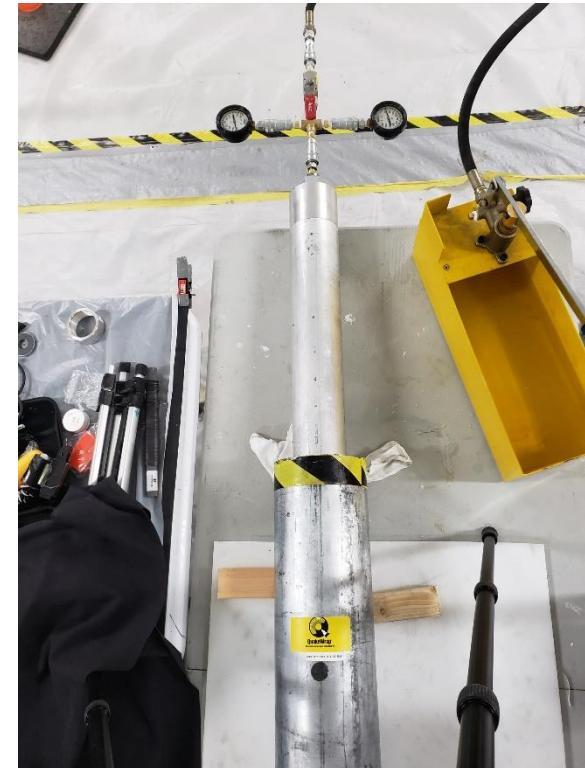
# Field Application

- First Project was completed in Feb 2011
- Client: PSE&G (NJ Gas Utility)
- Contractor: Progressive Pipeline Management
- 2-ft gap in 16" cast-iron pipe
- Winner of 2011 Trenchless Technology *Project of the Year Award*
- Over 60 similar applications



# EPA SBIR Grant

- Trenchless Water Main Point Repairs with SuperLaminate
- Phase I Grant -- \$100,000
- May – Oct 2019

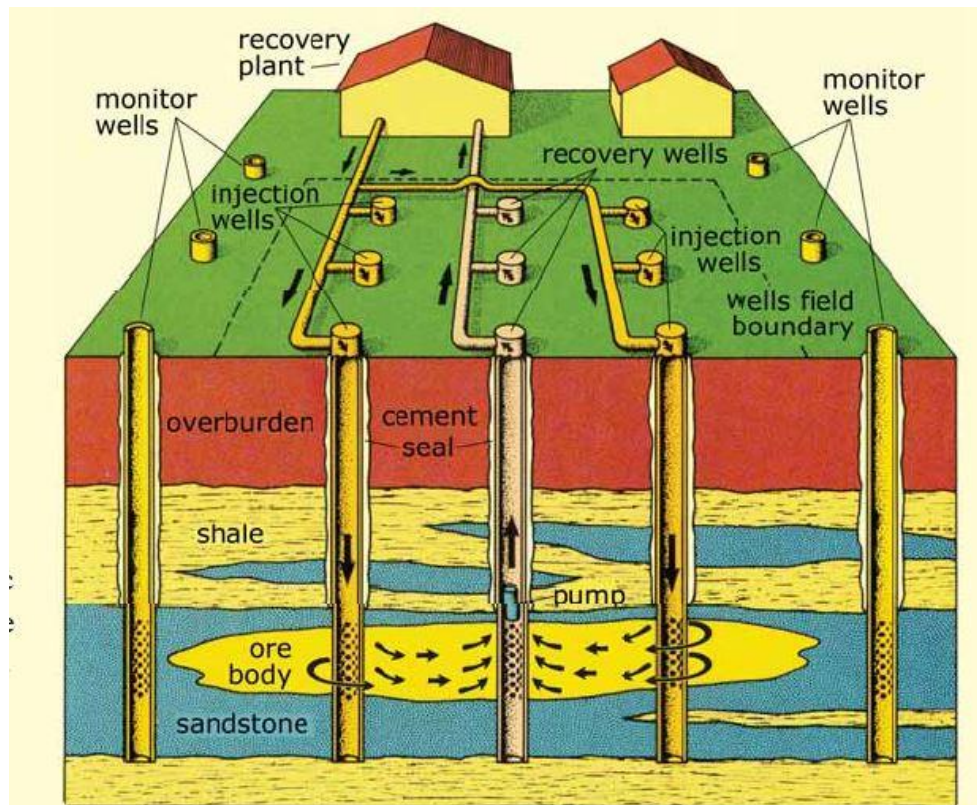


# USDA Grant for InfnitPipe®

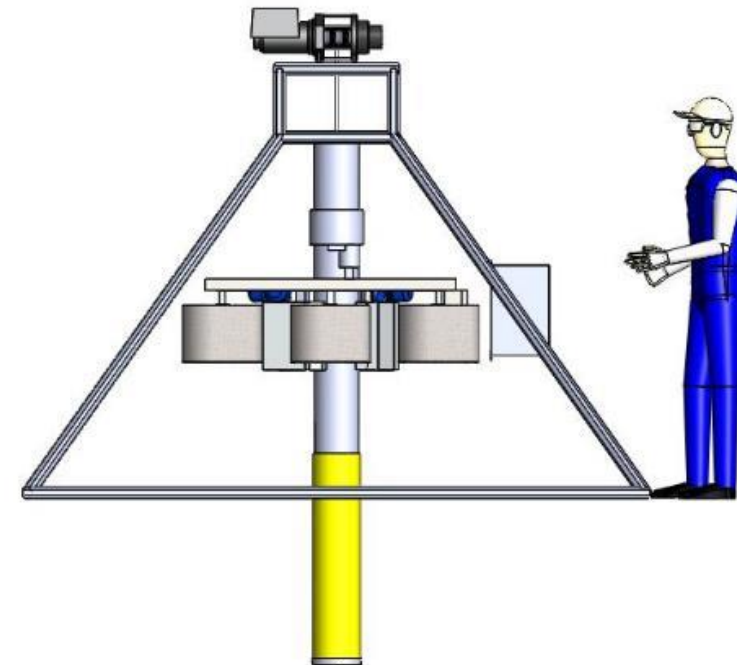


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- Phase II Grant -- \$625,000
- Sept 2019 – Aug 2021



*Schematic of the in-situ mining process.*

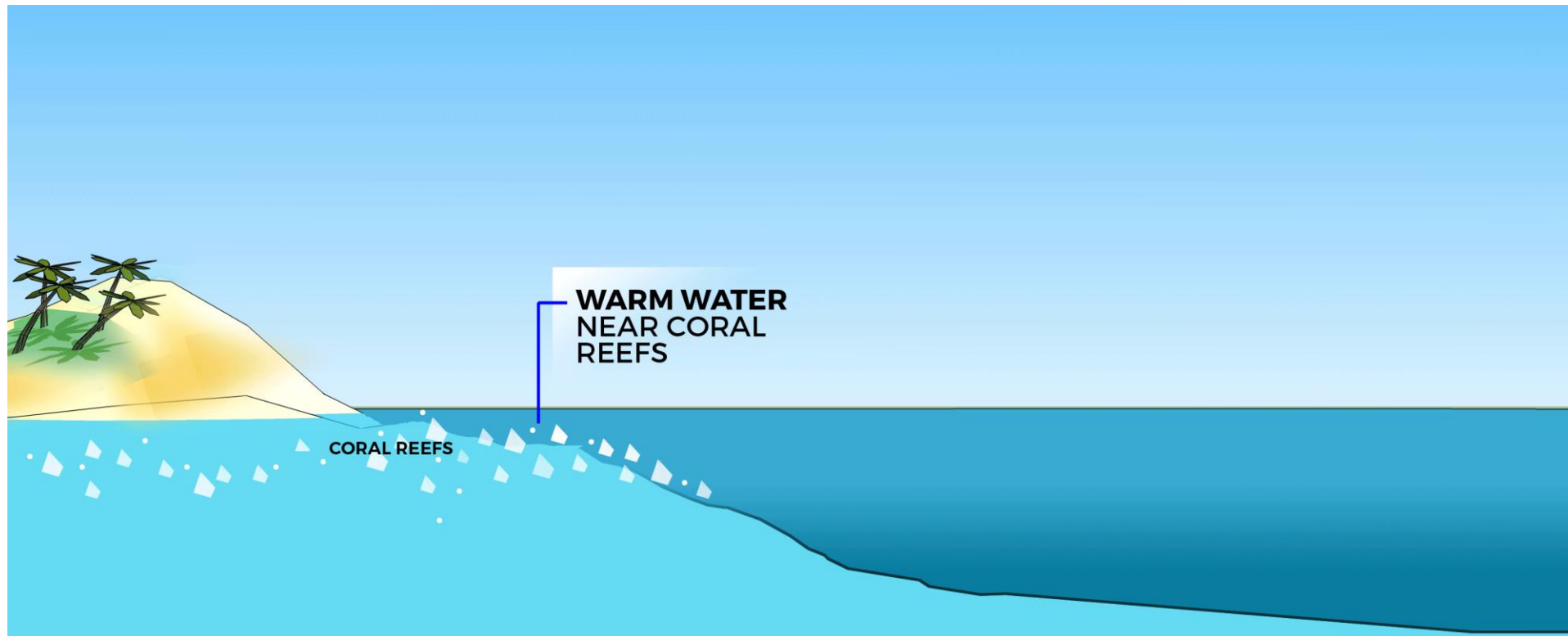


# Bleaching of Great Barrier Reef



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- **Reef lost 50% of its coral cover from 1985-2012**  
*(Australian Inst. of Marine Science)*



# *Grazie!*

## Questions?

*Mo@QuakeWrap.com*

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