Facilities Engineering Seminar
April 24-26, 2019
Jacksonville, FL

Panel I: Tech Forum: Using Tech to Extend Infrastructure

ENHANCING LIVE LOAD-CARRYING CAPACITY OF EXISTING INFRASTRUCTURE FOR EXTENDED LIFE SPAN

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OUTLINE

- Fiber-Reinforced Polymers
  - Material Properties
  - Common Types / Application Techniques
  - Advantages of FRP
- Advanced Computing Techniques
  - Advanced Structural Analysis
  - Soil-Structure Interaction
  - Damage Assessment
- Testing and Instrumentation
- Selected Projects

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FIBER-REINFORCED POLYMERS (FRP)

Constituent Materials

Fibers: Glass + Resins: Epoxy

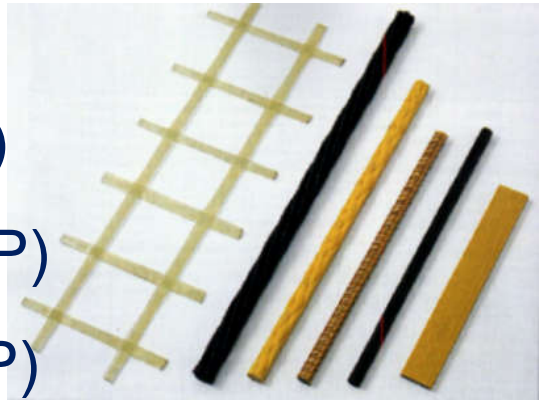
Carbon Polyester

Aramid Vinyl esters

Glass Fiber Reinforced Polymers (GFRP)

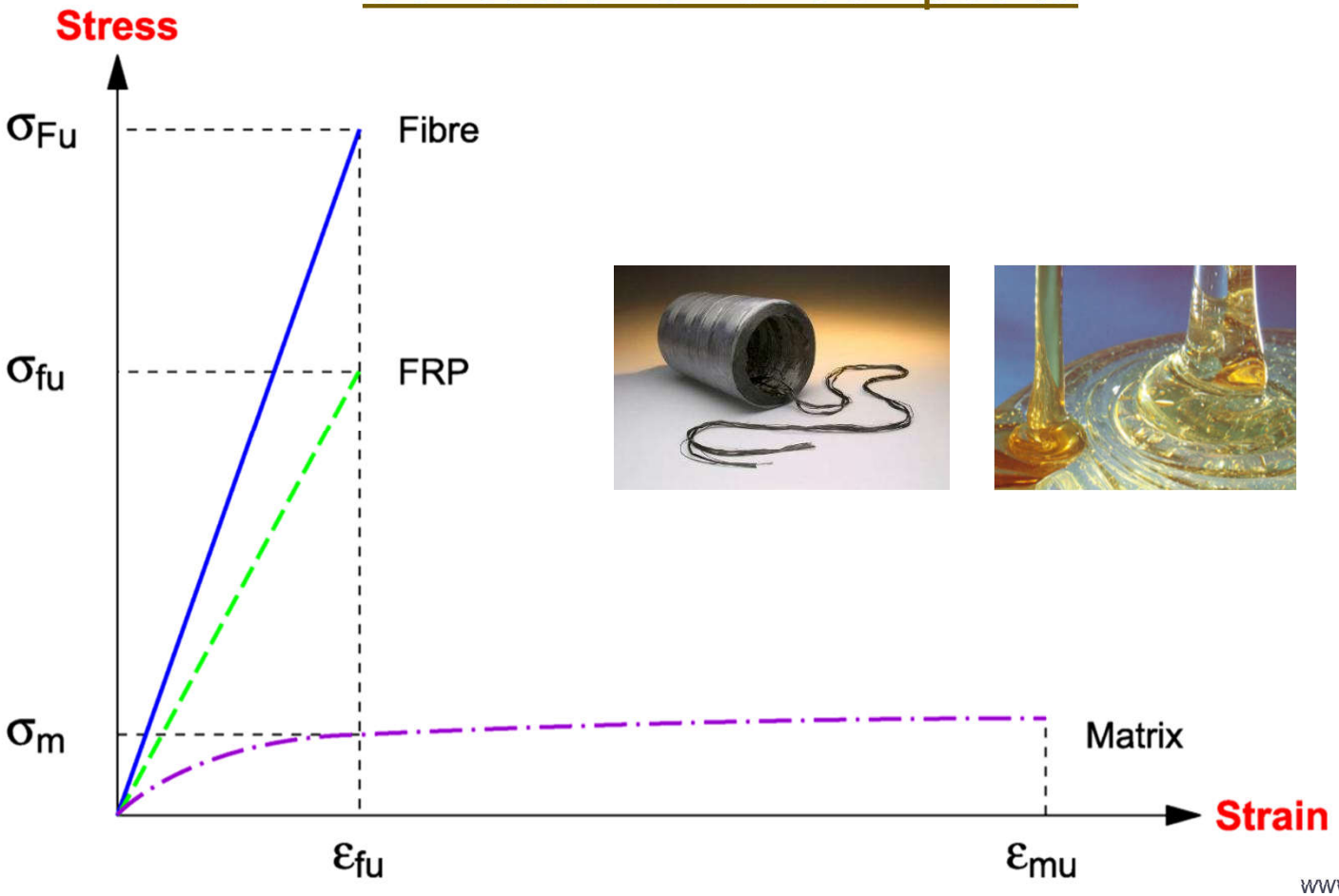
Carbon Fiber Reinforced Polymers (CFRP)

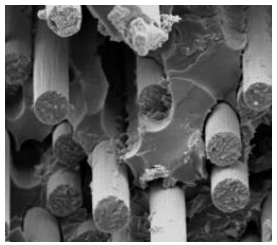
Aramid Fiber Reinforced Polymers (AFRP)



FIBER-REINFORCED POLYMERS (FRP)

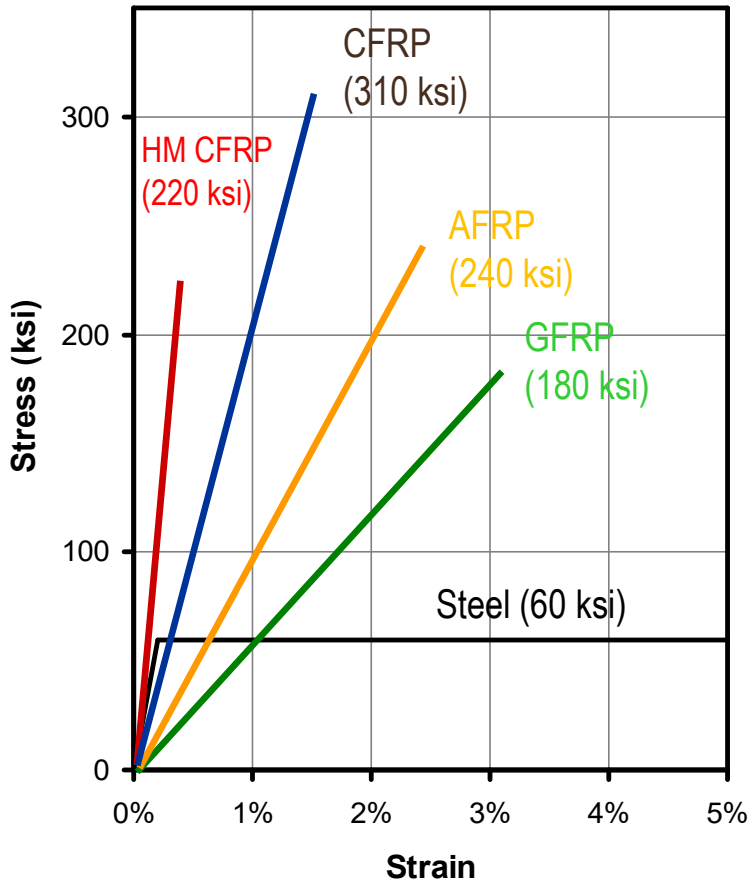
Constituents vs. Composite





FIBER-REINFORCED POLYMERS (FRP)

Mechanical Properties



FIBER-REINFORCED POLYMERS (FRP)

Advantages of FRP

- ✓ High strength-to-weight ratio
- ✓ Excellent durability
- ✓ Non-magnetic, Non corrosive
- ✓ Low profile when installed
- ✓ Fast and easy application

Table 4.2.1—Typical densities of FRP materials, lb/ft^3 (g/cm^3)

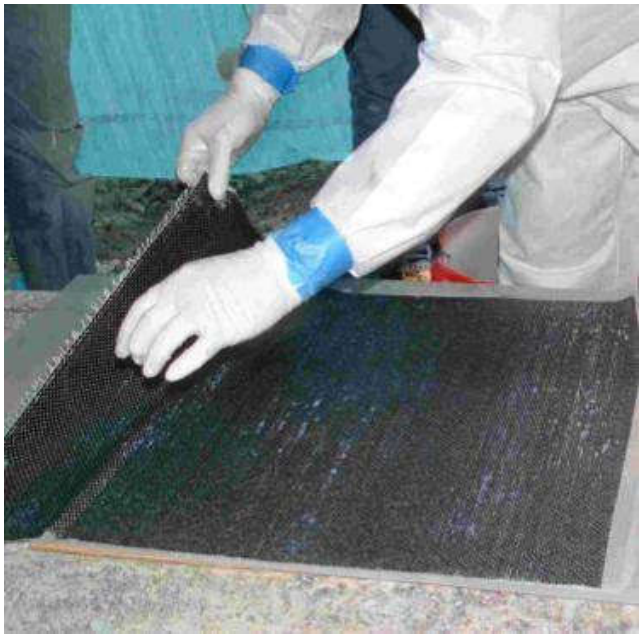
Steel	Glass FRP (GFRP)	Carbon FRP (CFRP)	Aramid FRP (AFRP)
490 (7.9)	75 to 130 (1.2 to 2.1)	90 to 100 (1.5 to 1.6)	75 to 90 (1.2 to 1.5)

ACI 440.2R

FIBER-REINFORCED POLYMERS (FRP)

Common Types of CFRP

Wet lay-up systems

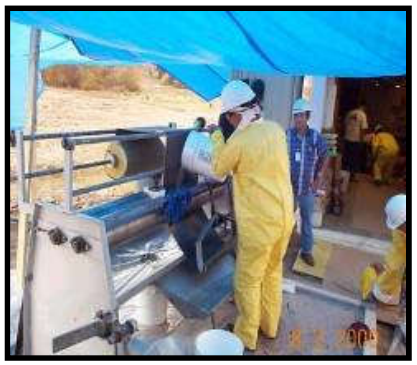


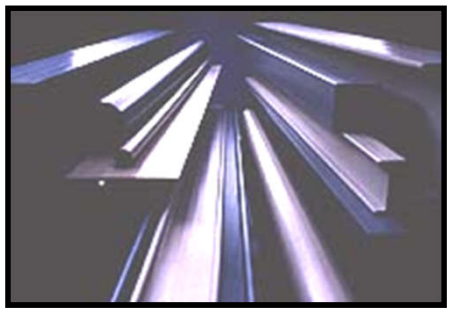
Pre-cured Laminates

FIBER-REINFORCED POLYMERS (FRP)

Common Types of FRP

Wet lay-up	Pre-cured	Pre-preg
Dry fiber sheets or fabrics impregnated with resin on-site	Pre-cured Composite shapes manufactured off-site	Pre-impregnated uncured fiber sheets or fabrics

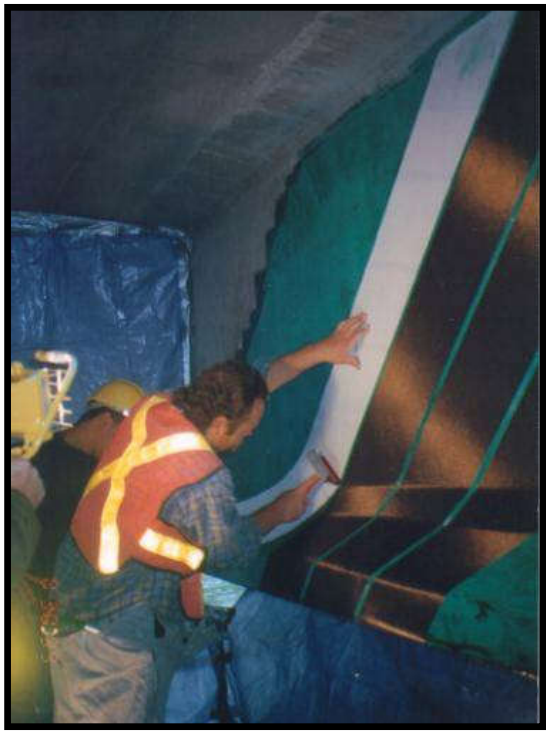




FIBER-REINFORCED POLYMERS (FRP)

Application Techniques

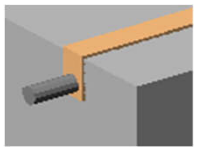
Externally Bonding (EB)



FIBER-REINFORCED POLYMERS (FRP)

Application Techniques

Near-Surface-Mounted (NSM)



NSM Bars

NSM Strips

FIBER-REINFORCED POLYMERS (FRP)

Application Techniques

Wrapping

FIBER-REINFORCED POLYMERS (FRP)

Reasons to Retrofit with FRP

- Increase load-carrying capacity
  - Flexure strengthening, shear strengthening, axial load strengthening
- Impact damaged structures
- Ductility enhancement
- Blast mitigation
- Structural upgrade and seismic retrofit
- Cutouts and penetrations

FIBER-REINFORCED POLYMERS (FRP)

Durability

- Environmental considerations
  - Alkalinity/acidity
  - Thermal expansion
  - Electrical conductivity
- Loading considerations
  - Impact tolerance
  - Creep rupture and fatigue

FIBER-REINFORCED POLYMERS (FRP)

Durability

- Environmental reduction factor (conservative estimates)
  - Fiber type & exposure conditions
- Protective coatings
- Projects that are more than 30 years old

Table 9.4—Environmental reduction factor for various FRP systems and exposure conditions

Exposure conditions	Fiber type	Environmental reduction factor C_E
Interior exposure	Carbon	0.95
	Glass	0.75
	Aramid	0.85
Exterior exposure (bridges, piers, and unenclosed parking garages)	Carbon	0.85
	Glass	0.65
	Aramid	0.75
Aggressive environment (chemical plants and wastewater treatment plants)	Carbon	0.85
	Glass	0.50
	Aramid	0.70

ACI 440.2R

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ADVANCED COMPUTING TECHNIQUES

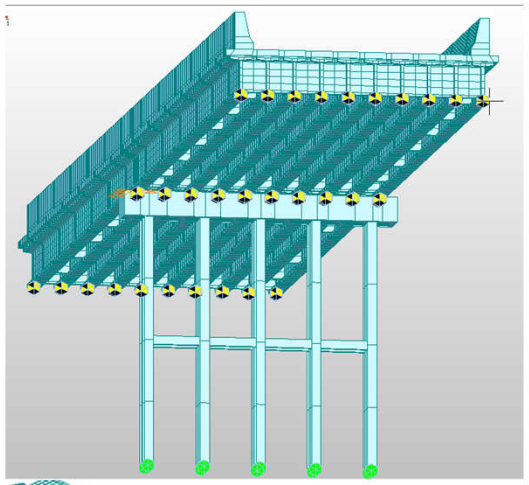
Advanced Structural Analysis

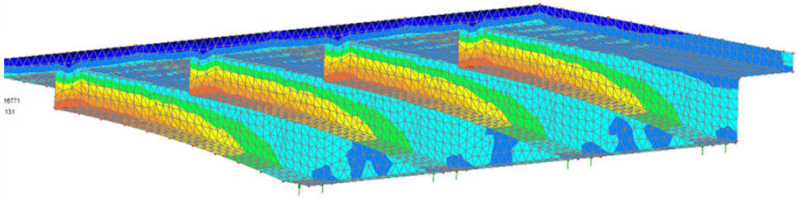
Finite Element Analysis (FEA)

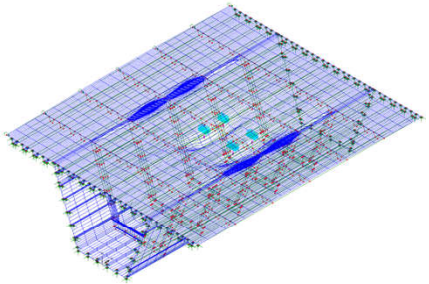
Non-linear analysis

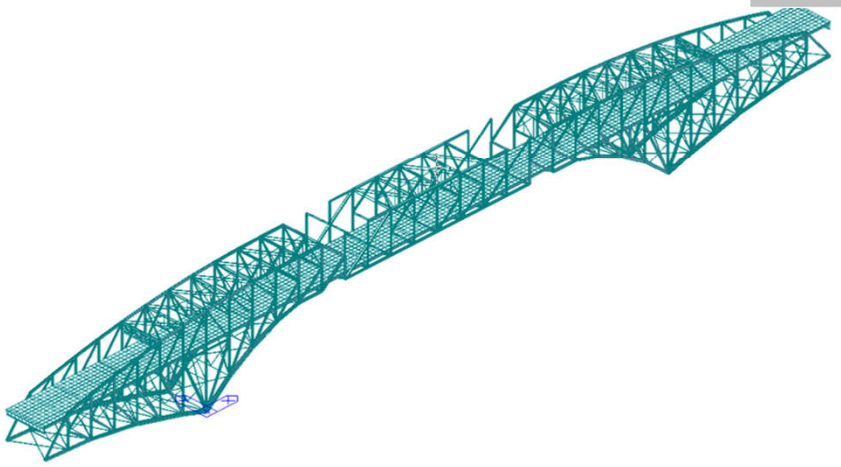
Geometrical non-linearities

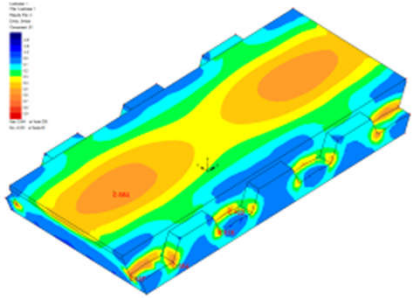
Shell elements, solid elements

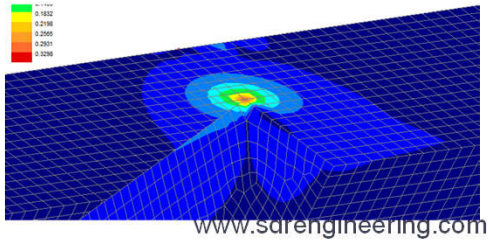












SDR

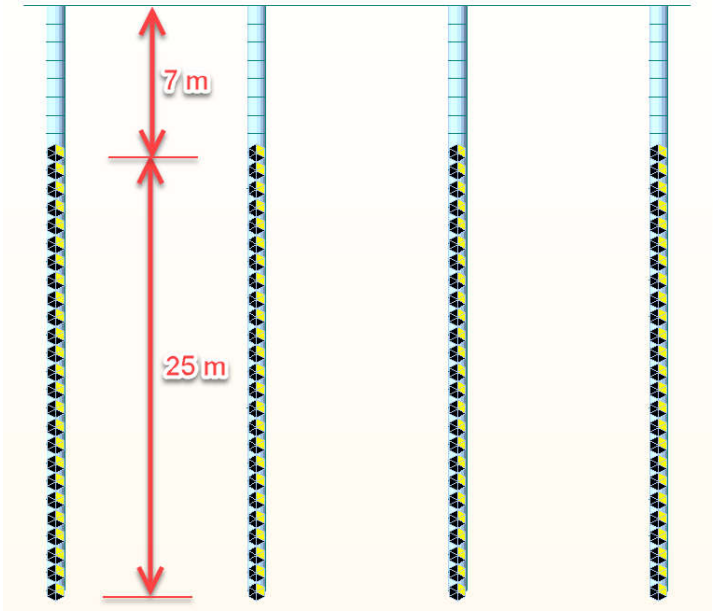
ADVANCED COMPUTING TECHNIQUES

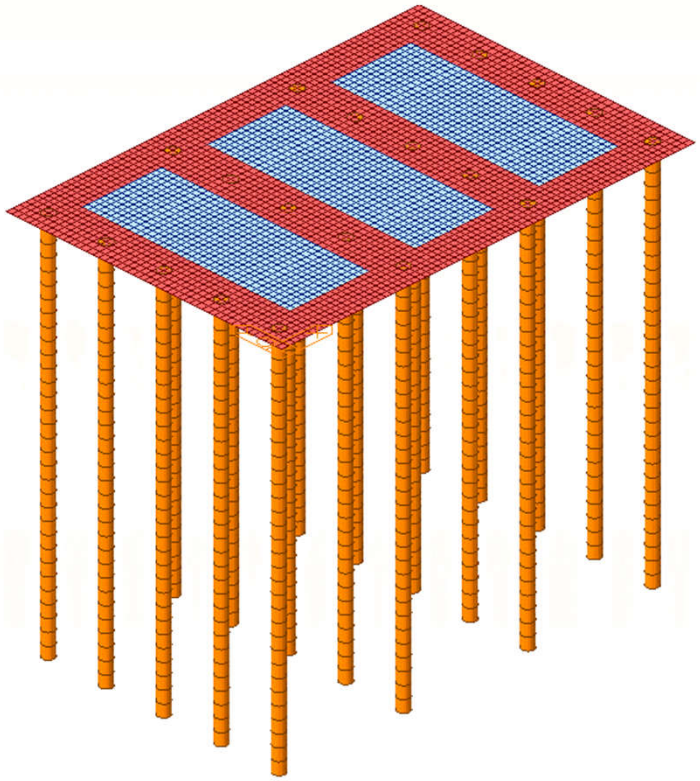
Soil-Structure Interaction

Piles: beam elements

Soil springs (P-y curves)

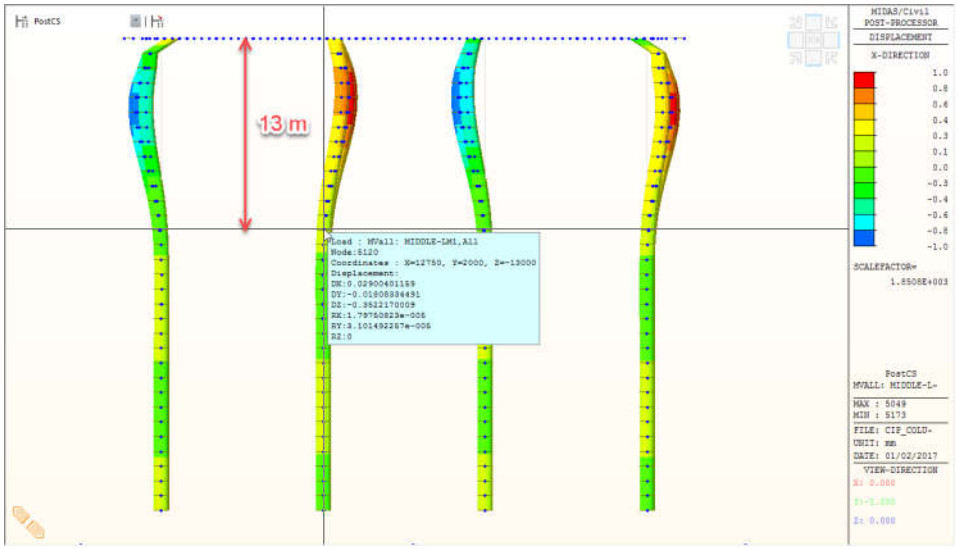
- ✓ Lateral springs
- ✓ Vertical springs



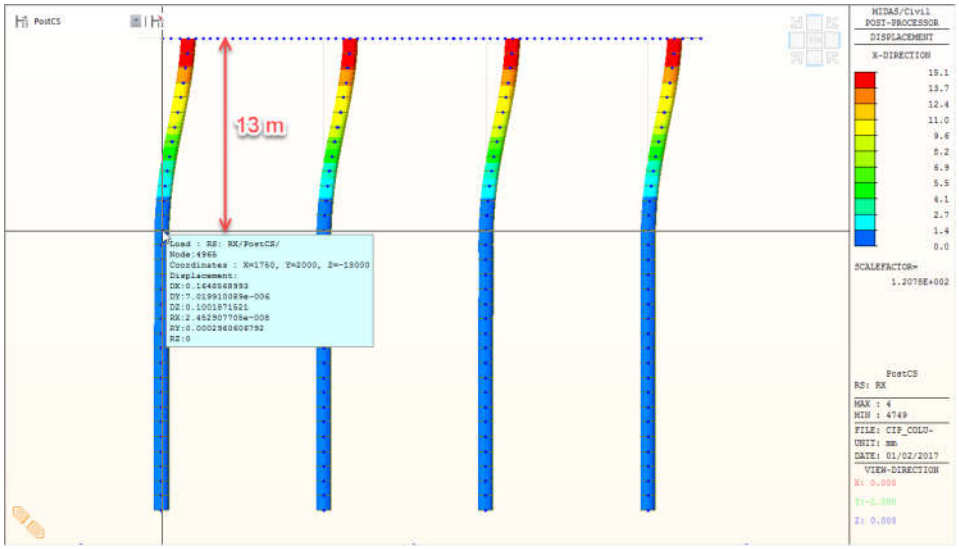


ADVANCED COMPUTING TECHNIQUES

Soil-Structure Interaction



Gravity Loads



Lateral Loads

ADVANCED COMPUTING TECHNIQUES

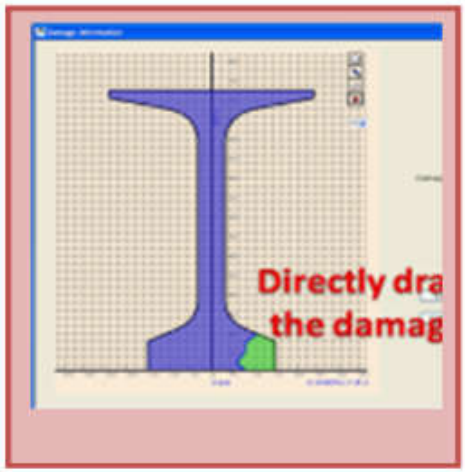
Damage Assessment

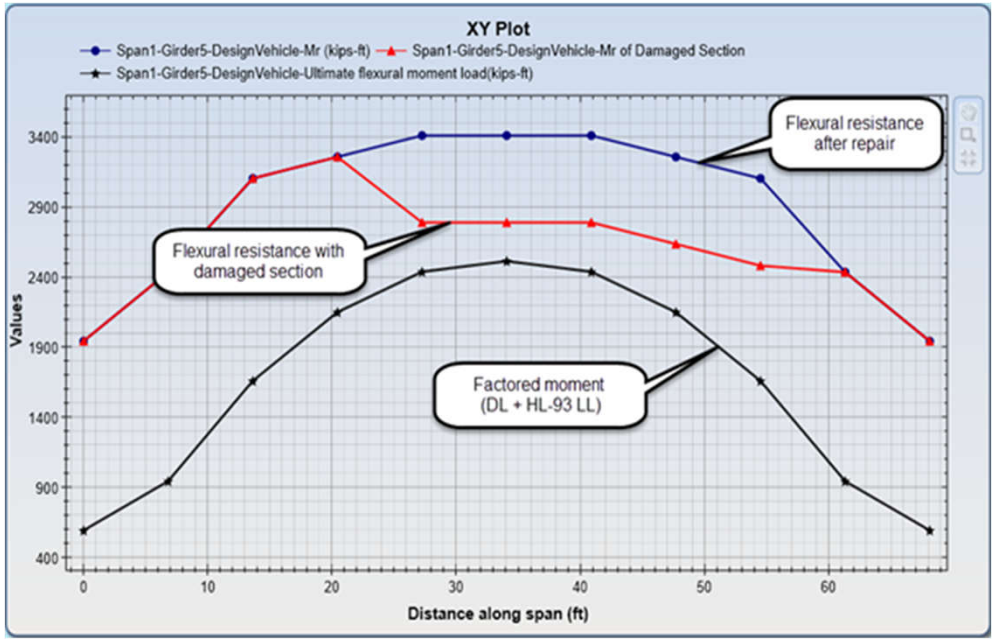
Section loss

Corrosion of steel

Loss of bond

Deterioration





SMART BRIDGE SUITE

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TESTING AND MONITORING

Load Testing

- Actual behavior of structure (load distribution)
- Strength enhancing factors not included in calculations
  - Composite actions
  - Continuity/fixation
  - Secondary members
- Static tests (proof test and diagnostic test)
- Dynamic tests

TESTING AND MONITORING

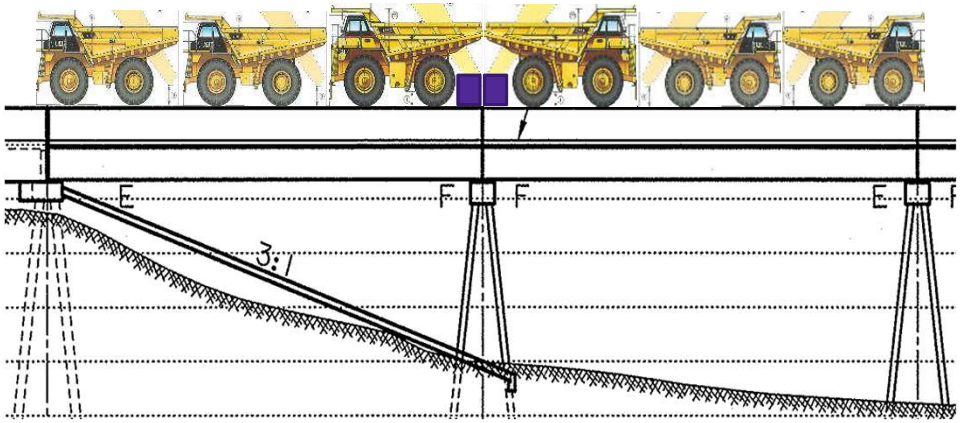
Load Testing

Counter weights

Trucks with known weights

TESTING AND MONITORING

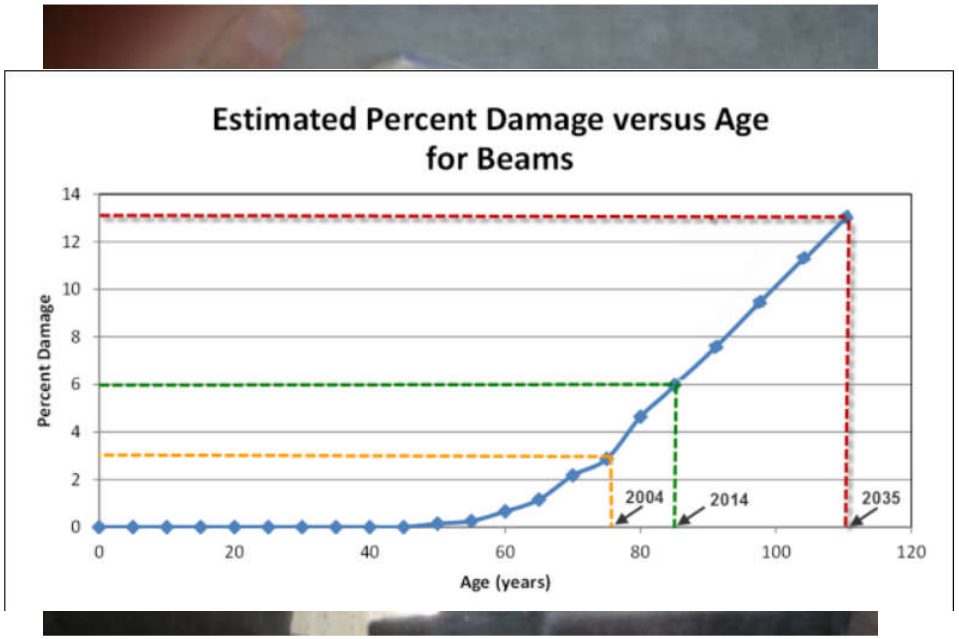
Load Testing



390 KIPS TRUCKS

TESTING AND MONITORING

Non-Destructive Testing



Chloride Ion Penetration

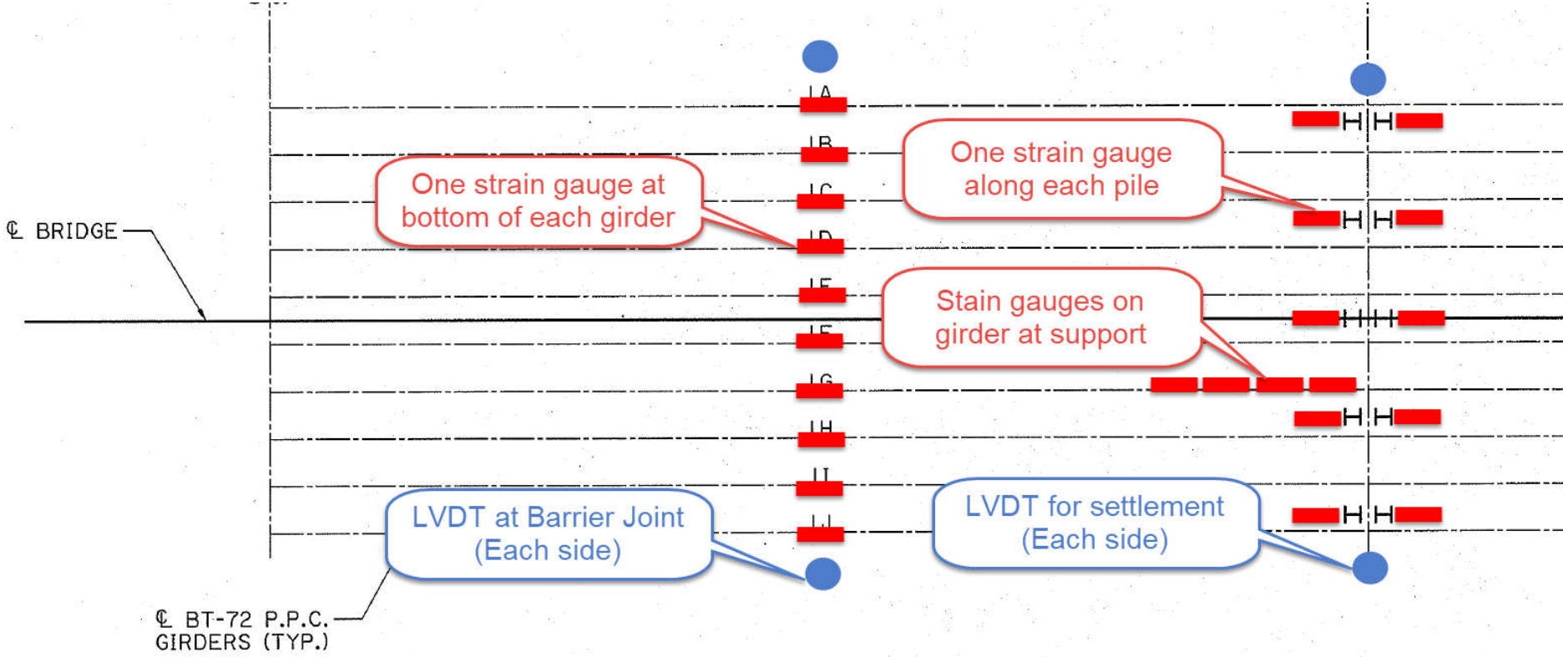
Cover removal and reinforcement inspection

TESTING AND MONITORING

Instrumentation

TESTING AND MONITORING

Instrumentation



Instrumentation plans are developed based on analysis of structure.

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SELECTED PROJECTS

Allen Creek Bridge
Clearwater, FL 2005

- ✓ Wrapping of piles
- ✓ Underwater application
- ✓ Splash zone

SELECTED PROJECTS

US 1 Bridge
Melbourne, FL 1994

- ✓ Corrosion of main reinforcement
- ✓ Girders repair
- ✓ Concrete section restoration

SELECTED PROJECTS

Rockaway Line Viaduct
New York, NY 2009

- ✓ Corrosion of reinforcement
- ✓ Girders repair
- ✓ Concrete section restoration

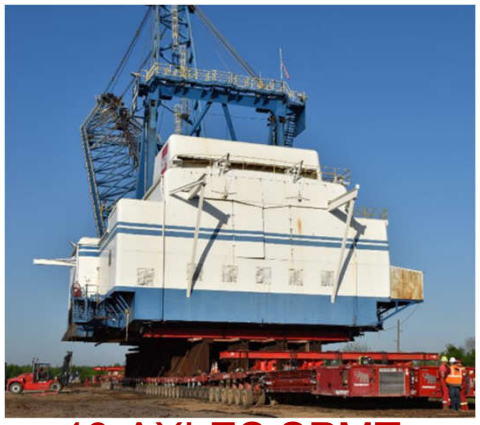
SELECTED PROJECTS

I-10 Bridge Over L&A Railroad
LA 2016

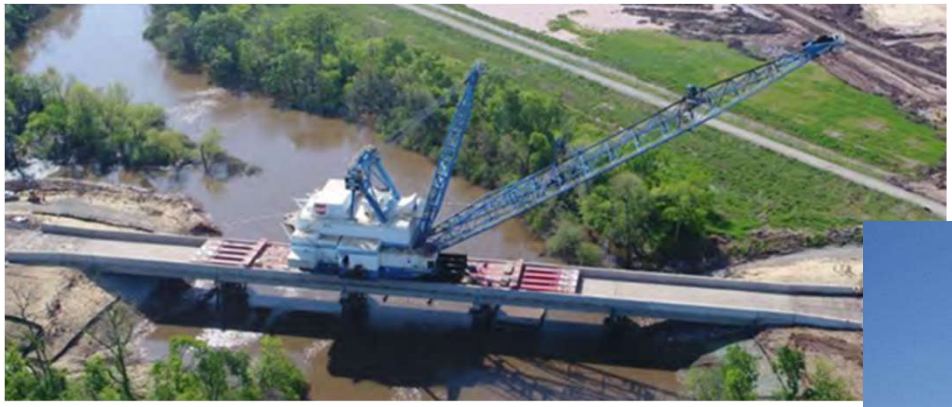
- ✓ Strengthening of deck slab
- ✓ Instrumentation & proof testing

SELECTED PROJECTS

Bayou Pierre Bridge
Desoto & Red River Parishes, LA 2018



46-AXLES SPMT



390 KIPS TRUCKS

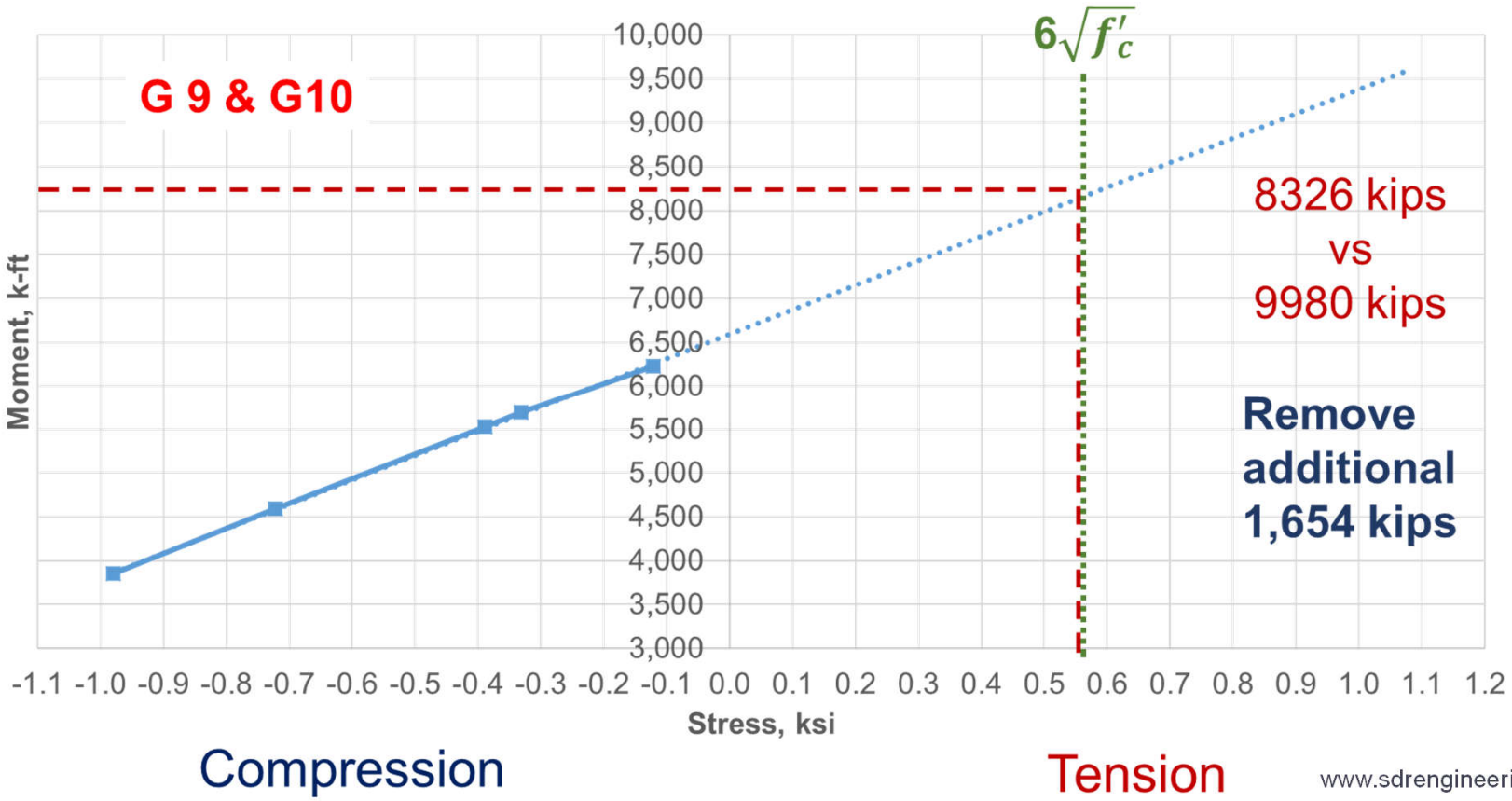
5-Span with total length of 500 ft.

10 PPC girders

10,000 kips (4,500 tons) DRAGLINE

SELECTED PROJECTS

Bayou Pierre Bridge
Desoto & Red River Parishes, LA 2018



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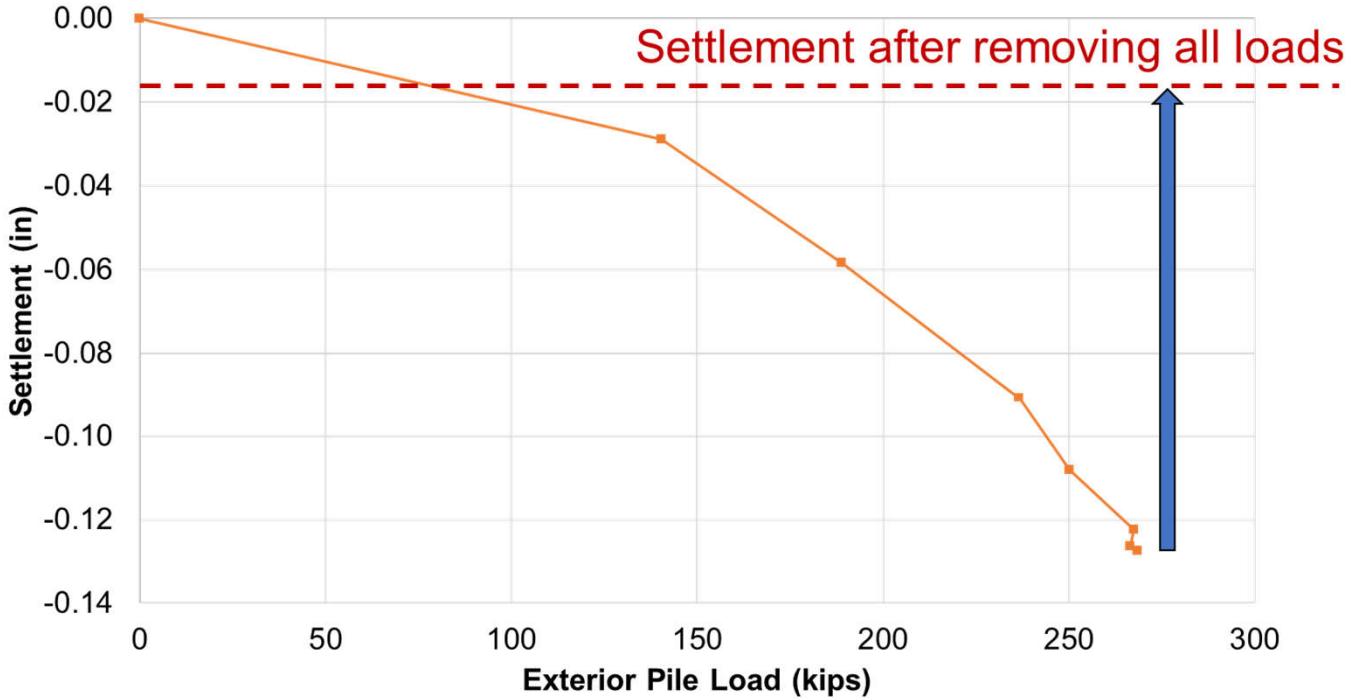

Elastic shortening + Temperature effect = -0.124”


Thank
You !