CIE-500 Prof. George C. Lee; 340C Bell Hall

FRP Composites for Bridge Applications

September 21, 2009

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Definition

- <u>FRP</u>: Fiber Reinforced Polymer
- <u>Composite</u>: A man-made (i.e. engineered) material that combines two or more components to make a material with improved properties over either of the two individual constituents. Each of the two components works in harmony with the other(s) but retain their own chemical and physical properties.

Outline

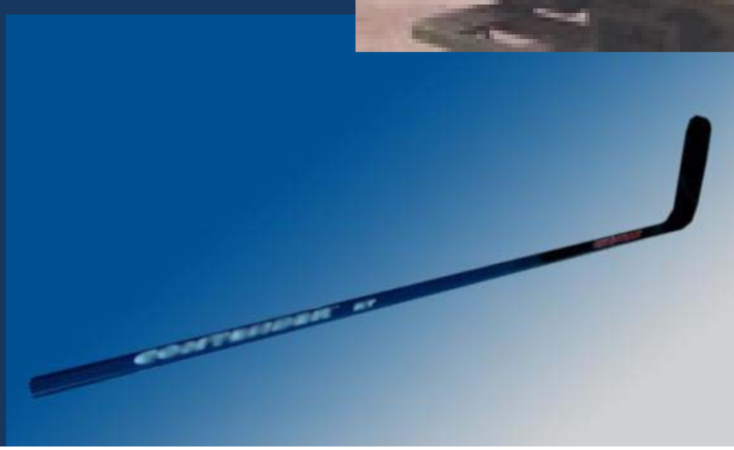
I. FRP Basics

II. Civil Engineering Applications

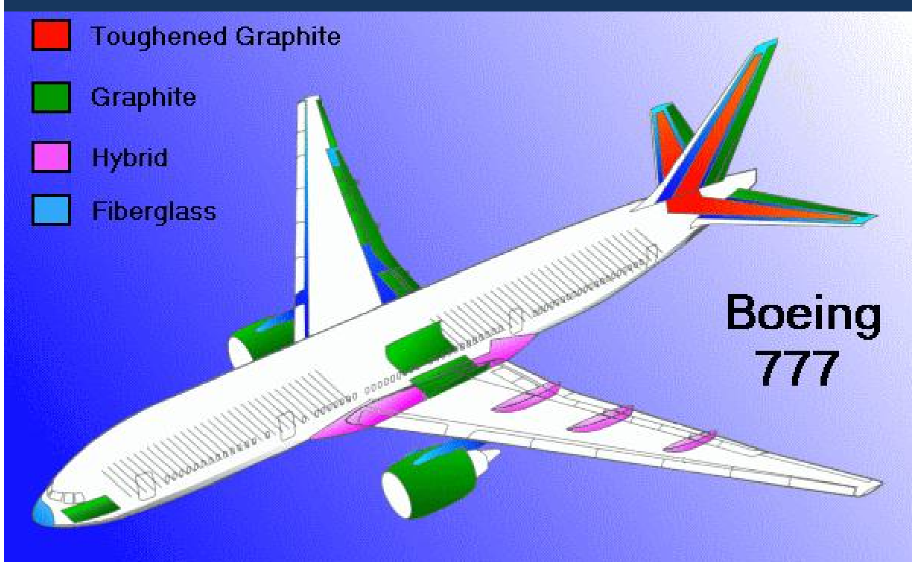
- Rebar (ppt)
- Seismic Retrofitting (go to)
- Aerodynamic Improvement (go to)
- Concrete Strengthening using sheet, rods, strips, plates (Techniques for strengthening steel with FRP is still evolving)
  - Beams
  - Columns Court St
- Overhead Sign Structure Repair (go to)
- Culvert Relining (go to)
- Bridge Decks Bentley
- Bridge Superstructures New Oregon PR-139

III. Handouts & References (go to)

General FRP Applications



Aerospace Applications



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Bridge of the Future

- Long life
- Less $
- Fast
- Minimal maintenance
- Shock resistant
- Adaptable
- (Reduced carbon footprint)

Available FRP Products

- Concrete reinforcement (2)
- External Concrete Reinforcement
  - Fiber sheets (8)
  - Near surface mounted rods and strips (3)
- FRP decks (8)
- FRP superstructures (6)
- Repair kits for aluminum overhead sign structures (2)
- Linings for existing culverts (3)
- Structural shapes (4)

Examples of Composites

- GFRP (glass fiber reinforced polymer)
- CFRP (carbon fiber reinforced polymer)
- AFRP (aramid fiber reinforced polymer)
- Wood with cellulose fibers is a natural composite
- Reinforced concrete uses steel reinforcing in a cement and aggregate matrix
- Renewable materials (natural fiber such as hemp combined with bio-resins)
- MMC (metal matrix composite)
- CMC (ceramic matrix composite)
- ECC (engineered cementitious composite, aka ‘bendable concrete)

Definition

FRP = Fiber Reinforced Polymer Composite

Carbon
E-Glass
Aramid
Phenolics

Epoxy
Vinyl Ester
Polyester

thermo-set

Each component retains it own properties yet act in concert with one another.

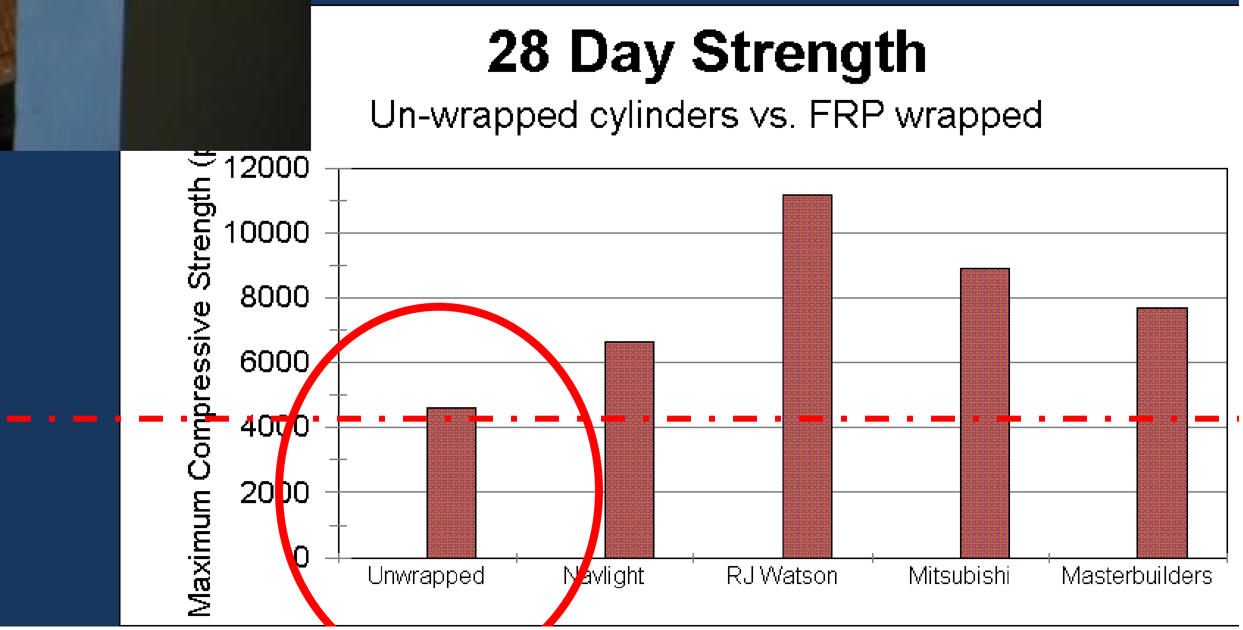
Advantages

- Light weight (high strength-to-weight ratio)
- Corrosion resistant
- Chemical resistant
- Anisotropic
- High tensile strength
- Fatigue resistant
- Potential for good, consistent quality
- Engineer-able
- Non-magnetic


Steel bridge beam

Advantages

Hybrid Use e.g. Enhance concrete compressive strength



Disadvantages

- Higher initial *material* cost
- Civil engineers typically have little education and experience with composites; Contractors and construction crews are very familiar with concrete, steel, asphalt and less so with FRP
- Failure of fibers is not ductile
- More sophisticated design is sometimes needed (e.g. Finite Element Analysis , FEA)

Design Considerations

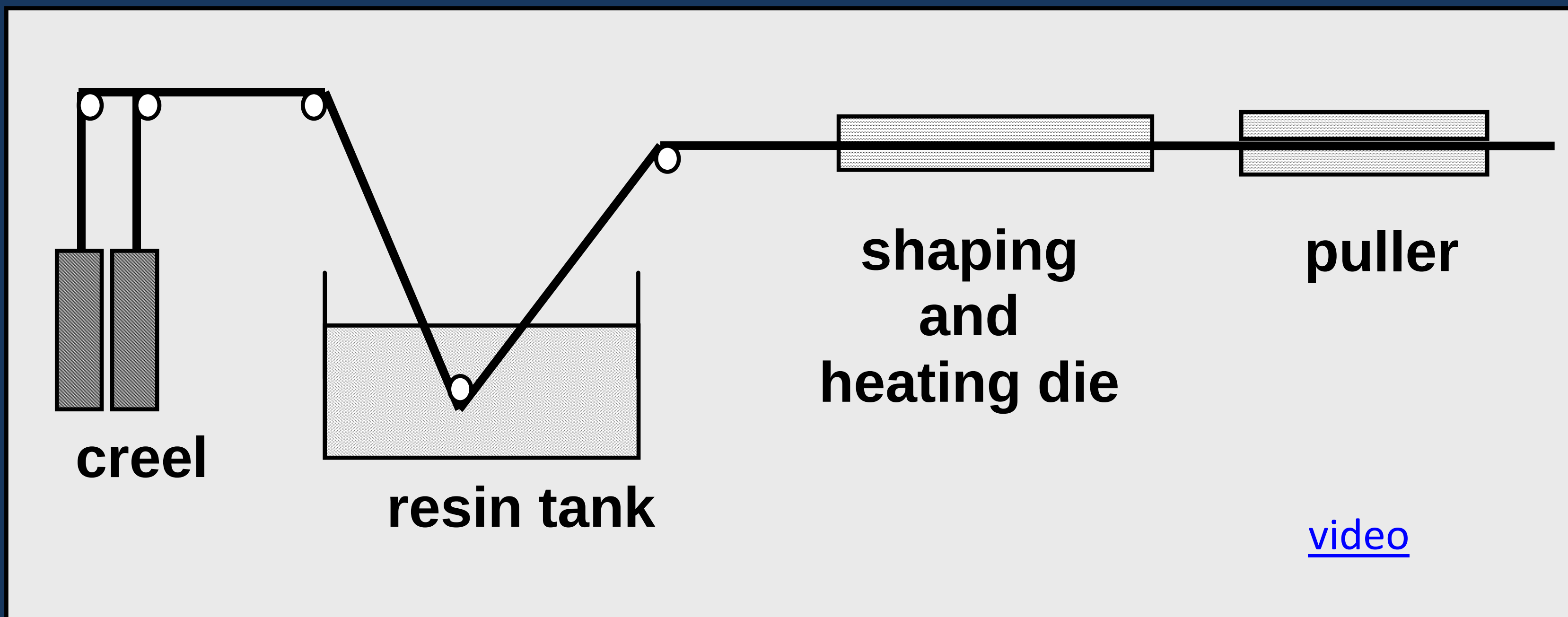
- Low shear strength relative to tensile
- Low modulus of elasticity (~ stiffness)
- Susceptible to creep under sustained loading
- Needs UV protection
- Anisotropic
- Theoretically engineer-able (may not be practical in practice; standard designs may be more cost effective)

Manufacturing Methods

- Filament winding (used mainly for pipes)
- Hand Lay-up
- Pultrusion
- Vacuum Assisted Resin Transfer Molding (VARTM)

- Shop fabrication vs. field

Manufacturing Methods
- Pultrusion -



Fibers in pultrusions are predominately uni-directional (longitudinal).

Manufacturing Processes

Open Mold hand lay up

Manufacturing Methods
VARTM

Strength Determined by

- Type of fiber
- Type of resin
- Fiber volume fraction
- Fiber orientation
- QC during manufacturing
- Rate of Curing

Post-cure

- Some composites, especially one used for aerospace applications are heated to accelerate the cure and increase its strength
- Field applications on bridges (such as column wrapping) typically do not get a post cure

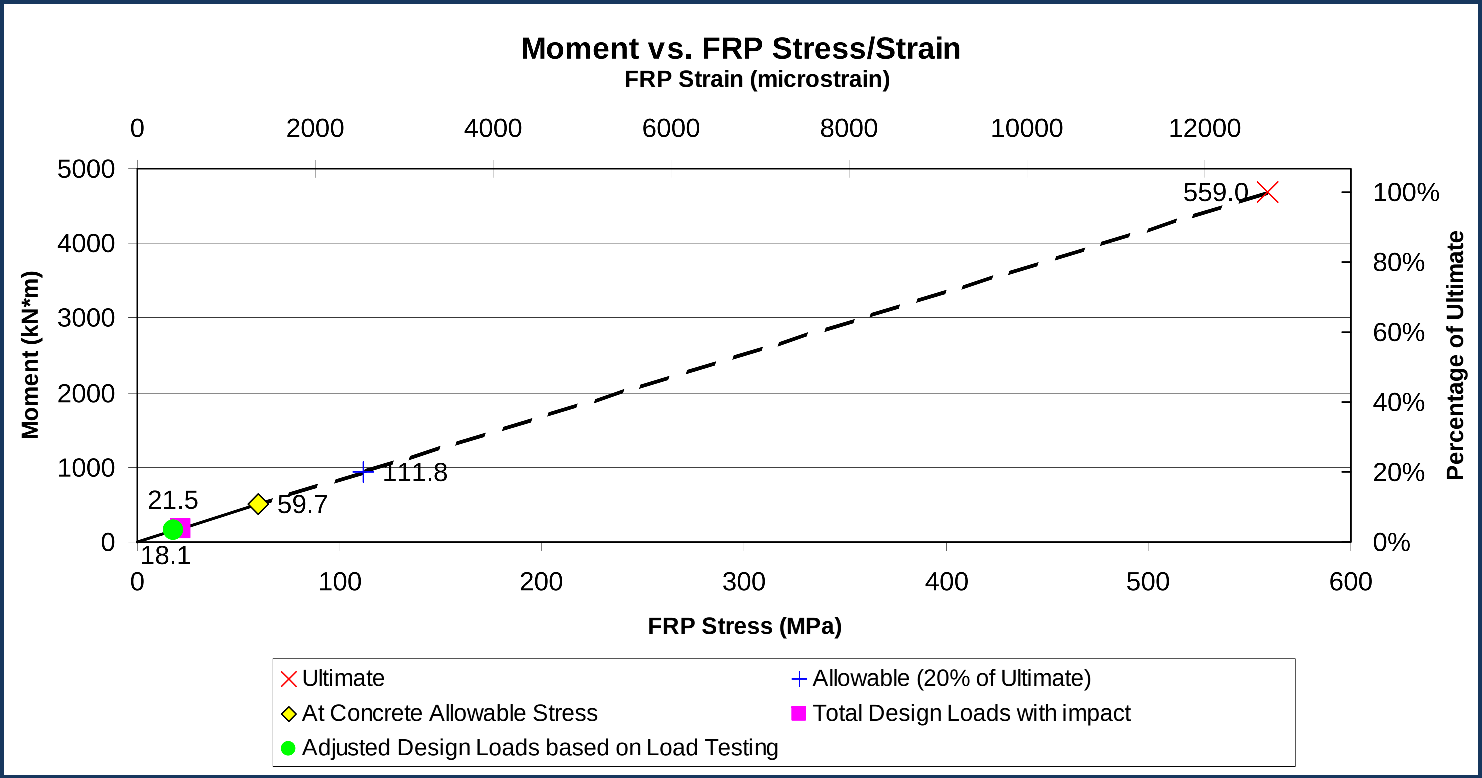
PROPERTIES

Thermo-plastic vs. Thermo-set

- Thermo-plastic: resin has a melting temperature at which it turns to a liquid. It can be recooled to form a solid again. Thermoplastic resins are easily recyclable.
- Thermo-set: a liquid resin hardens only after addition of a catalyst in a non-reversible chemical reaction. It does not melt into a liquid a high temperatures but has a glass transition temperature (T_g) at which the mechanical properties change and it loose strength. Most civil applications use thermo-set composites.

Linear Elastic

- Fibers do not exhibit ductility prior to rupture
- Linear elastic until failure



Creep

- Deformation (i.e. deflection) under sustained load
- Can lead to creep rupture (sudden failure)
- Potential problems can be avoided by keeping dead load stresses < 20-30% of FRP ultimate tensile strength

Anisotropic

Stiffness

- Stiffness is driven by Modulus of Elasticity E for a given Moment of Inertia I
- Bending Rigidity = EI
- E can vary
- CFRP can have a higher E than steel
- GFRP has a low E. Despite this, GFRP is typically used for bulk applications because of cost

Material Characteristics
Determined by

- Type of fiber
- Type of resin
- Fiber volume fraction
- Fiber orientation
- QC during manufacturing
- Rate of Curing

Fiber Architecture

- Type of fiber
- Weave vs. uni-directional
- Number of layers
- Fiber orientation
- Void Ratio (want <1%)
- Fiber content
  - % by weight – convenient for fabricator to use
  - % by volume determines strength and long term durability
    - The fibers are the load carrying component of the FRP so the higher the fiber density, the higher the strength of the composite
    - Denser material reduces the potential for water intrusion

% Fiber by volume

- 100% is not physically possible
  - Resin takes up space
  - Even dry packing fibers would result in voids between fibers
- Typical
  - High grade aerospace: 50%-75%
  - Civil applications
    - Pultruded in factory: 30%-60%
    - Field application: 25%-30%
    - VARTM

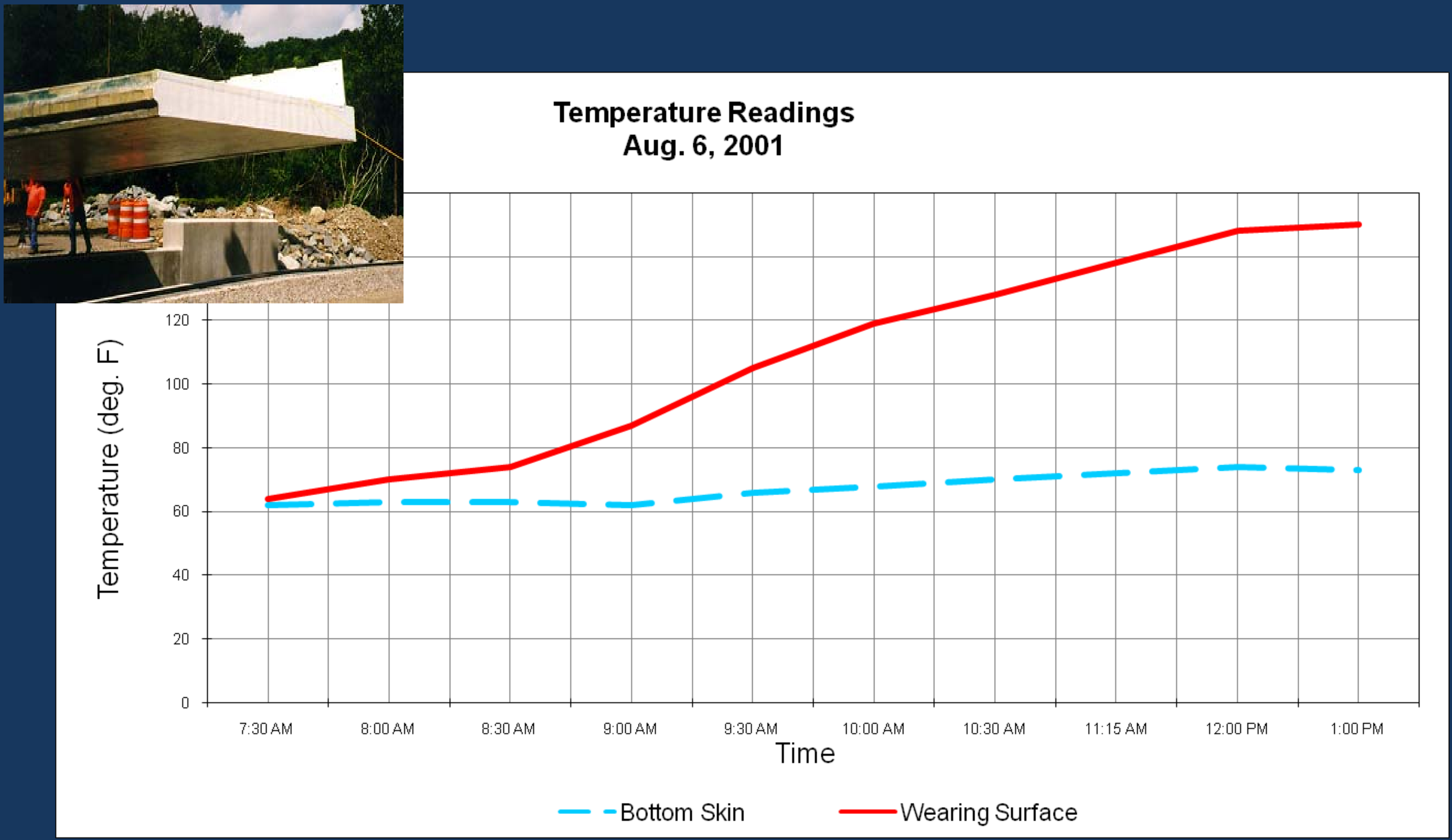
Thermal Properties

- Different from materials conventionally used in civil works projects
- Different behavior in each direction
- CFRP coefficient of thermal expansion (CTE) is negative

Thermal Properties

Nov 13, 2001 9:30 am

Sample Temperature Gradient



Temperature readings at 248 / Bennetts Creek 6/1 BIN 1043150

Sample Temperature Gradient

Temperature readings at 248 / Bennetts Creek 6/1 BIN 1043150

Time	Bottom skin temperature in °F	Top wearing surface temperature in °F (black color)	Difference
7:30 AM	62	64	2
8:00 AM	63	70	7
8:30 AM	63	74	11
9:00 AM	62	87	25
9:30 AM	66	105	39
10:00 AM	68	119	51
10:30 AM	70	128	58
11:15 AM	72	138	66
12:00 PM	74	148	74
1:00 PM	73	150	77

POSSIBLE RESULTS: 1) Panel can "hog"; 2) High thermal stresses

Hygral

- Hygral expansion and relaxation shrinkage
- Need to prevent water intake from extended immersion or high humidity

Fatigue

- FRP is good in fatigue but good quality control during fabrication is essential to getting good results.
- Tested and used extensively in other industries (aerospace, military, sports)

Connections

- Bonded (examples of adhesives are listed below)
  - ITW's Plexus (methyl-methacrylate)
  - Ashland's Pliogrip (polyurethane)
  - ProSet (two-part epoxy)
  - Loctite, 3M, Permabond (acrylic)
- Mechanical
- Hybrid

Properties Time Dependant

- Materials degrade over time (~5% over 100 year life)
- Account for this using “knockdown” factors for material properties

Fire & Heat Resistance

- Will not support flame spread due to lack of oxygen and high % of fiber
- Resin softens at Glass Transition Temperature (T_g) e.g. 150-250 degrees
- At 480 degrees F, tests show 20% strength reductio
- At T_g bond strength may reduce by 40%

vs. Steel & Concrete

FRP vs. Steel

Can have greater ultimate strength	Standard grades
Linearly elastic until failure, i.e. no yielding	Elastic until yield point
Sudden brittle failure	Exhibits <u>ductility</u> in plastic range
Shear strength typically 1/25 of tensile	Shear strength is ½ of tensile
Low E and low stiffness	E = 29,000,000 psi
Uni directional properties	isotropic

Material Characteristics

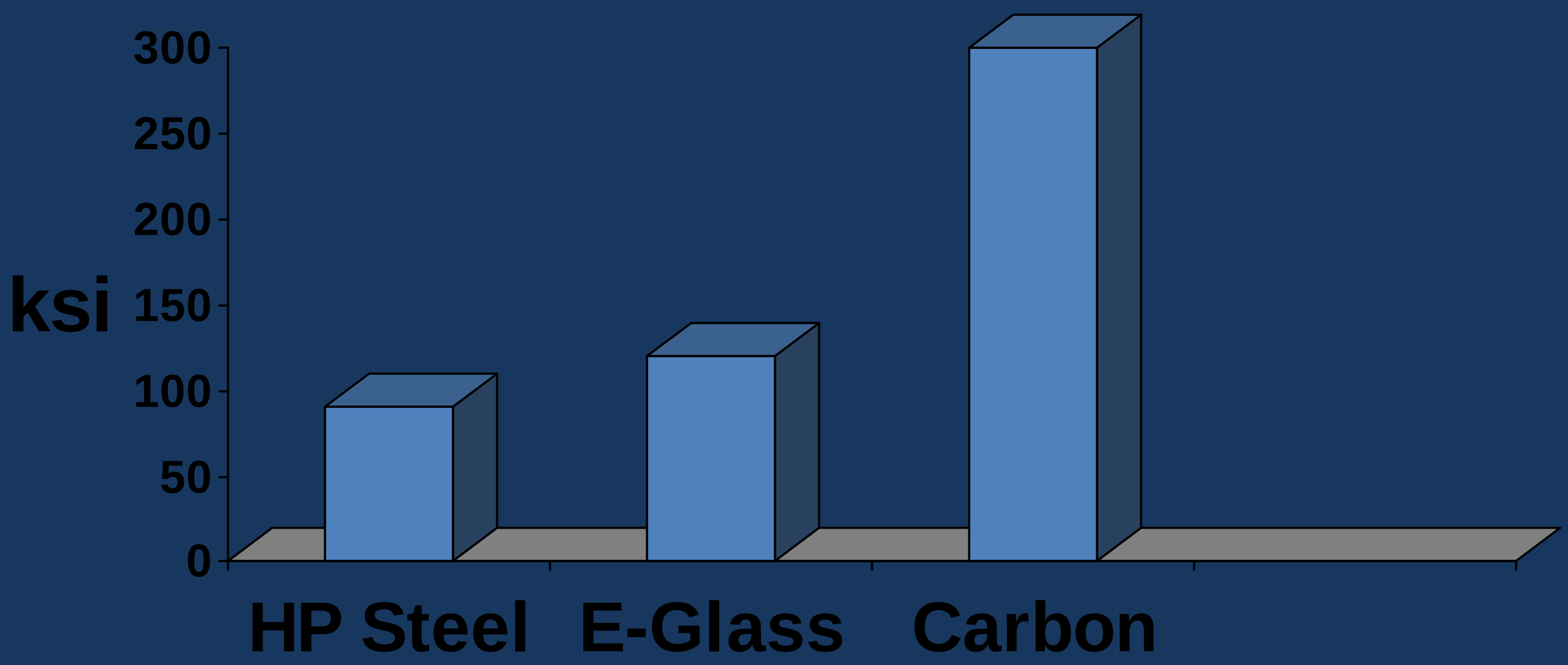
Tensile Strength

ksi				
E-glass	Carbon	Aramid	Steel	Concrete
70 to 230	87 to 535	250 to 368	70 to 100	NA

per ASTM D3039

Material Characteristics

Ultimate Tensile Strength



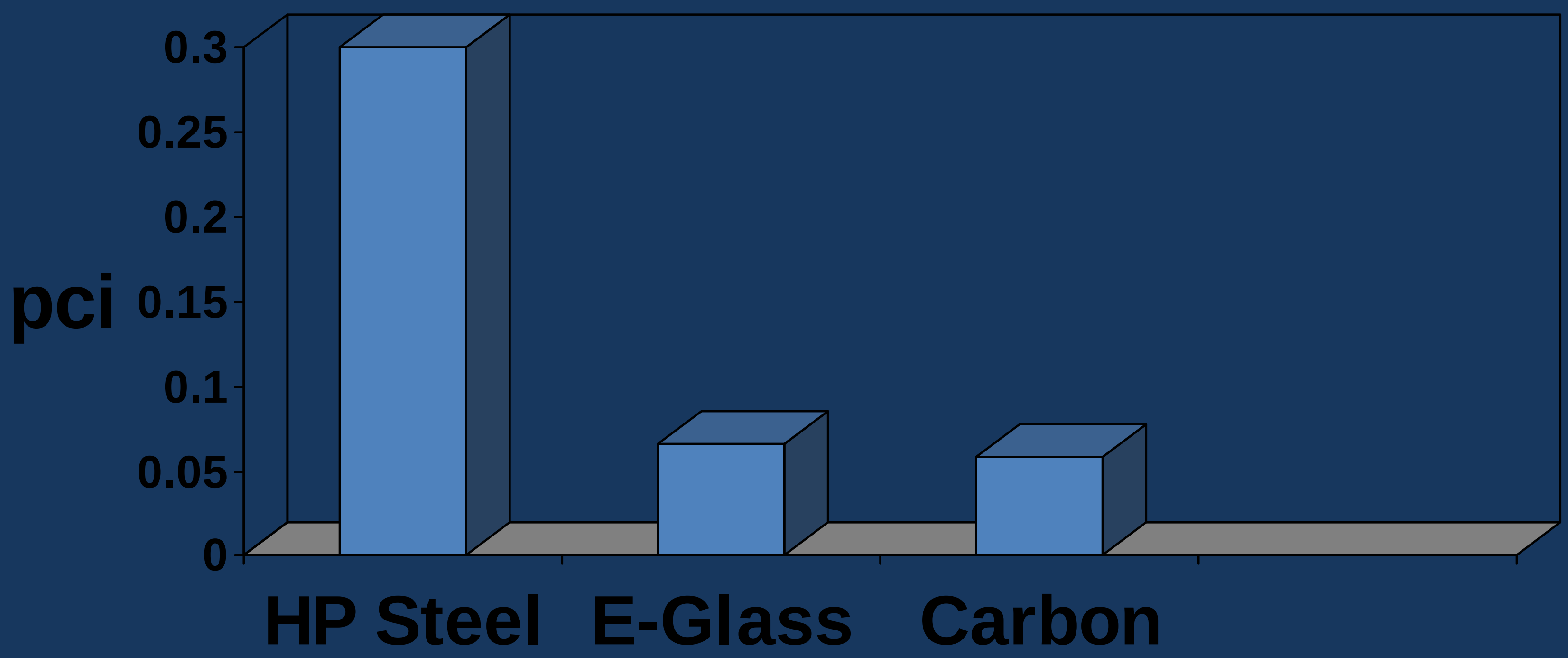
Material Characteristics

Rupture Strain

% at failure				
E-glass	Carbon	Aramid	Steel	Concrete
1.2 to 3.1	0.5 to 1.7	1.9 to 4.4	6 to 12	NA

Material Characteristics

Density



FRP density is approximately 1/5 that of steel

Material Characteristics

Coefficient of Thermal Expansion (CTE)

	CTE, X 10^{-6}/F				
	E-glass	Carbon	Aramid	Steel	Concrete
Longitudinal	3.3 to 5.6	-4 to 0	-3.3 to -1.1	6.5	5.5
Transverse	11.7 to 12.8	41 to 58	33.3 to 44.4	6.5	5.5

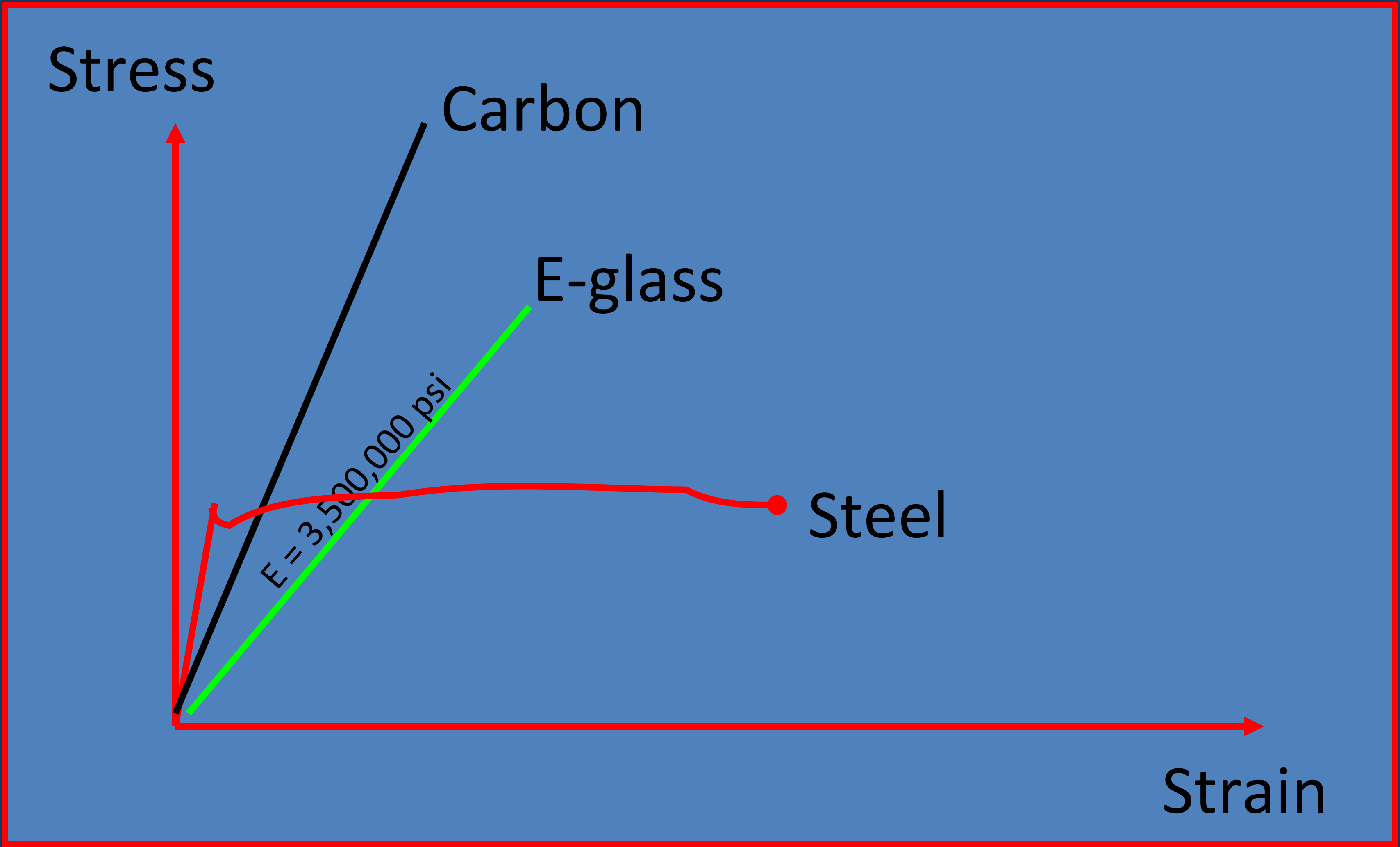
- Anisotropic so very different properties parallel and perpendicular to the fibers
- Negative CTE means material shrinks as temperature rises

Material Characteristics

E: Modulus of Elasticity

E, X 10^{-3} ksi				
E-glass	Carbon	Aramid	Steel	Concrete
3.3 to 5.6	15.9 to 84	6 to 18.2	29	NA

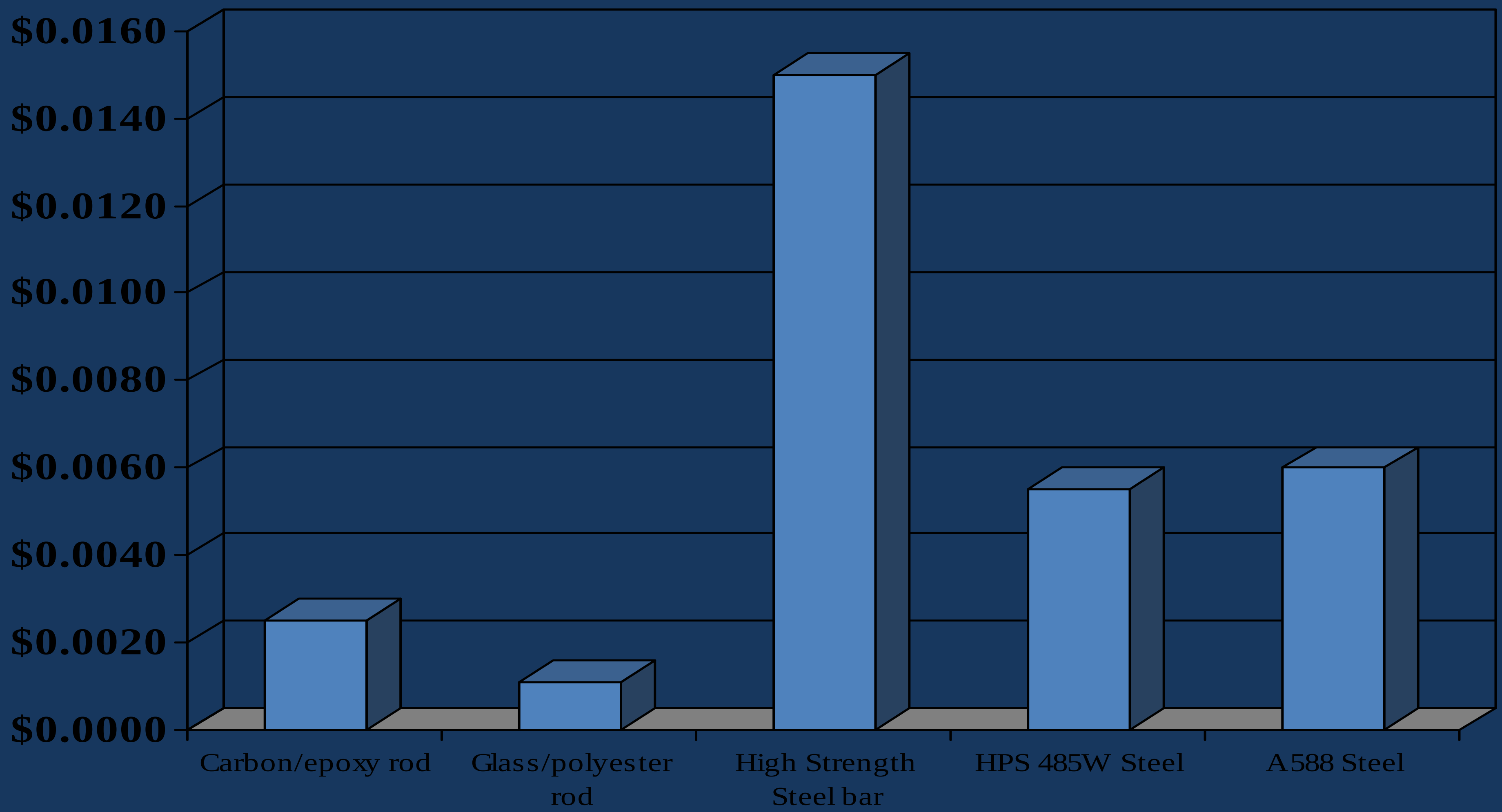
Typ. Stress-Strain Relationship



E steel = 29,000,000 psi

Material Characteristics

Cost for yield Strength



BRIDGE APPLICATIONS

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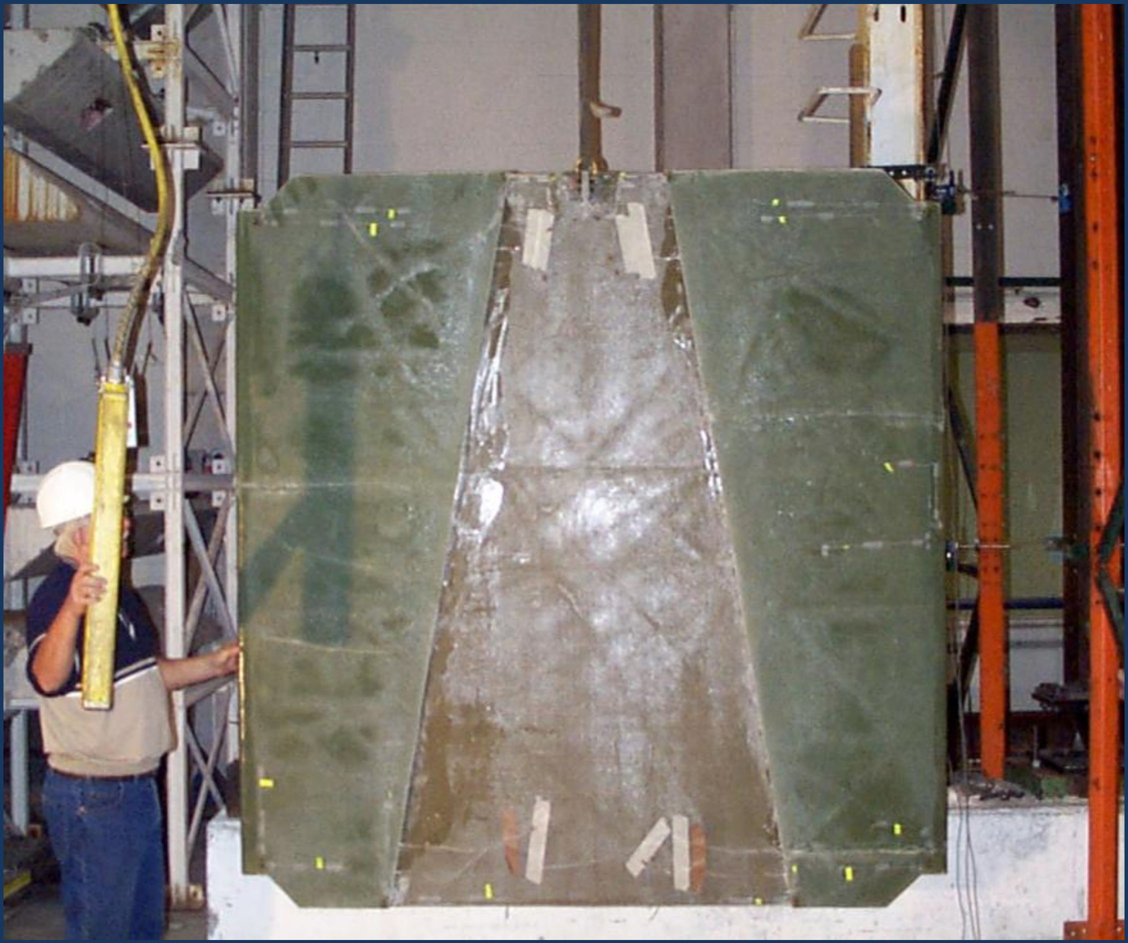
Seismic

- Column Wrap
  - Adds confinement
  - Improves shear
  - Improves ductility
  - Reduces possibility of lap splice failure
  - http://www.fhwa.dot.gov/bridge/frp/calcomp.htm
- UB In-fill panels
- Concrete arch retrofit

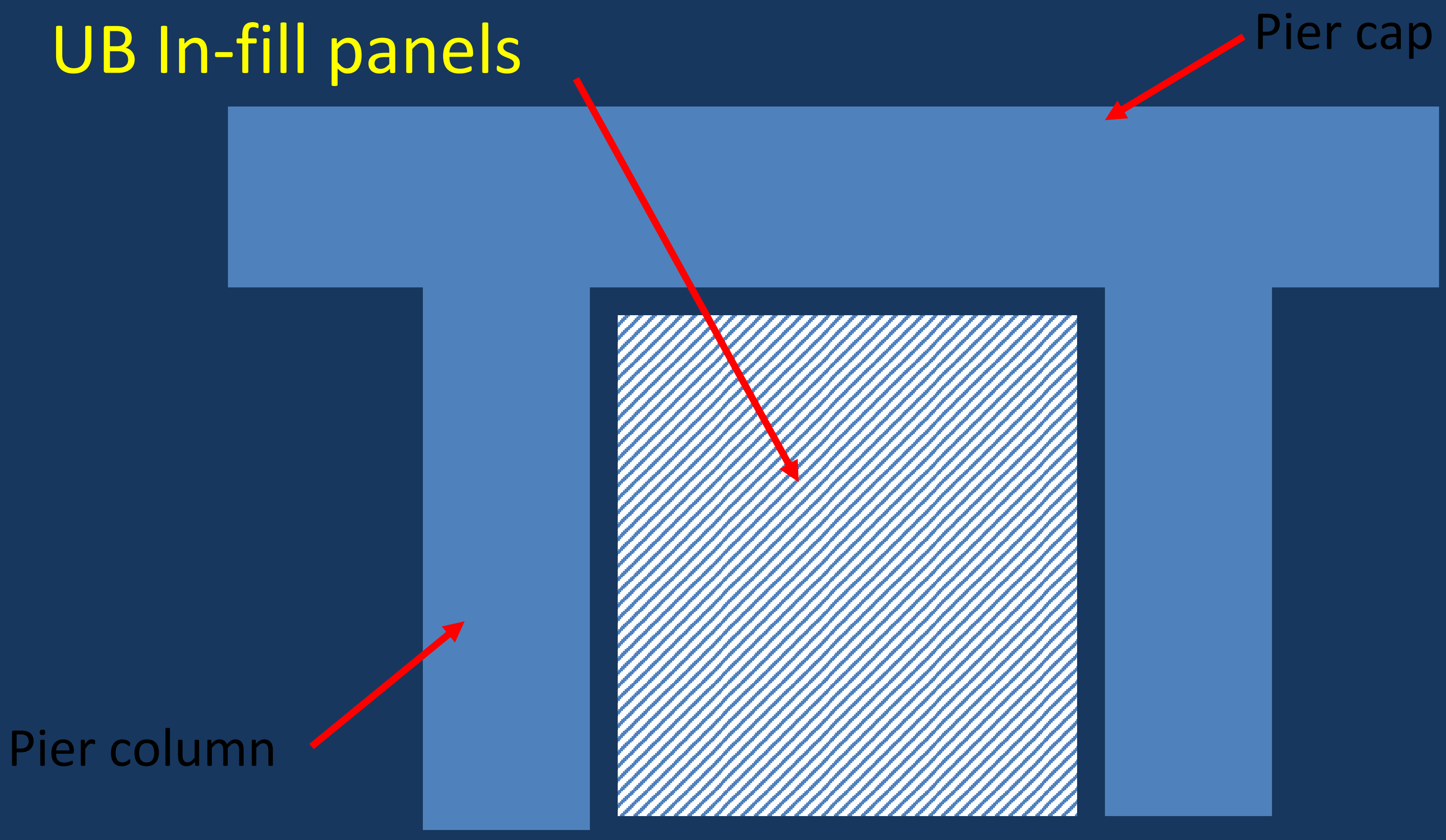
Seismic

In-fill panel



University at Buffalo's Lee, Aref, Kitane

Seismic



Seismic

Woodlawn Viaduct, NY
by R. J. Watson / Fyfe

Aerodynamics

Bronx-Whitestone Bridge, NYC
by Hardcore Composites

Strengthening Concrete

- Maintenance Applications
  - Beams
  - Columns
  - Strengthening
  - Column wrapping for deterioration
- Concrete arch rehabilitation

Strengthening Concrete

Beams

- Strengthening
  - To increase load capacity
  - Deficient design

Strengthening Concrete

Columns

- Strengthening
- Improving ductility
- Column wrapping for deterioration
  - Court St. evaluation
  - Railroad over I-86

Strengthening Concrete

Court St. Columns

Court St. PPT

Strengthening Concrete

I-86 Columns

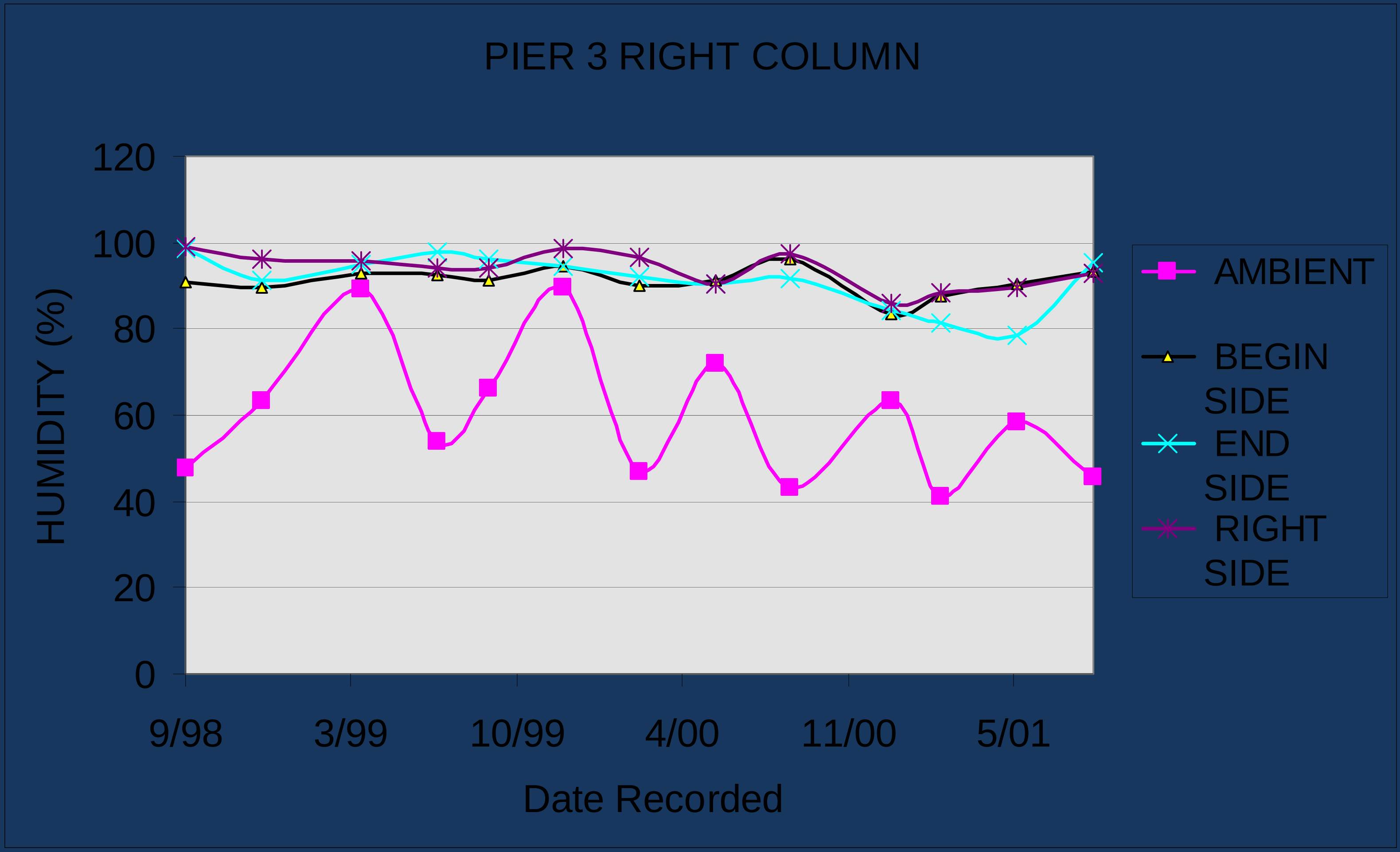
- Railroad over I-86

Strengthening Concrete

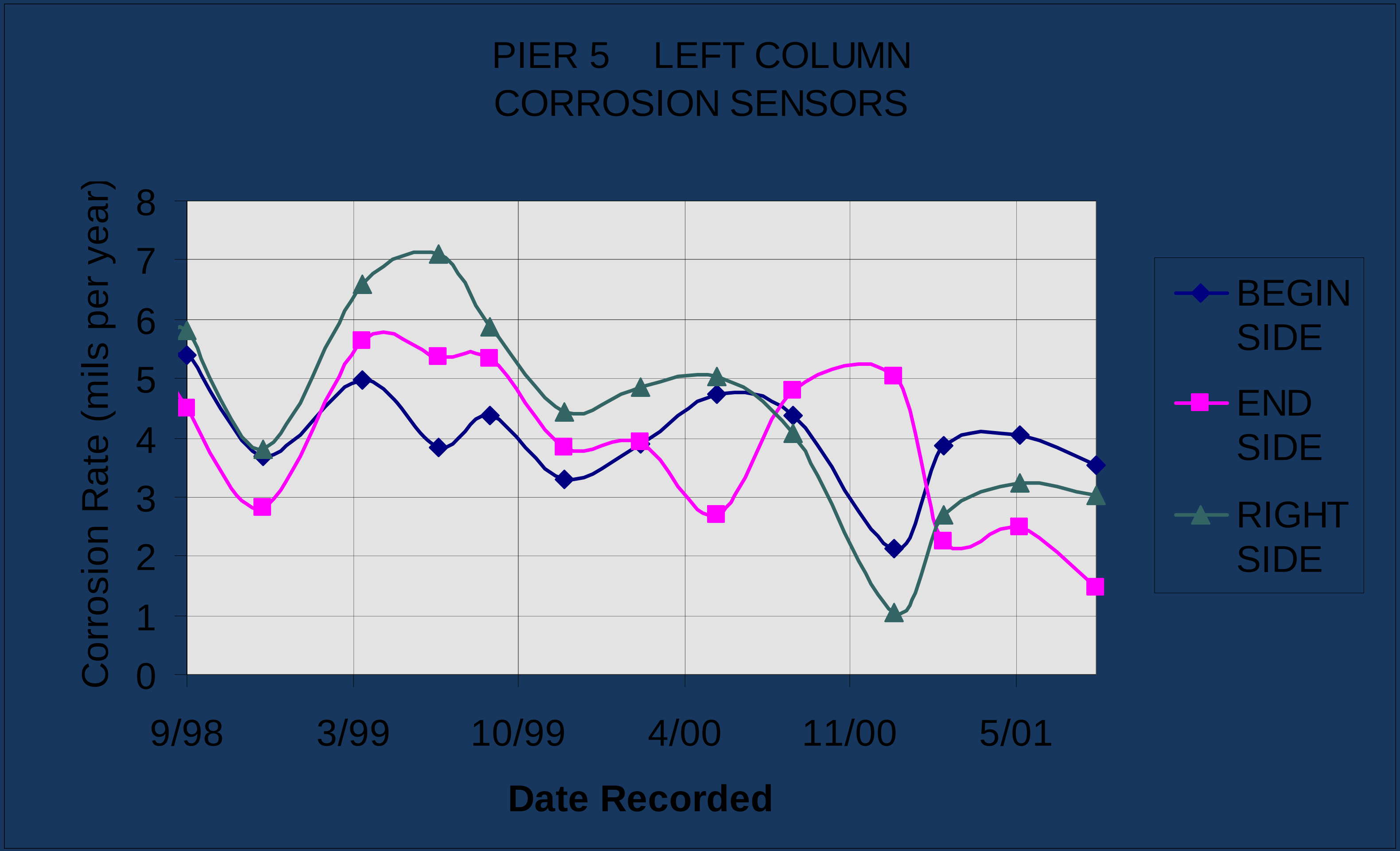
Columns

Sealing the top

Typical Humidity Data



Sample Corrosion Data



Repair of
Overhead Sign Structures

- Issues
  - Aging aluminum structures not originally designed for fatigue
  - Poor welds
  - Fatigue cracking
  - Broken welds
  - >10% of trusses inspected had damage
  - 1999 fatality

Repair of Overhead Sign Structures

Repair of
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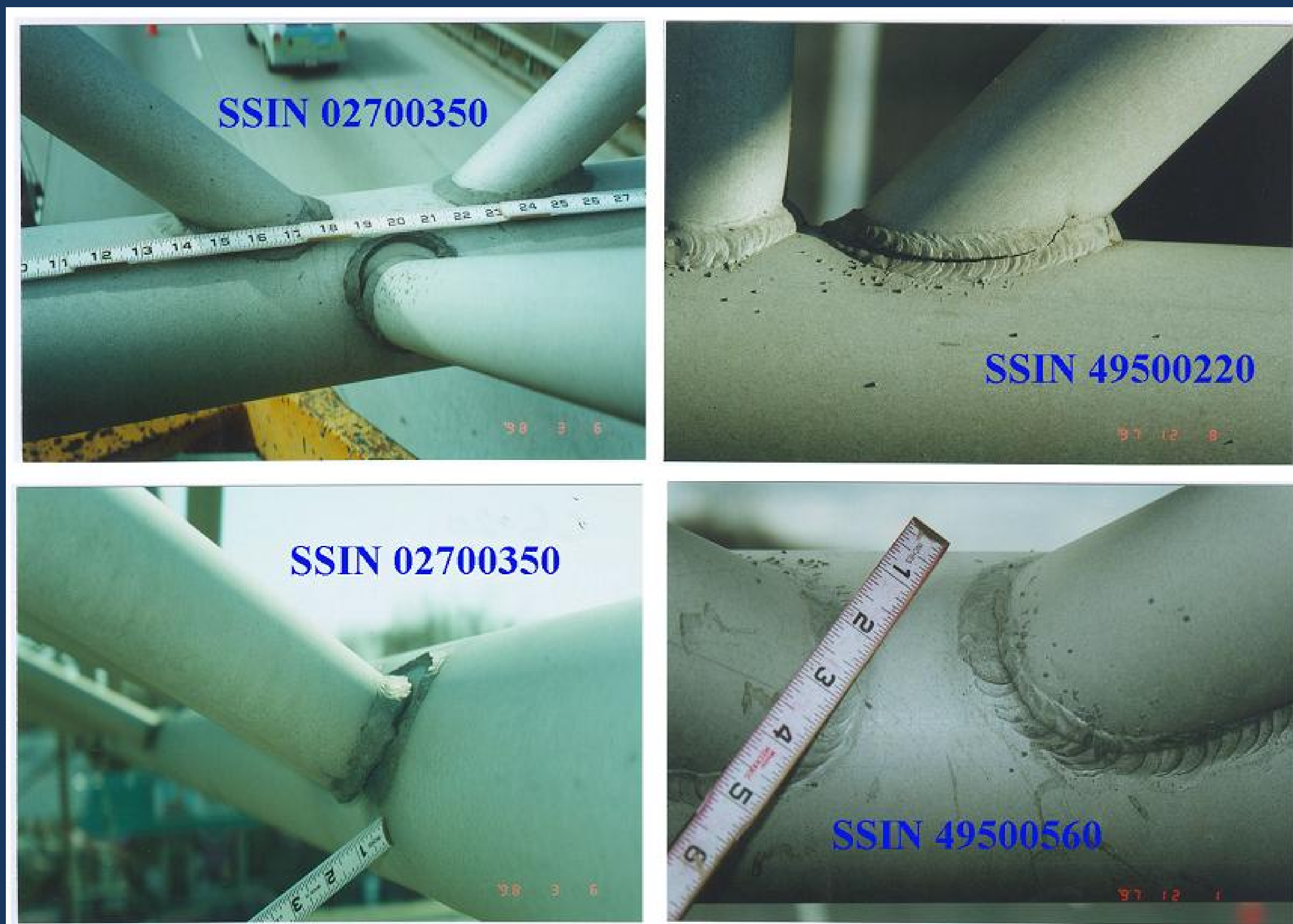
Overhead Sign Structures



Repair of
Overhead Sign Structures

Repair of
Overhead Sign Structures

Repair of
Overhead Sign Structures

Repair of Overhead Sign Structures

- Benefits
  - May be used to temporarily repair an OSS (may prove to be a long term repair)
  - Time efficient (<3 hours/joint)
  - Personnel efficient (3 workers)
  - Cost effective (<$3,000/joint)
  - Allows replacements to be scheduled, rather than on emergency basis

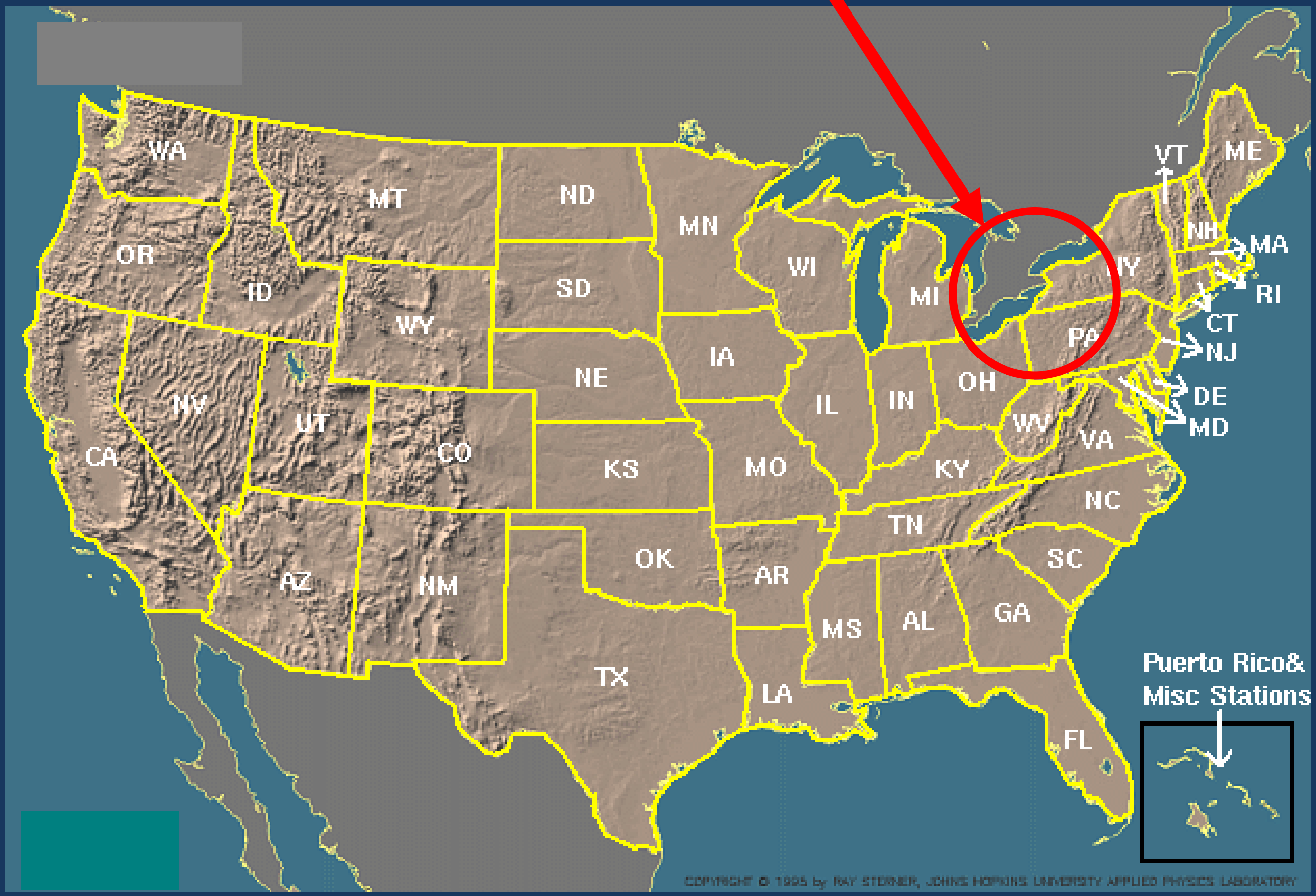
Repair of Overhead Sign Structures

- Resources
  - Harry White, NYSDOT (518) 485-1148
  - Franz Worth, Air LogisticsCorp.(626) 633-0297
  - Sarah Witt, Fyfe Co.(858)642-0694
  - AASHTO Technology Implementation Group
  - http://www.dot.state.ny.us/tech_serv/trdb/files/winter2003.pdf

Culvert Re-lining

Erie County, NY

Buffalo, NY



Dick Road Culvert BR 317-4 over U-Crest Ditch

Erie County NY Town of Cheektowaga

Problem Statement

1. Replace or reline corroded steel multi-plate arch on concrete footings.

2. Maintain 38,500 vehicles per day.

Solution

Reline the existing structure with an fiber reinforced polymer (FRP) liner to avoid disruption of traffic.

Culvert Re-lining

Erie County, NY

Culvert Re-lining

FRP insert

Culvert Re-lining

FRP Inserts

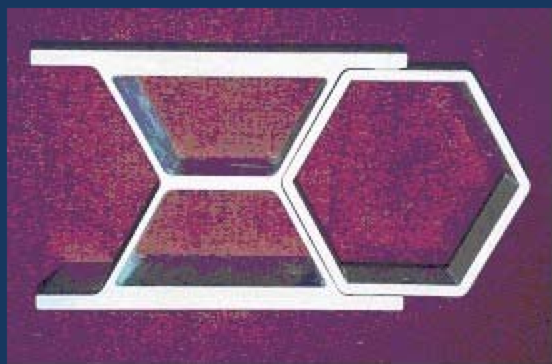
Culvert Re-lining

Culvert Re-lining

$300,000 construction cost

DECKS & SUPERSTRUCTURES

FRP Bridge Decks

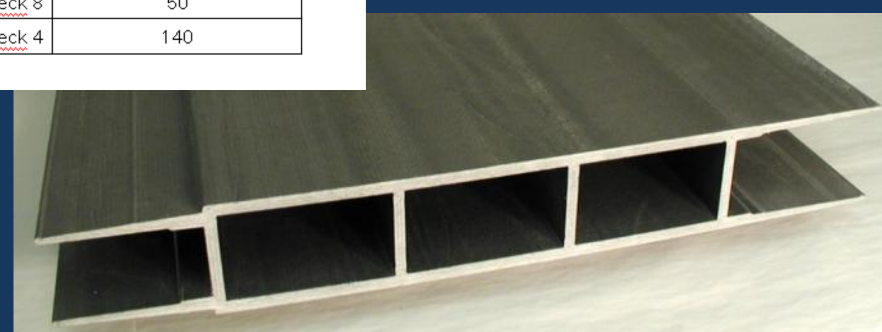


CP SuperDeck

CP SuperDeck- gen2

Deck Type	Ultimate buckling load (Kips)
ProDeck 8	50
ProDeck 4	140

BP ProDeck 8



BP ProDeck 4

FRP Bridge Decks

Hardcore Composites

MMC Duraspan

xxx

xxx

Deck design considerations

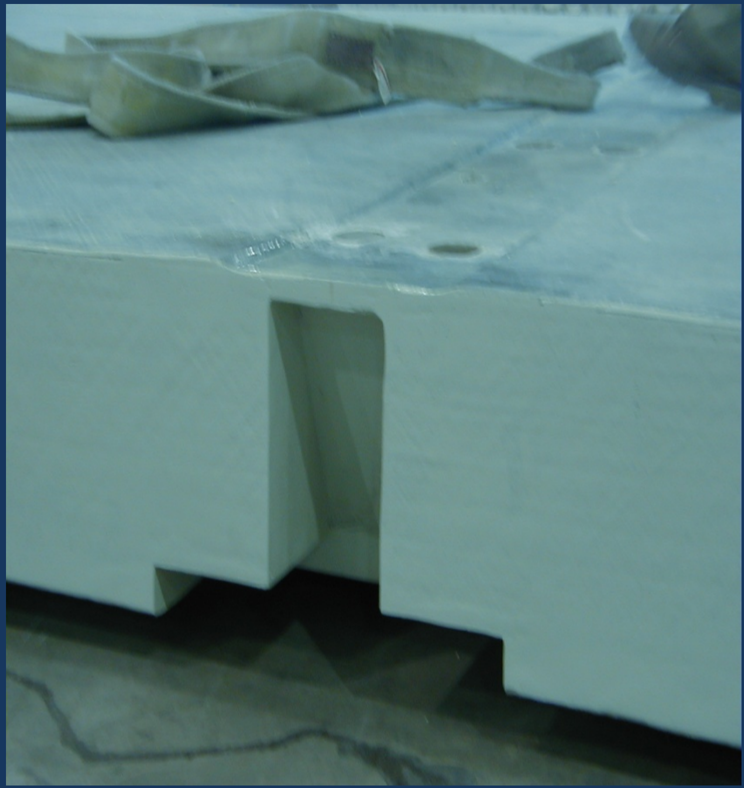
Deck & Superstructure Design Considerations (1)

- Standard AASHTO design vehicle (HS20, HS25, HL93)
- Allowable Stress Design (ASD) used
  - In ASD, the member is selected so that the area and moment of inertia are large enough to prevent the maximum induced stress and deflection from exceeding the allowable values.
- Deflection criteria
  - L / 800 is typical for end supported superstructure slab (global deflection)
  - Stringer supported bridges are predesigned by the supplier. (S / 500) (deck deflection in relation to stringers)
- Allowable stress limits for DL (10%) & DL/LL/impact (20%
- Connections to stringers
  - Composite behavior vs. need to avoid cracking
  - Composite behavior can be obtained between FRP deck and steel stringer using shear studs, but the composite moment of inertia is only 7% higher than that of steel plate girder moment of inertia

Deck & Superstructure Design Considerations (2)

- Field joints between panels
- Bridge joints at end of bridge or over piers
- Drainage
  - Cross slope
  - Scuppers
  - Curbs
- Ease of installation, special cutouts
- Wearing surface
- Bridge railing
- Fatigue

Special Details



Drainage

- Cross slope
- Scuppers
- Curbs

Haunch

Connections

End Bearing Slab

1” dowel as anchor rod

Deck to Steel Connections

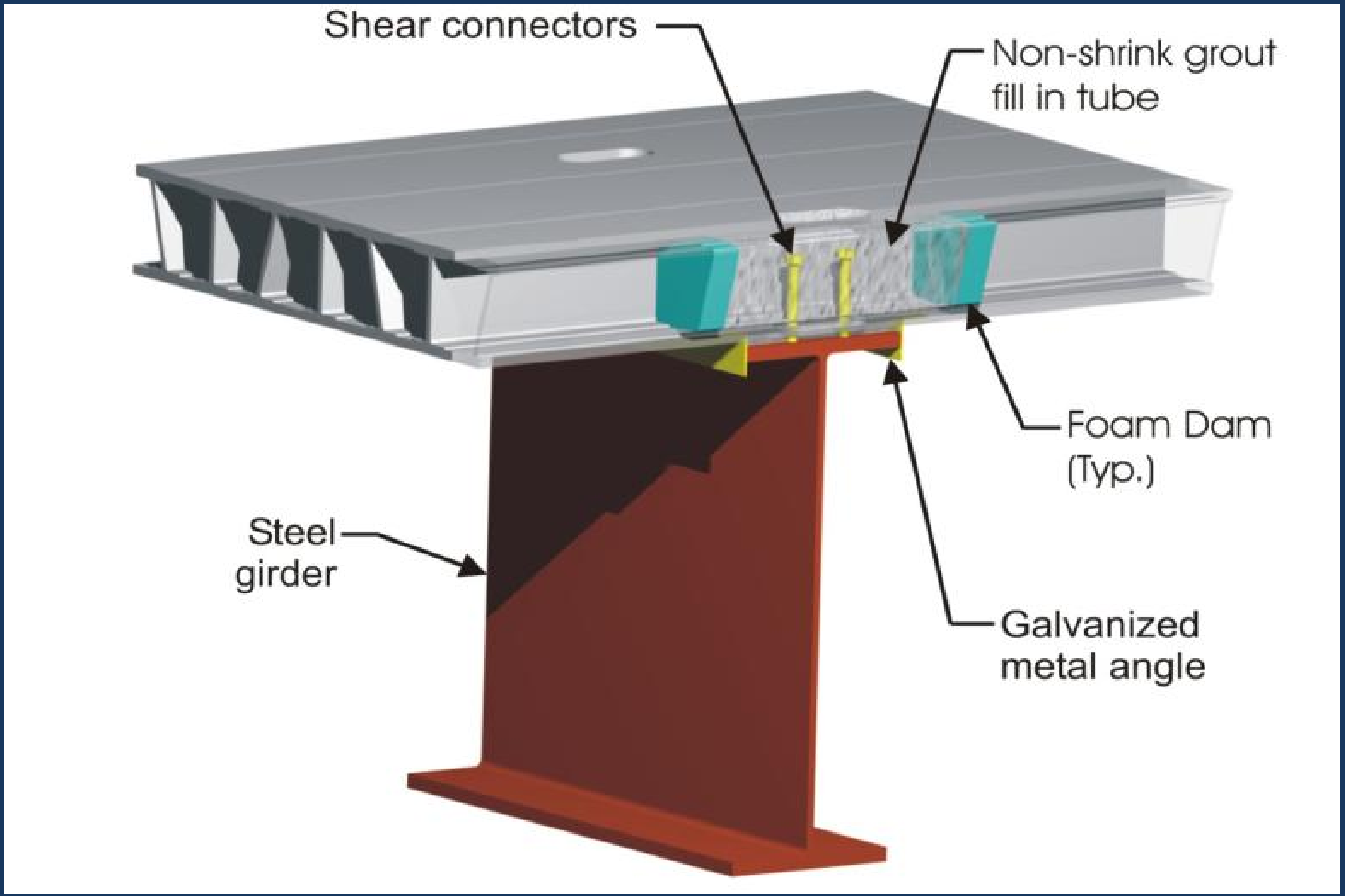
- Stud Shear Connectors
- S-Clips
- Bolted connection
- Adhesives
- Pop rivets

Non-composite Connections

- S-clips
- Z-clips

Composite Connections

Stud shear connectors



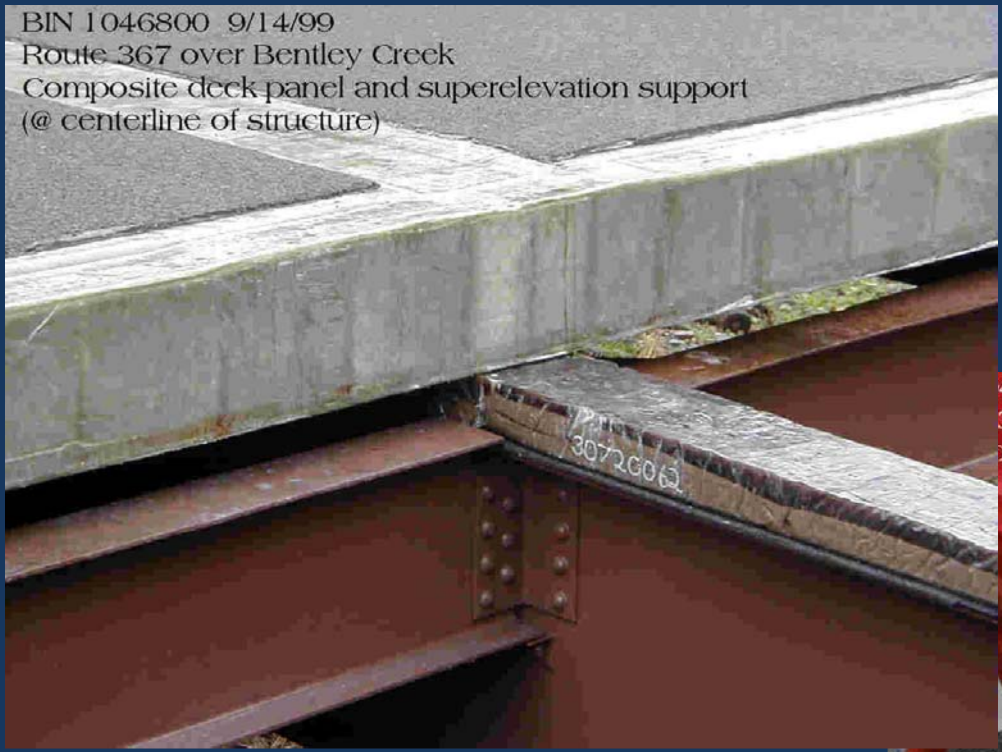
Stud Sear Connectors

Formed haunch

Stud Shear Connectors

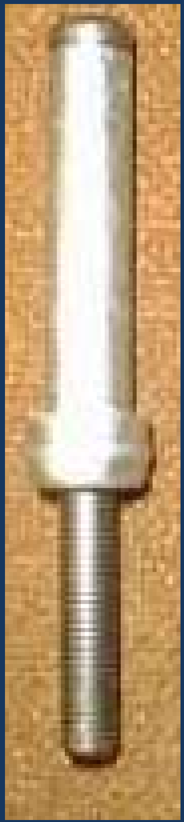
Stud Shear Connectors

Bolted Connection



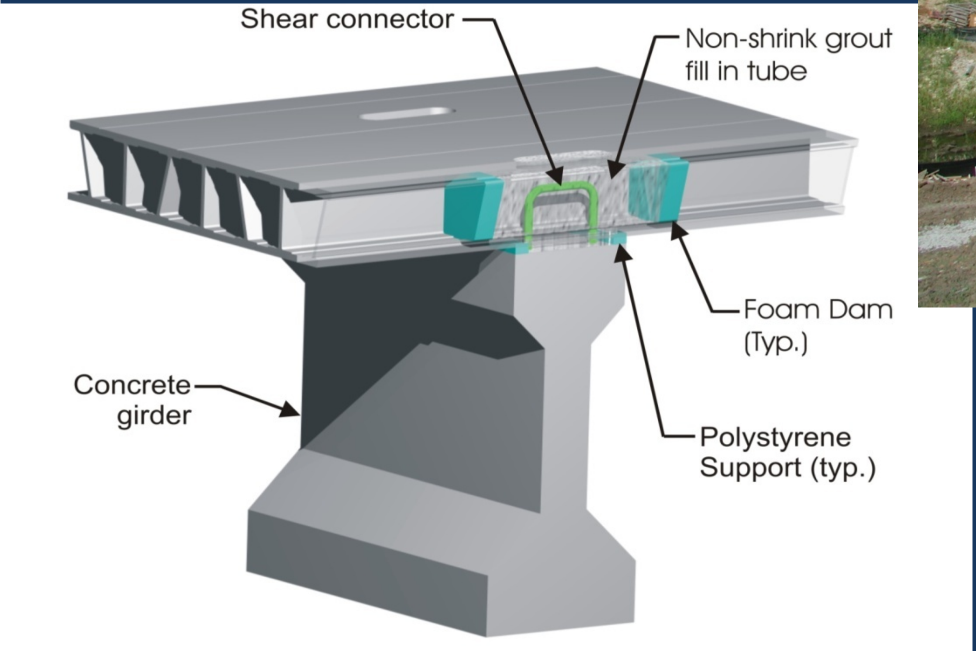
Adhesives

“Pop Rivets”



1/2"(13mm) BOM® blind bolts, by Huck International, Inc., mechanically fasten the deck to the steel beams.

Connection to Concrete



Field Joints

- A wet lay-up to reinforce the joint has been found to be effective in reducing reflective cracks over the adhesive joints between panels

Wearing Surface

Wearing Surfaces

Polymer Concrete (thin, watertight but not as familiar)
48% of projects

1) Epoxies
2) Polyesters
3) MMA

Asphalt (heavy & porous but easy & familiar)

41% of projects

1) 2” Superpave
2) 1/2” microsurfacing
3) polymer modified asphalt

PCC or Latex modified Portland cement concrete

11% of projects

Prototype Wearing Surface

developed for NYSDOT by R. Aboutaha at Syracuse University

Performance Objectives

- Permanent bond
- Skid resistance, durability, protection of FRP

1” Polymer Modified Concrete (for wear)

3/8” Polymer Concrete (for bond)

FRP deck surface

Bridge Railing

Overview of Experience in the U.S. with FRP Decks & Superstructures

Jerome S. O’Connor, P.E., F,ASCE
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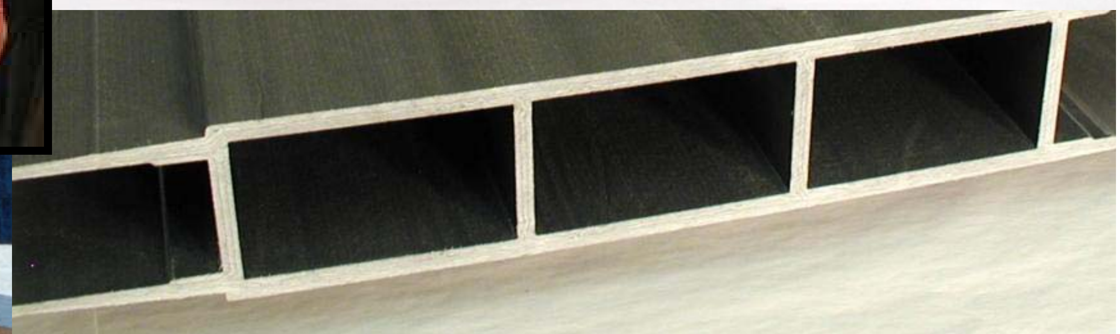
Sample FRP Deck Sections



Sample FRP Superstructures

E. T. Techtonics

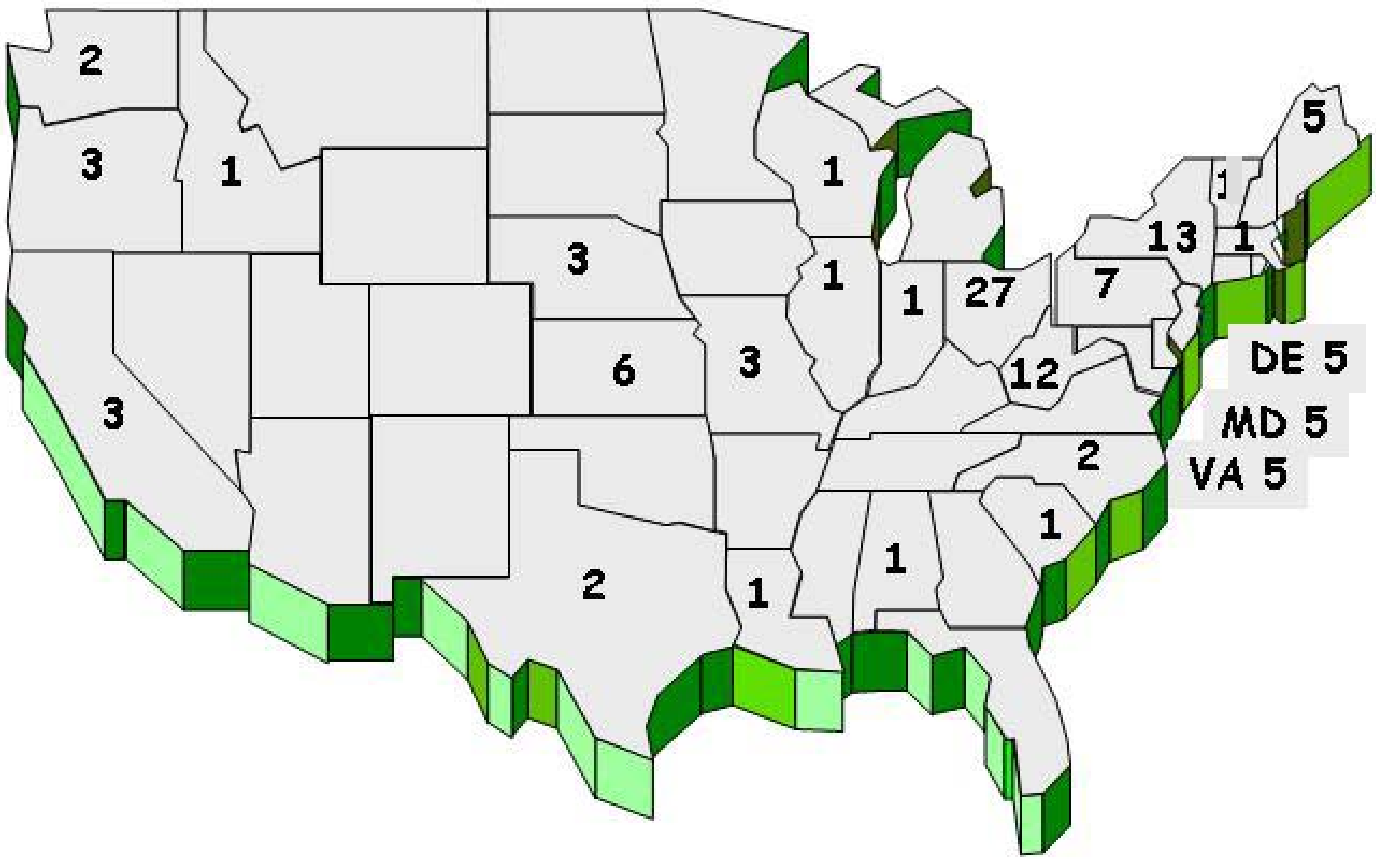
Pedestrian bridges

Why?

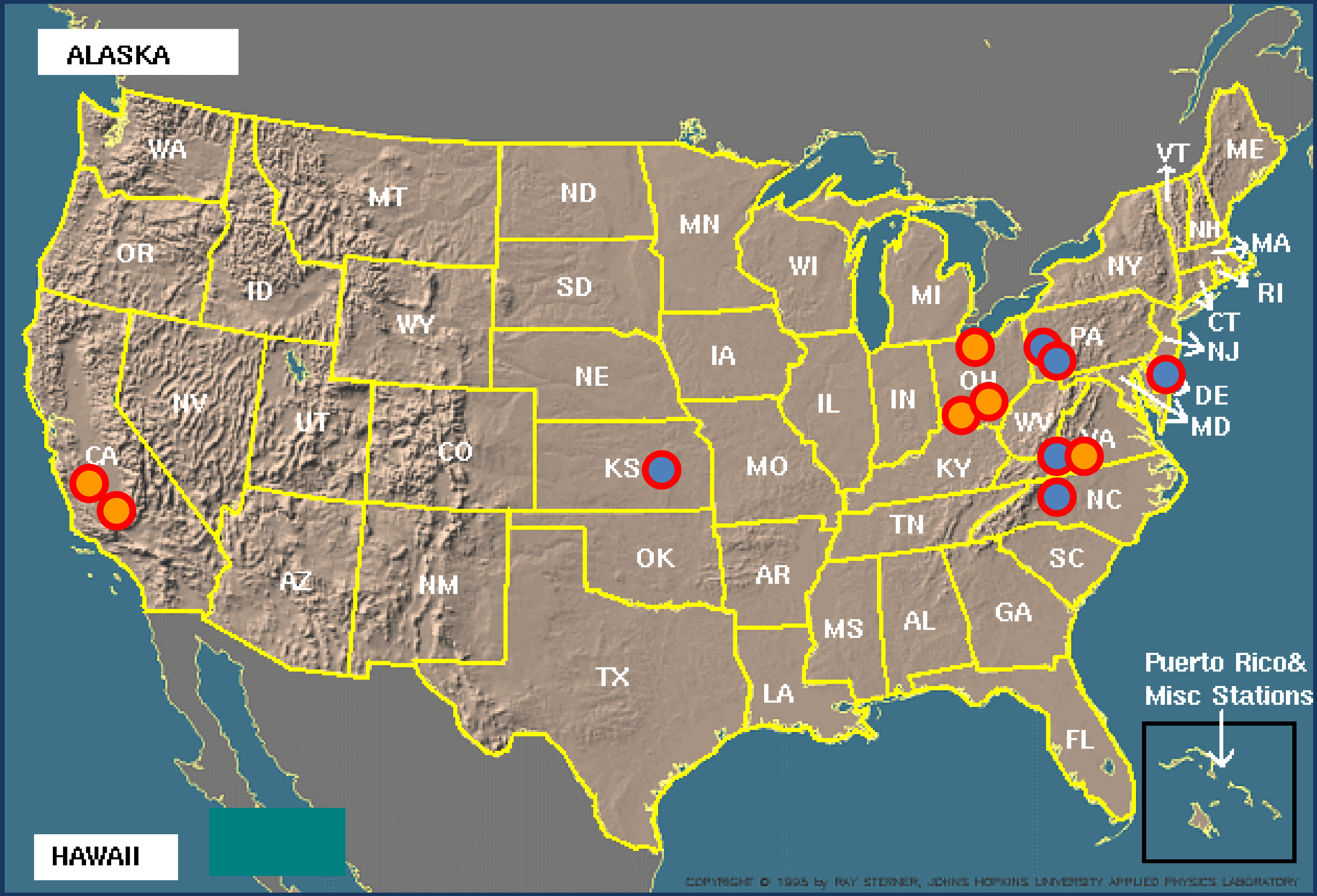
Doesn't rust, crack, spall, or rot

Salt takes its toll

of FRP Decks and Superstructures



Manufacturers ● ●*



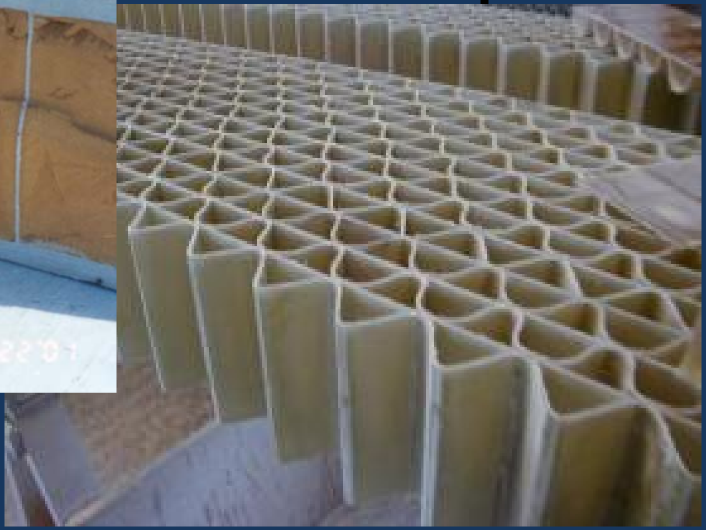
*● has supplied only 1 or 2

Suppliers

1. Martin Marietta Composites (NC)-30
2. Hardcore Composites (DE)-28
3. Creative Pultrusions (PA)-9
4. Kansas Structural Composites (KS)-9
5. Bedford Plastics (PA)-6
6. Strongwell (VA)-5
7. Webcore, FRS, ICI, MFG, Wagner, others

Manufacturing Processes

andwich Construction vs. Pultrusion



Manufacturing Processes

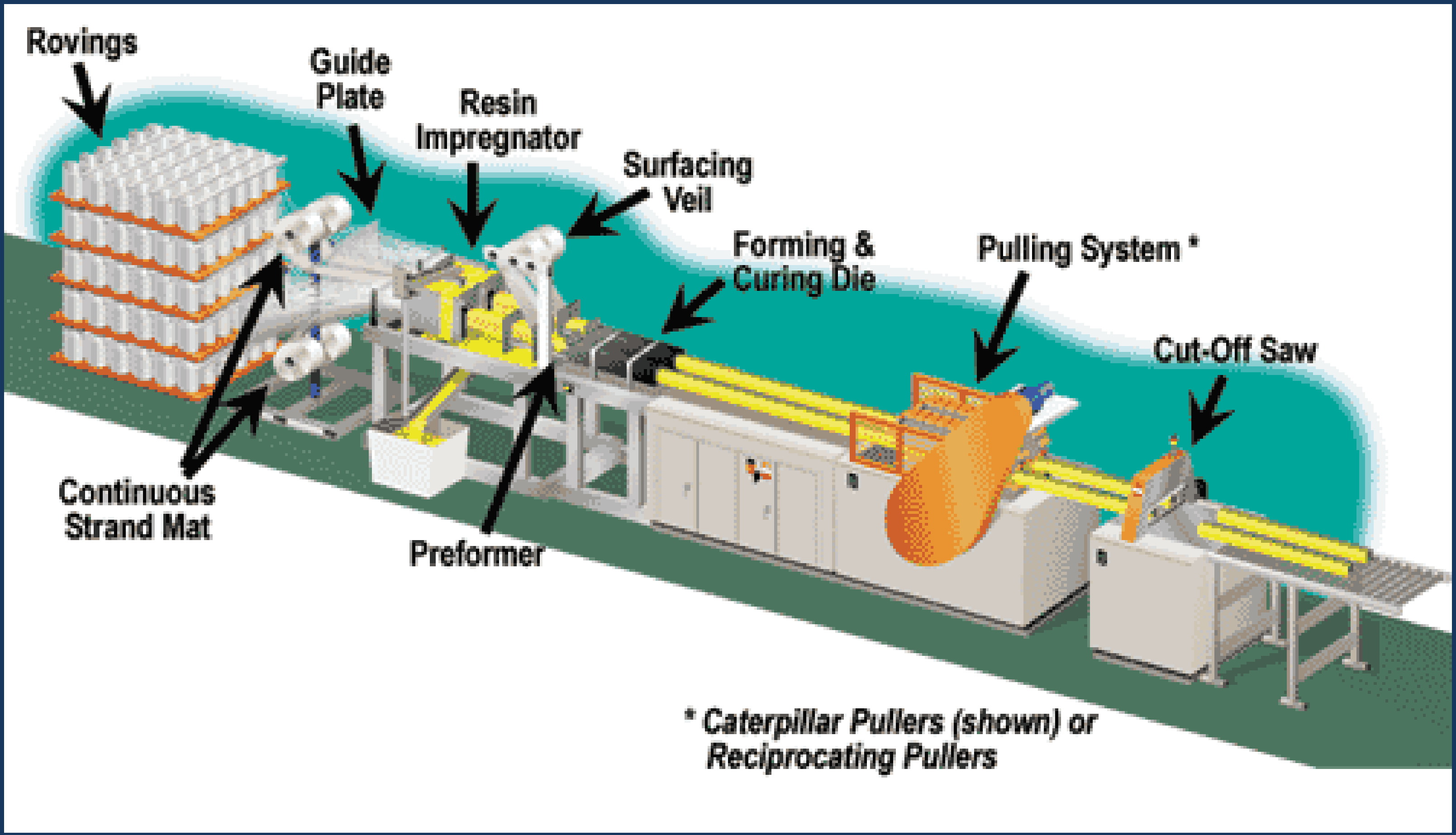
1. VARTM (vacuum assisted resin transfer molding)
2. Open-mold hand lay-up
3. Pultrusion

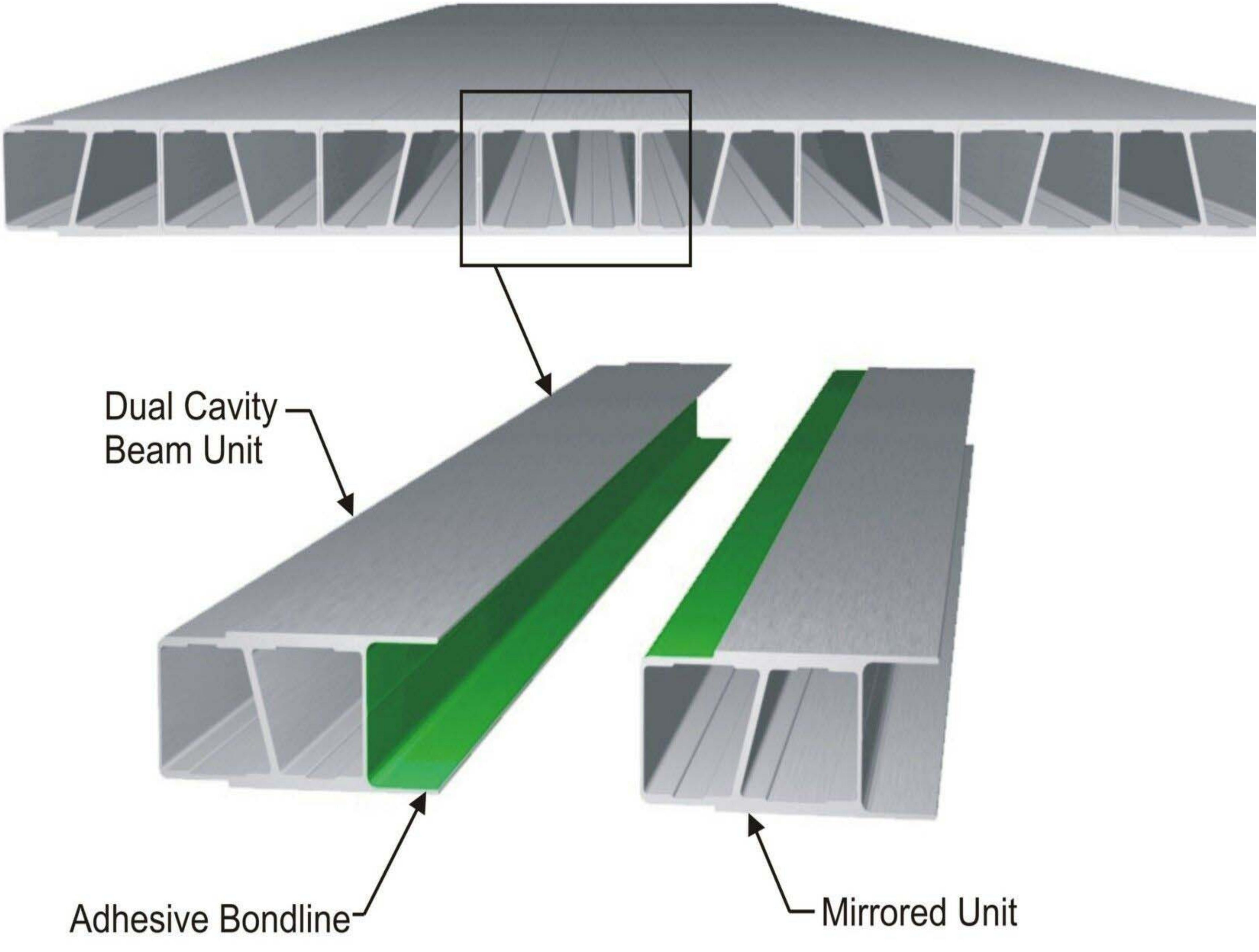
Manufacturing Processes

Manufacturing method	Ability to customize	Adherence to dimensional tolerance	Attractive cost	Ability to incorporate special features (e.g. scuppers)	Overall quality
1. Pultrusion	L	H	L	L	H
2. VARTM	H	L	H	H	M
3. Open mold	H	M	H	M	M

Manufacturing Processes

Pultrusion

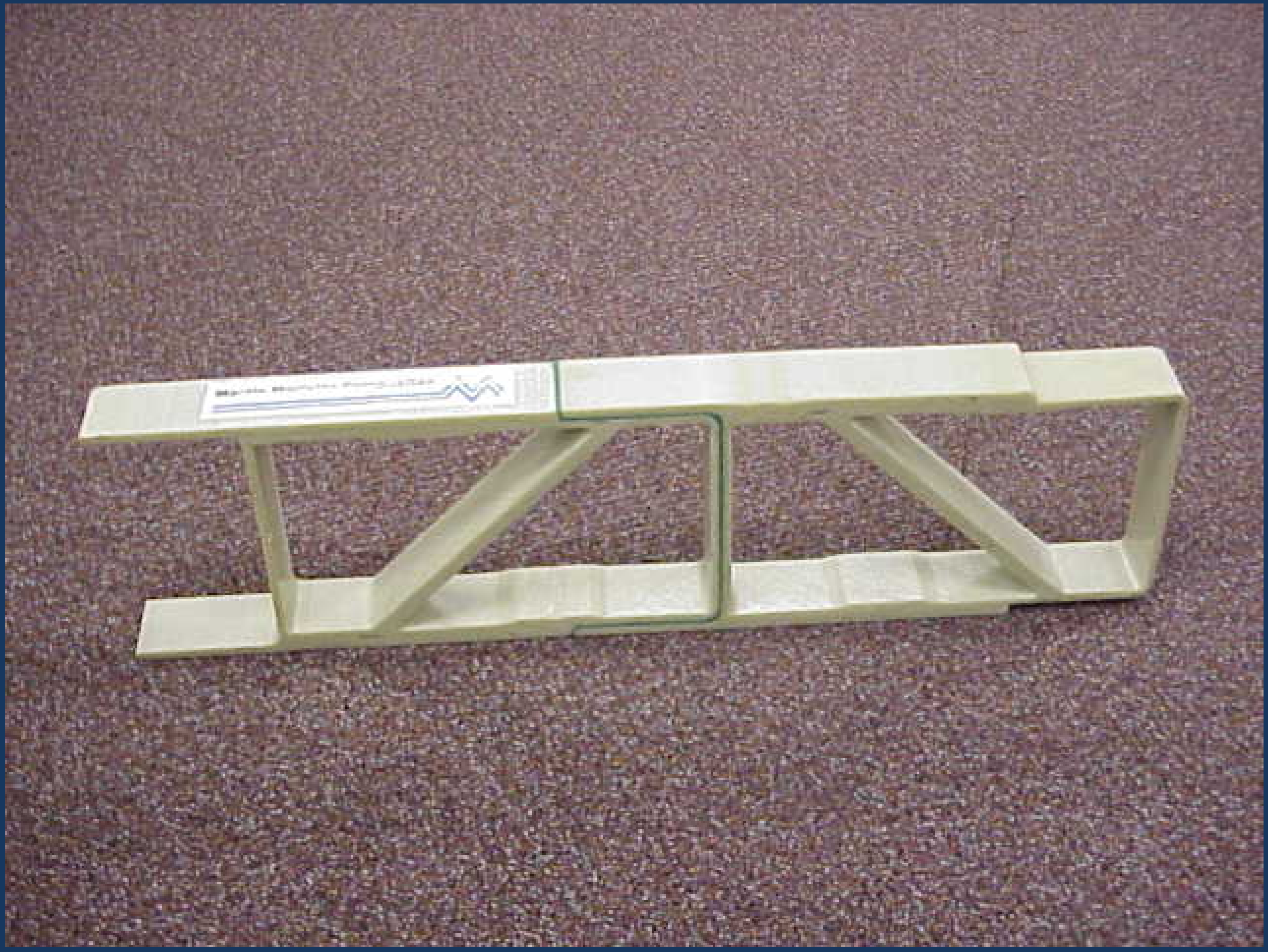




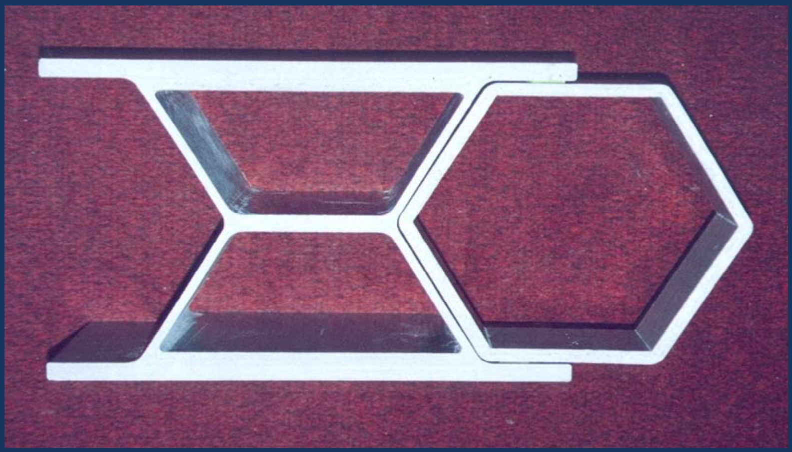
Dual Cavity
Beam Unit
Adhesive Bondline
Mirrored Unit

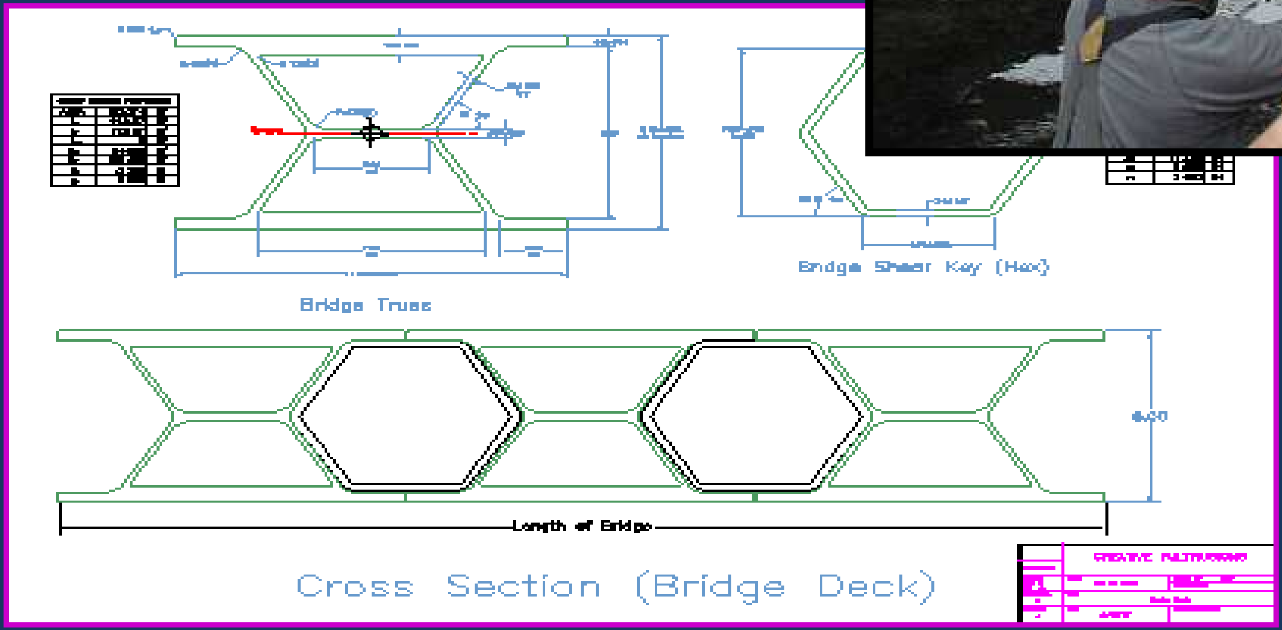
Martin Marietta Composites

7 5/8” deep



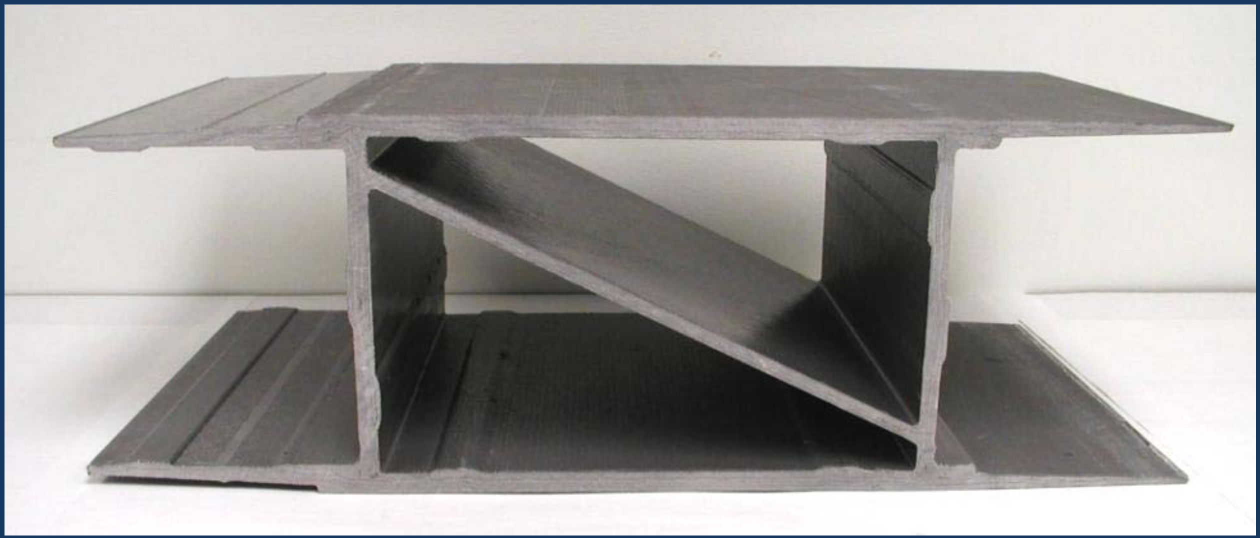
Creative Pultrusions



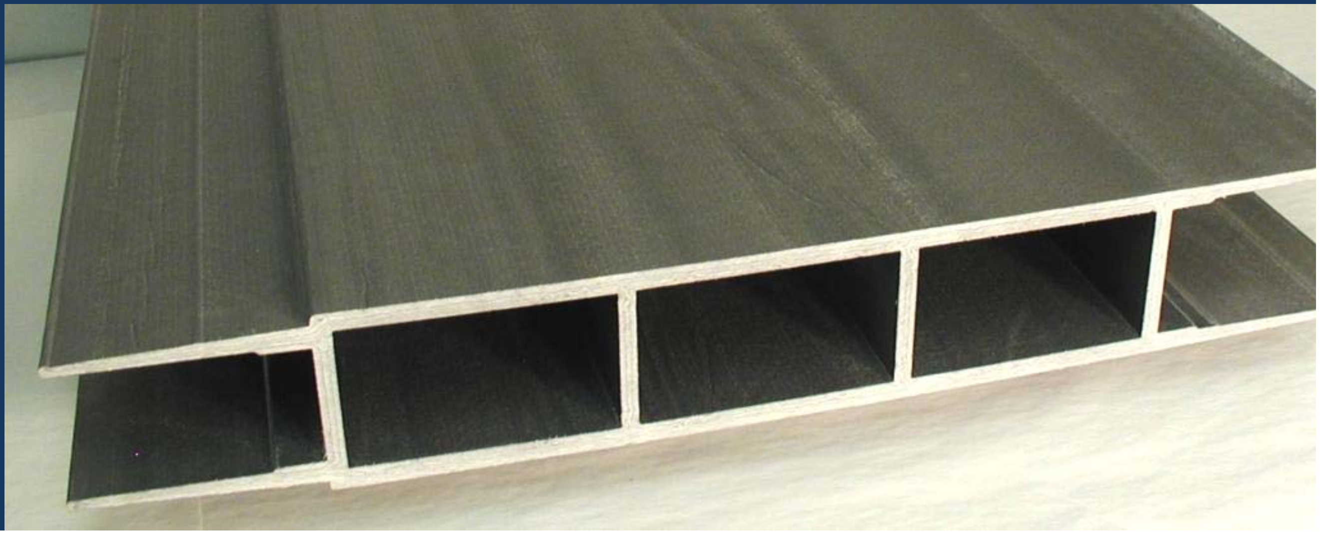


Bedford Plastics Inc.

Prodeck 8

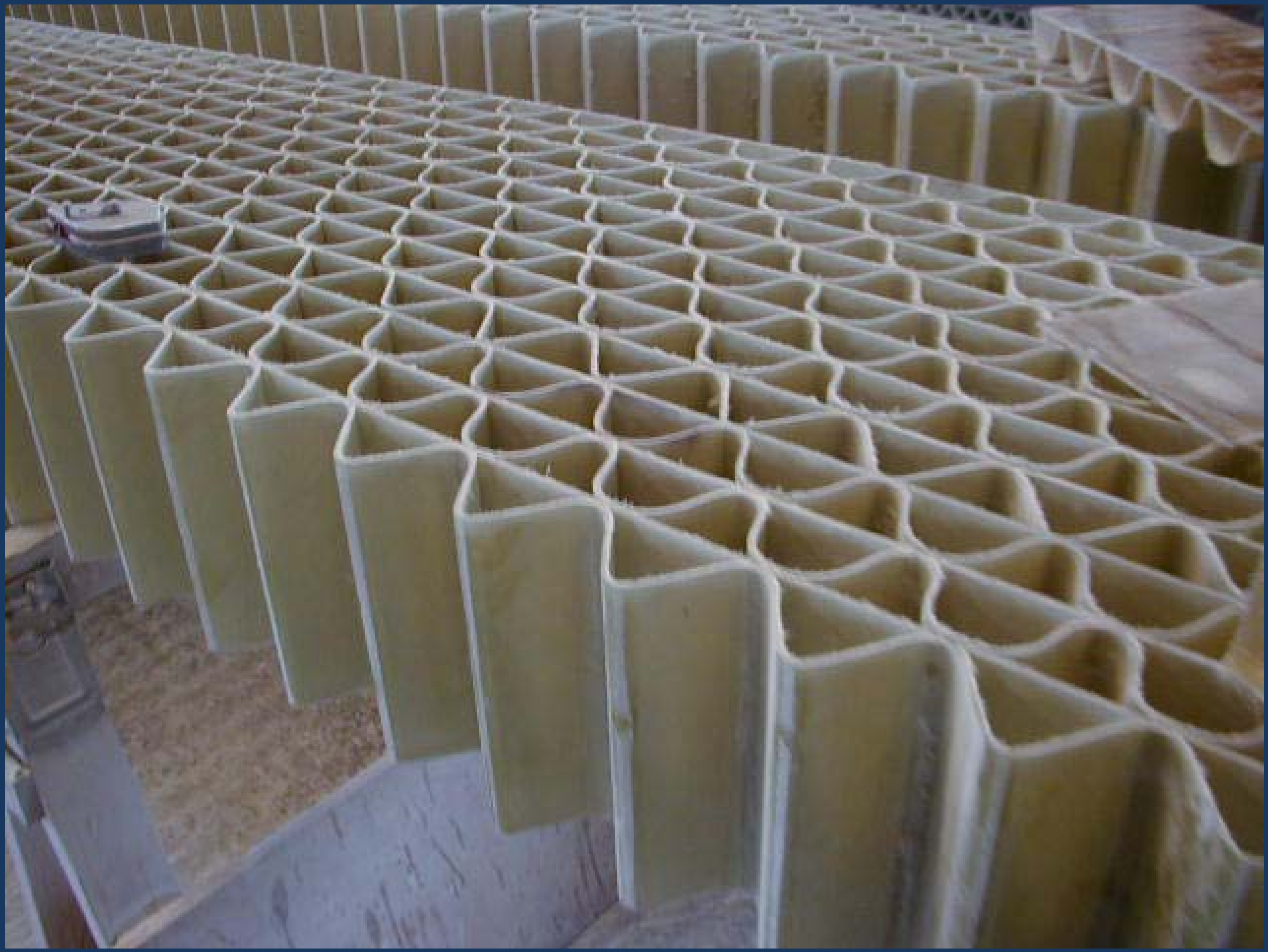


Prodeck 4



Strongwell

Kansas Structural Composites, Inc.



Hardcore Composites

Zell Comp

Composite Advantage

- Solid laminates or sandwich construction with fiberglass skins surrounding a fiber-reinforced-foam core

Trend toward Hybrids

Hybrids

- Amjad Aref’s hybrid deck, University at Buffalo
- Erie County’s Australian superstructure
- Niagara County’s timber-FRP-concrete

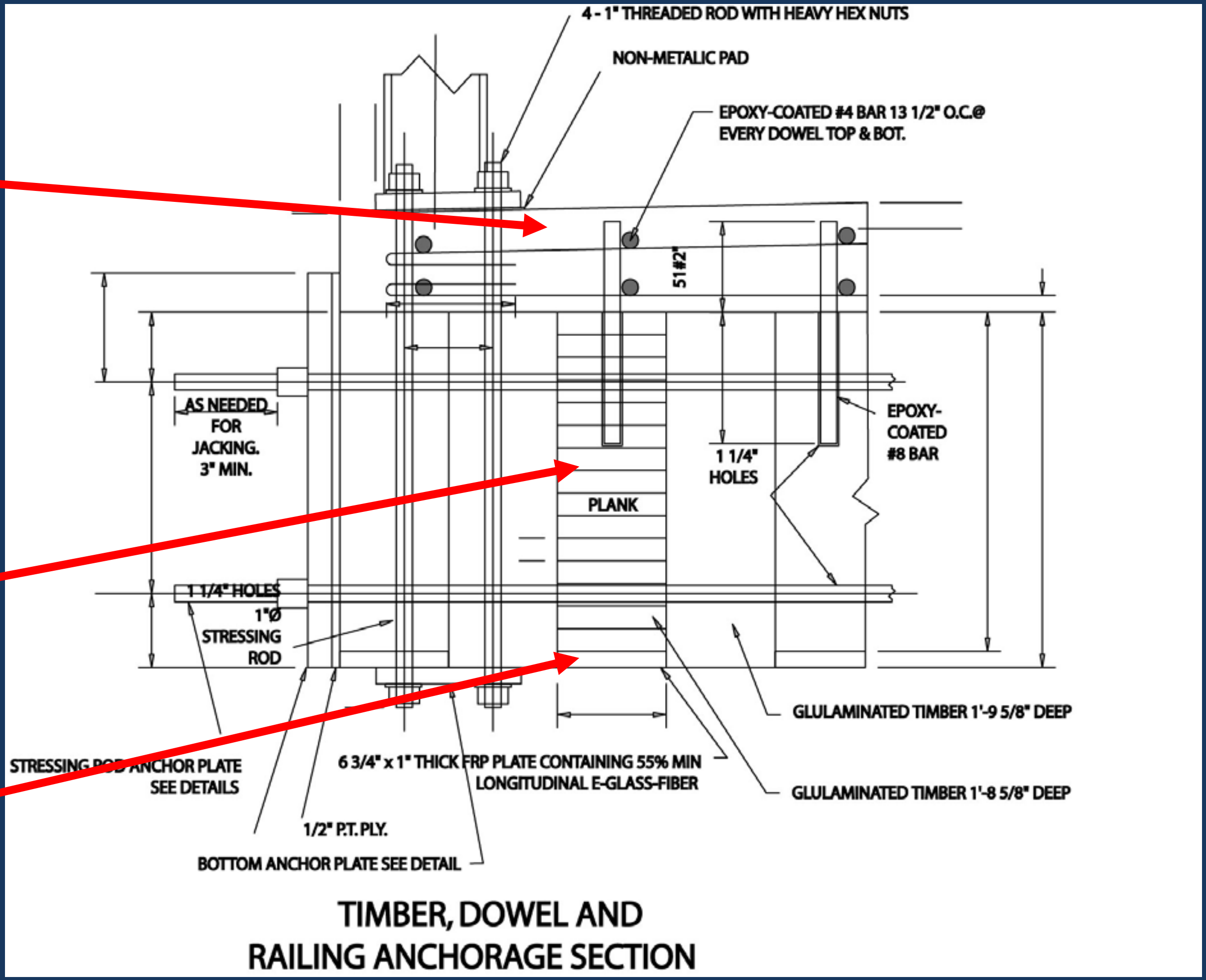
Hybrids

Concrete deck

Glu-lam

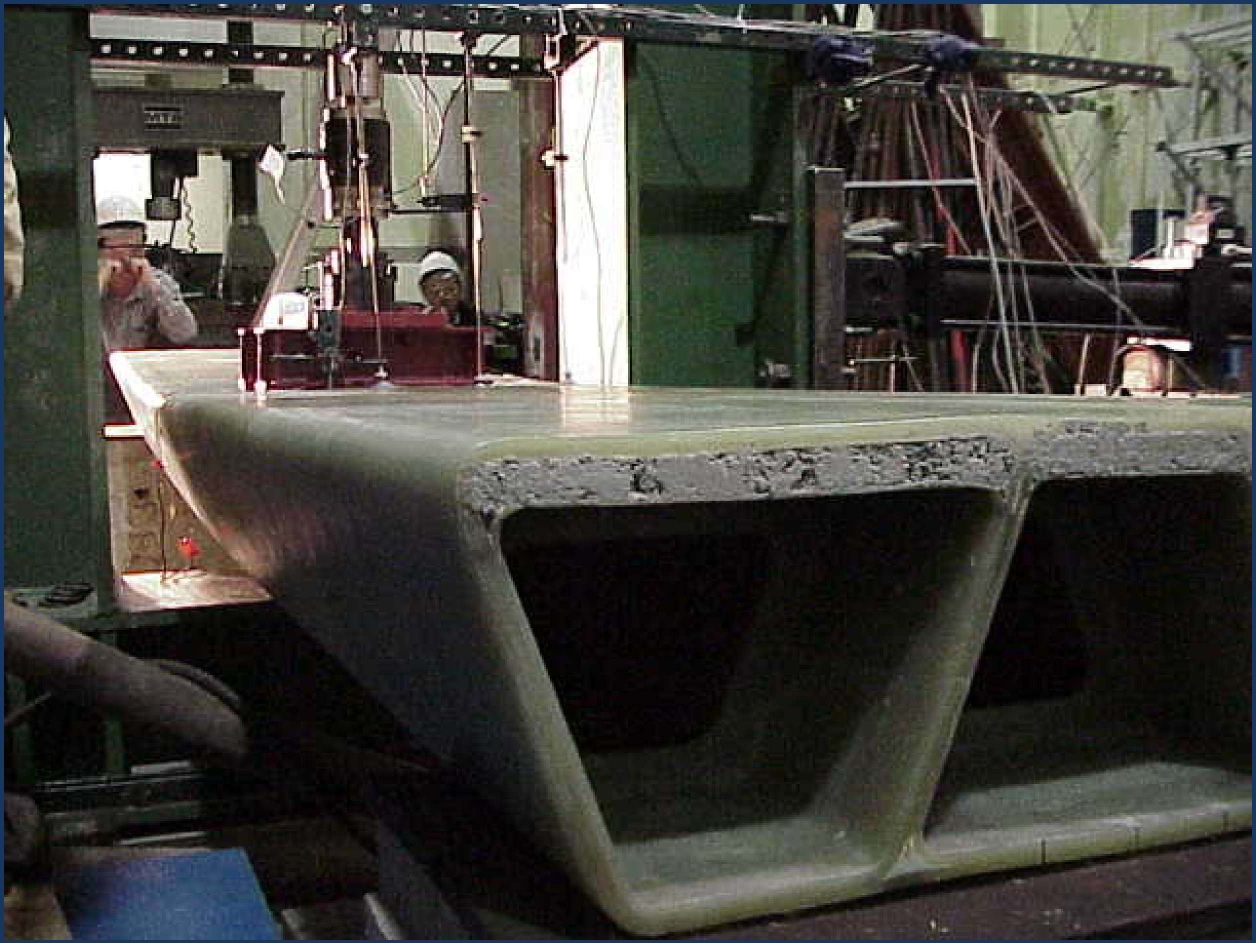
Timber beam

FRP laminate



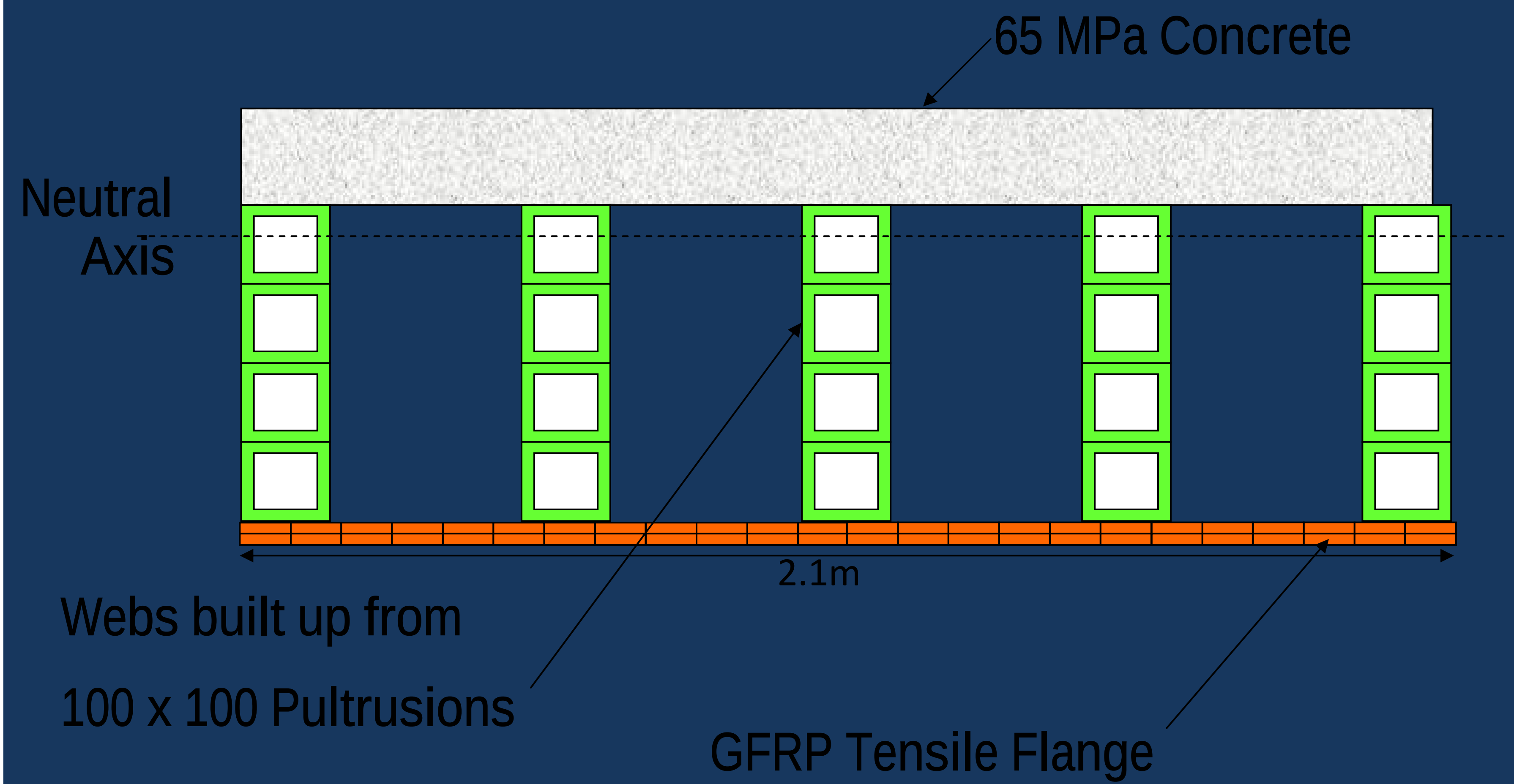
Niagara County's Timber-FRP laminate-Concrete

Hybrids



University at Buffalo’s Hybrid deck conducted by Prof. Amjad Aref
(development sponsored by NYSDOT)

Hybrids



Erie County – Australian Hybrid Superstructure

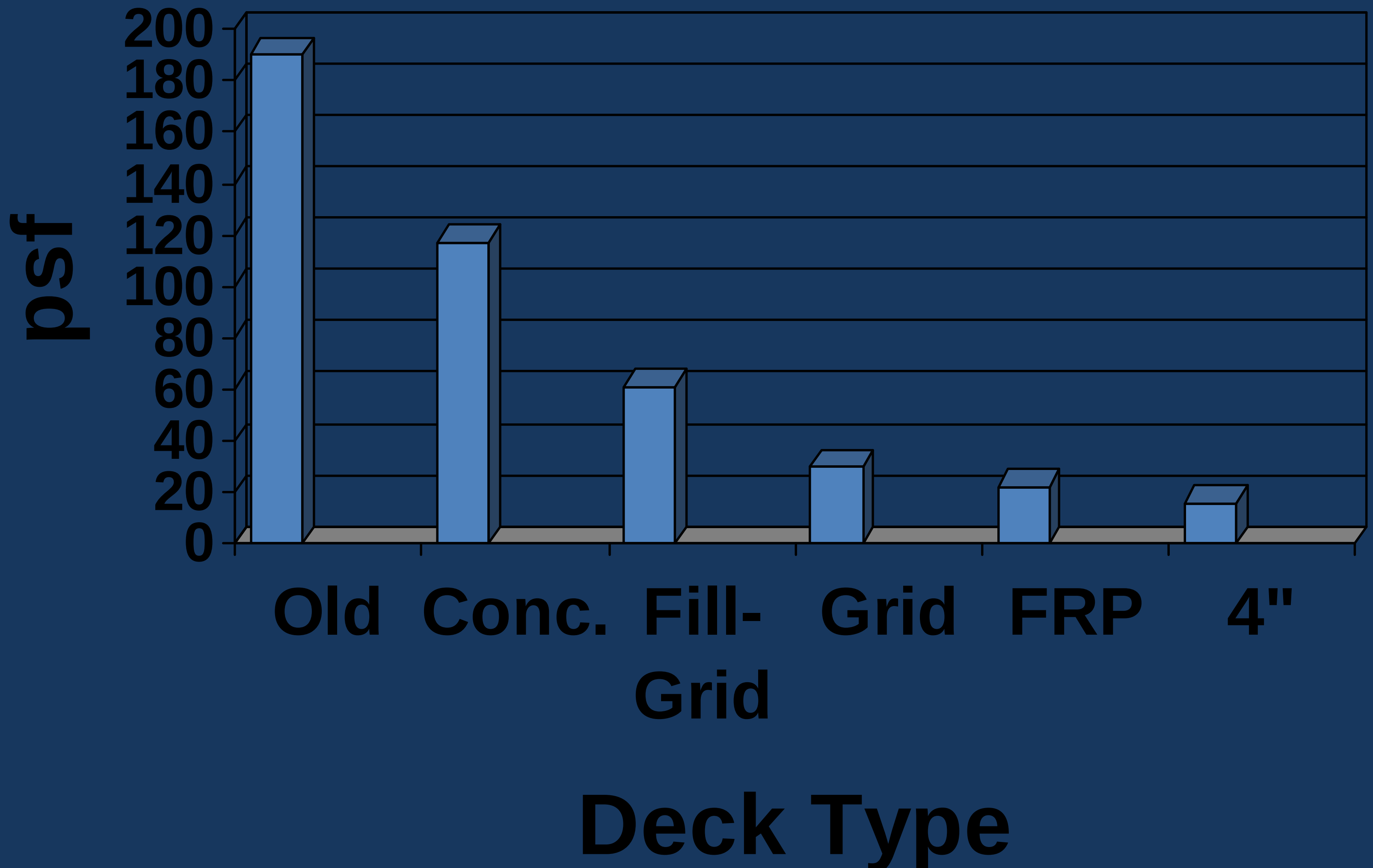
V-team FRP

Survey

Information Collected

- 68% used IBRC or other special funding
- ½ the projects were new construction
- FRP decks were attached to steel stringers (95%), concrete girders, FRP beams
- Design live load HS-20 or HS-25 + impact
- Largest deck area = 11,970 SF
- Highest traffic volume = 30,000 vpd

Deck Weight

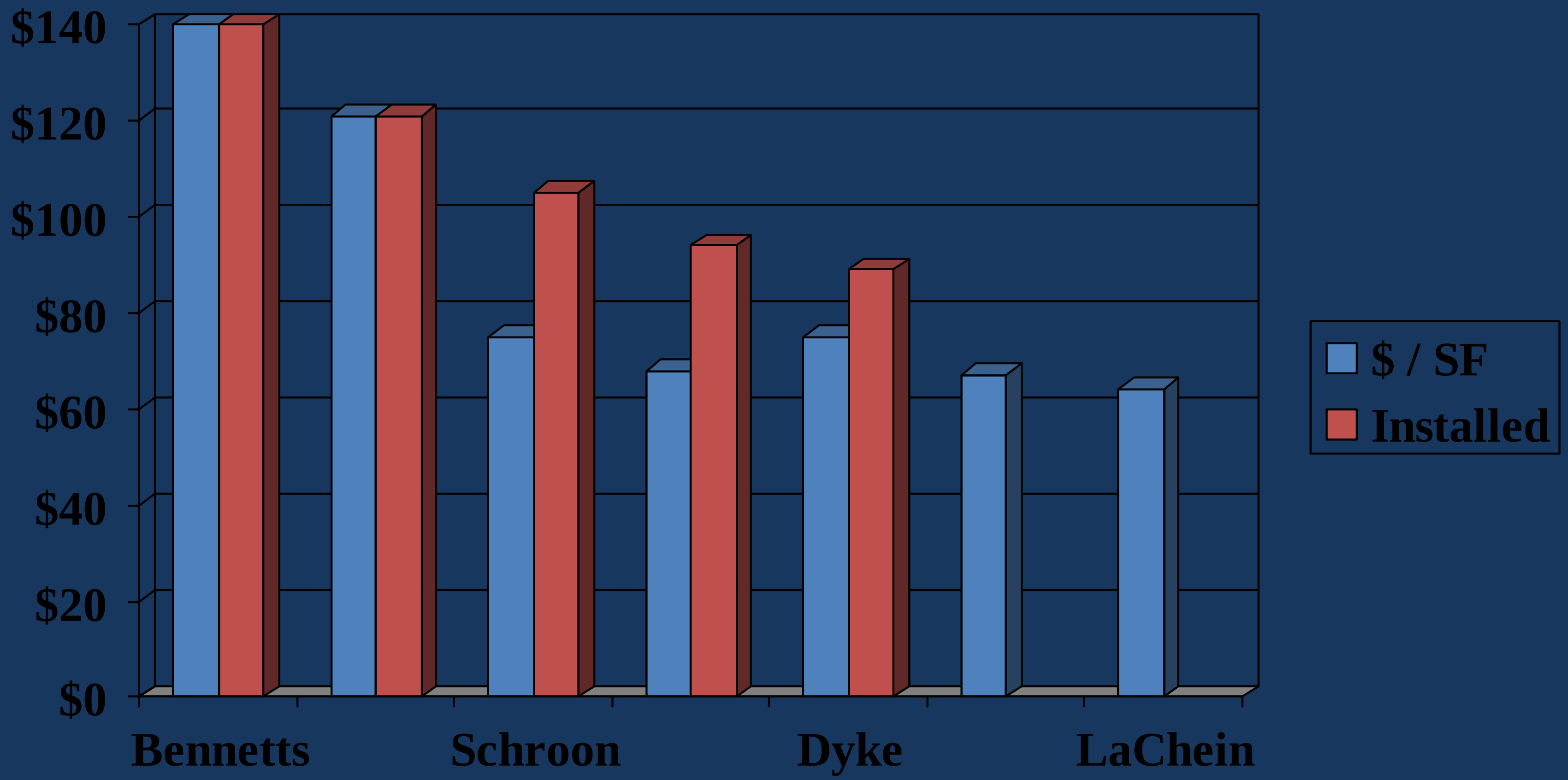


psf
200
180
160
140
120
100
80
60
40
20
0
Old
Conc.
Fill-Grid
Grid
FRP
4"
Deck Type

Deck Cost

	Material Cost	Installed
8” deck	$65-75 / sf	$70-85 / sf
4-5” deck	$35-60 / sf	$45-70 /sf

Cost / SF



Projects with FRP Deck on Steel

Best Applications

Replace Heavy Decks

Before

Inventory	*Operating*
HS 12 (22 Tons)	**HS 18 (33 Tons)**

After

Inventory	*Operating*
HS 23 (42 Tons)	**HS 34 (61 Tons)**

Replace Light Decks

South Broad Street over Dyke Creek,
Wellsville, NY Oct. 2000
Hardcore Composites

Maintain Historic Structures

NY Route 418 over Schroon River,
Warrensburg, NY   Nov. 2000
Martin Marietta Composites

Build 'em Fast

Accelerated bridge construction in high traffic areas enhances <u>safety</u>

Rte. 248 over Bennetts Creek
Rexville, NY Sept. 1998
Hardcore Composites

D-I-Y Bridges

LaChein Bridge
Monroe, WV 2002
Bedford Reinforced Plastics

Reduce Seismic Vulnerability

Schuyler Heim Bridge, Long Beach CA
Martin Marietta Composites

Moveable Bridges

Lewis & Clark Bridge, OR
Martin Marietta Composites

Reduce Environmental Impact

E. T. Techtonics

Pedestrian Bridges

1. 300 +/- in USA
2. 80% by E.T.Techtonics, 20% by others
3. Bridge Cost ~ $60 / SF
4. Draft Guide Spec

Outline

I. FRP Basics

II. Civil Engineering Applications

- Rebar (ppt)
- Seismic Retrofitting (go to)
- Aerodynamic Improvement (go to)
- Concrete Strengthening using sheet, rods, strips, plates
  (Techniques for strengthening steel with FRP is still evolving)
  - Beams
  - Columns Court St
- Overhead Sign Structure Repair (go to)
- Culvert Relining (go to)
- **Bridge Decks Bentley**
- **Bridge Superstructures New Oregon PR-139**

III. Handouts & References (go to)

TESTING,
INSPECTION, &
STRUCTURAL HEALTH MONITORING

Structural Health Monitoring (SHM)

- The importance of SHM is becoming more apparent as our older bridges are kept in service longer
- It is easy to incorporate sensors in FRP at the time of manufacture (e.g. fiber optic strain sensors)

Inspection

- What to look for? (integrity of joints and connections, water intrusion, debonding, delaminating)
- Infrared thermography as a tool
- Load testing
- Tap test
- NCHRP Project 10-64 Report 564 “Field Inspection of In-Service FRP Bridge Decks”

Video 248 debonding of bottom faceskin
Video 240 debonding of top faceskin

Infrared Thermography

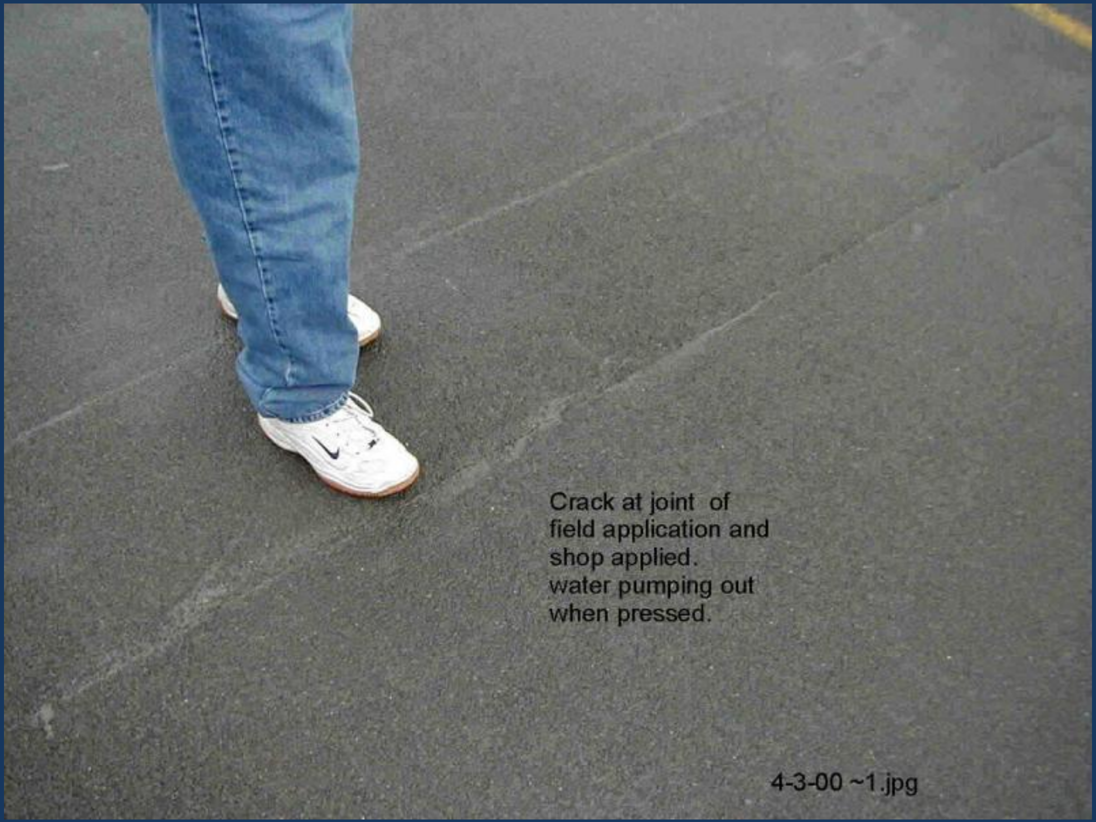
NY248/Bennetts Cr

POTENTIAL PROBLEMS

Wearing Surface Cracking & Debonding

NY367 / Bentley Cr

Wearing Surface Cracking



Wearing Surface Debonding

Wearing Surface Debonding

NY367/Bentley March 2009

Thermal Incompatibility

Wearing Surface Debonding (from Concrete)

- Proper <u>surface preparation</u> is essential
- Extremely dry surface needed

Tap Test of Bottom Faceskin

NY248 / Bennetts Cr

[Mark's tap test]

Tap Test of Epoxy Injection Repair

De-bonded Sandwich Section and Water Intake

Video 1 2 3 4

Insufficient wet-out of fibers

RESOURCES

Resources

FHWA Virtual Team web site

NCHRP project reports

DOT's web sites

DOT research reports

DOT project summaries (e.g. NY, WV)

Conference proceedings (e.g. WV)

ASCE Journal

Other trade journals

Resources

1. FHWA FRP Virtual Team web site
2. WVU biennial conference and past proceedings)
3. NYSDOT's research reports, e.g. wearing surfaces for FRP decks
4. WV and NYS project summaries
5. Former MDA project list
6. Summary paper for TRB Int'l Br Conf (IBEC-0020)

Resources

FHWA

Louis N. Triandafilou, P.E.

Team Leader, FRP Virtual Team

Federal Highway Administration

Phone: (410) 962-3648

Fax: (410) 962-4586

Email: lou.triandafilou@dot.gov

Resources

Syracuse Maintenance Manual

Guide for Maintenance and Rehabilitation of Concrete Bridge Components with FRP Composites – Research into Practice

Riyad S. Aboutaha, PhD., FACI
Syracuse University

Resources

Reinforced Plastics "decks & SS summary"

GRP bridge decks and superstructures in the USA

Jerome S. O'Connor of the University of Buffalo, USA, reviews the use of composite materials for bridge decks and superstructures in the USA. A review of this information should be useful to a civil engineer or bridge owner who wants to assesses the state-of-the-practice and make a judgment about using FRP for bridge decks or superstructures.

The Federal Highway Administration (FHWA), the Transportation Research Board (TRB), and universities have been researching the possibility of using non-corrosive, light-weight FRP materials for bridge decks for over 25 years. The first vehicular bridge in the US was built in 1996 over an unnamed creek in the state of Kansas. Since then, 117 more bridges have been built or rehabilitated with FRP, accounting for over 250 000 ft^2 of bridge deck area[1].

The focus of this paper is on vehicular bridges that have FRP materials as a bridge deck, the superstructure, or both. By definition, a bridge superstructure must have a span greater than 20 ft (6.1 m).

Figure 1 gives a graphic representation of the distribution of the projects in the USA. With a casual look at the map, one will immediately notice that the majority of completed projects are located in the Northeast part of the country. This is because this part of the country was settled first and:

a) the population of bridges is older and in need of rehabilitation;
b) steel has traditionally been the material of choice in this region but was frequently not given the maintenance it needed; and
c) corrosion of both steel and concrete bridges is hastened by the application of salt in the winter to control ice.

GRP deck systems

Although the American Association of State Highway and Transportation Officials (AASHTO) is developing a guide specification for acceptance of FRP decks, this was not available when most projects were built. A review of past practice shows that E-glass fibre is universally used (because of cost). Vinyl ester resin is preferred because of its good long term durability characteristics. Decking panels are assembled in a shop and then trucked to the job site for installation. After bonding panels together and securing, a thin polymer concrete is typically applied in the field to give a uniform layer to protect the deck and provide a skid resistant wearing surface.

Figure 1: Number of FRP decks and superstructures in the USA (2004 data).

Reinforced Plastics, Elsevier Ltd.

Jerome O'Connor. PE, F,ASCE
University at Buffalo

Resources

(list for decks & superstructures)

FRP Deck Suppliers

http://www.fhwa.dot.gov/bridge/frp/decksupl.htm

FRP Completed Projects

http://www.fhwa.dot.gov/bridge/frp/deckproj.htm

Resources

ACMA

John Busel,

Director , Composites Growth Initiative

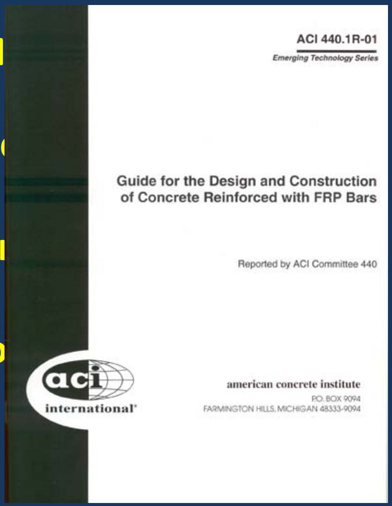
American Composites Manufacturers Association

(703) 525-0511

jbusel@acmanet.org

Resources
ACI-440

- **440.1R-06: Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars**
- **440.2R-08: Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures**
- **440.3R-04: Guide Test Methods for Fiber-Reinforced Polymers (FRPs) for Reinforcing or Strengthening Concrete Structures**
- **440.4R-04: Prestressing Concrete Structures with FRP Tendons**
- **440.5-08: Specification for Construction with Fiber-Reinforced Polymer Reinforcing Bars**
- **440.5M-08: Specification for Construction with Fiber-Reinforced Polymer Reinforcing Bars (Metric)**
- **440.6-08: Specification for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement**
- **440.6M-08: Specification for Carbon and Glass Fiber-Reinforced Polymer Bar M Reinforcement (Metric)**
- **440R-07: Report on Fiber-Reinforced Polymer (FRP) Reinforcement for Concret**
- **SP-215: Field Applications of FRP Reinforcement: Case Studies**
- **SP-245CD: (CD-ROM) Case Histories and Use of FRP for Prestressing Applicatio**
- **SP-257CD: (CD-ROM) FRP Stay-In-Place Forms for Concrete Structures**
- **SP-258CD: (CD-ROM) Seismic Strengthening of Concrete Buildings Using FRP Co**



http://www.concrete.org/COMMITTEES/committeehome.asp?committee_code=0000440-00

Resources

Additional

- NCHRP 04-27 Application of Advanced Composites to the Highway Infrastructure: Strategic Plan
- NCHRP 10-64 Field Inspection of In-service FRP Bridge Decks (University of Wisconsin, Madison)
- FHWA DTFH61-00-C-00021,22 Acceptance Test Specifications for FRP Bridge Decks and Superstructures (WVU & Georgia Tech)
- http://www.fhwa.dot.gov/bridge/frp/deckprac.htm

Resources

Handouts

- New Oregon Road trifold brochure
- Sample column wrap design
- Reinforced Plastics ‘decks & superstructures’ article

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