Composites Industry's Perspective on Transportation Infrastructure Opportunities

John P. Busel
American Composites Manufacturers Association
Virginia Fiber Reinforced Polymer Composite Showcase
Bristol, VA

composites
Multiple strengths, infinite possibilities

From the beginning…

- 1st FRP rebar – early 1970's - USA
  - 2nd company, more R&D – early 1980's
  - Bridges – 1980's – Japan
- 1st FRP dowel bar in concrete pavements – USA – 1977 (dug-up in 1985)
- 1st FRP Vehicular Bridge – China – 1982
- 1st FRP Pedestrian Bridge – China – 1986
- 1st FRP tendon, prestressing – 1986
  - Germany
- 1st FRP Glulam beams – USA – early 1990's

More firsts…

- 1st FRP Strengthening System
  - Experimental work, 1978, Germany
  - 1st application, RC columns, 1980's, Japan
  - 1st application, flexural strengthening of RC bridges, 1987
- 1st Bridge "Wind Fairing" – USA – 2003
- …and more to come

FRP Products

- Vehicular & Pedestrian Bridge Decks
  - All composite
    - Pultruded Profiles
    - Resin Infusion
    - Hand lay-up
- FRP Reinforcement in concrete
    - Rebar
    - Tendons / cables
    - Thin Grid
    - “Thick Grid”
- Structural profiles
    - Deck (pultruded)
    - Girders (pultruded, hand lay-up)

FRP Products

- Concrete Strengthening Systems
  - Sheets
  - Strips/plates
  - bars
- Dowel Bars for Concrete Pavements
- FRP/Wood Glulam Beams for bridge decks
- Marine Piles (fender, bearing, sheet)
- Bridge Fendering Systems
- Other
  - Sidewalks
  - Guardrails
  - Bridge Enclosures / Fairings

The customer

- Civil / Structural Engineer
  - FRP composites are new
  - Very conservative
  - Life safety issues are important
  - Must understand the long term performance
  - Litigation

Drivers

- Traditionally, 10-20 years to accept new technology
- Cost
- Cost
- Long term solutions needed to repair or replace existing deteriorated bridges
- Experience with technology - Risk
- Design Protocols

Influence factors

- Visionary companies – Owners accepting risk
- Academic Institutions – Centers of Excellence
  - Applying the “never been done”
  - Testing and research – getting the data
- Trade associations
- Conferences / Workshops
- Independent consortiums
- Government Agencies / programs
  - National Science Foundation
  - Federal Highway Administration
    - Research
    - TEA-21 Transportation Bill

TEA-21

- FY 98-03 - IBRC Program
- 124 FRP Projects - $87M funded
  - 44 decks
  - 14 rebar
  - 33 repair
  - 6 tendons
  - 27 others (i.e. FRP glulam)
- 19 states with FRP decks
- Future funding - uncertain

Are composites being accepted by the bridge engineers and infrastructure community?

Yes, acceptance is growing

What changed?

- FRP provides many tools for the practitioner
- Graduate researchers – now employed
- Design firms specializing in FRP – wanting to stay ahead of a “hot” issue
- Academic courses
- Codes / Specs
  - North American (US and Canada)
  - European (various countries)
  - Japan

ACI COMMITTEE 440
FIBER REINFORCED POLYMER REINFORCEMENT

- Established 1991
- Chairman – J. Busel
- **Mission**:To study and report on research, development and uses of FRP and produce design guidelines
- 2006 - Largest Committee in ACI
    - Current Membership - 210 members
- 11 Technical Sub-Committees
- 19 Countries represented (including US)

ACI 440 Published Doc's

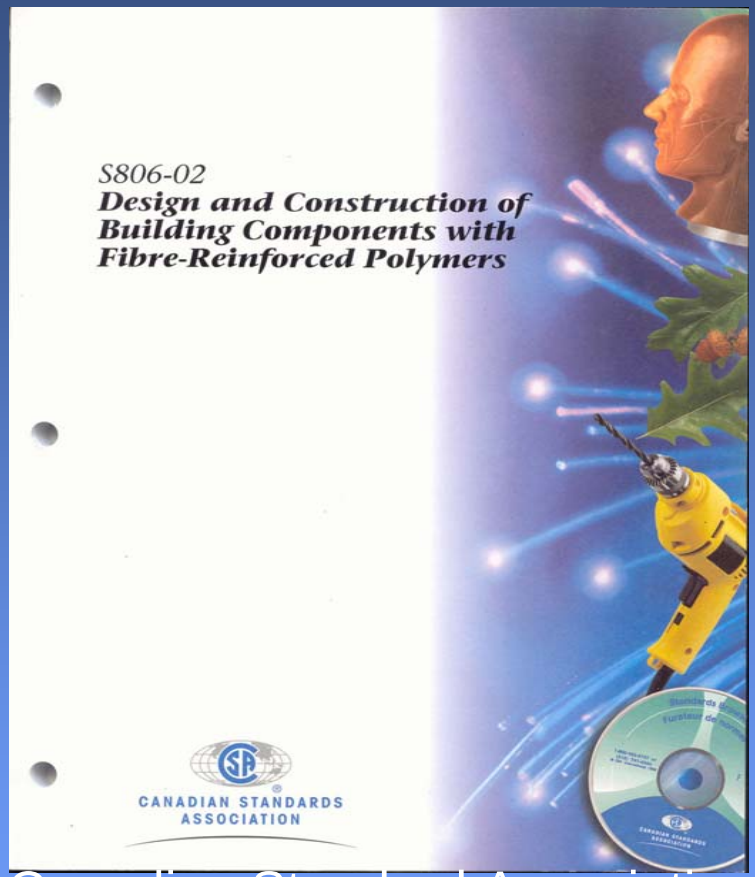
- **ACI 440.1R-03**
  Guide for the Design and Construction of Concrete Reinforced with FRP Bars

- **ACI 440.2R-02**
  Guide for the Design and Construction of Externally Bonded FRP Systems For Strengthening Concrete Structures

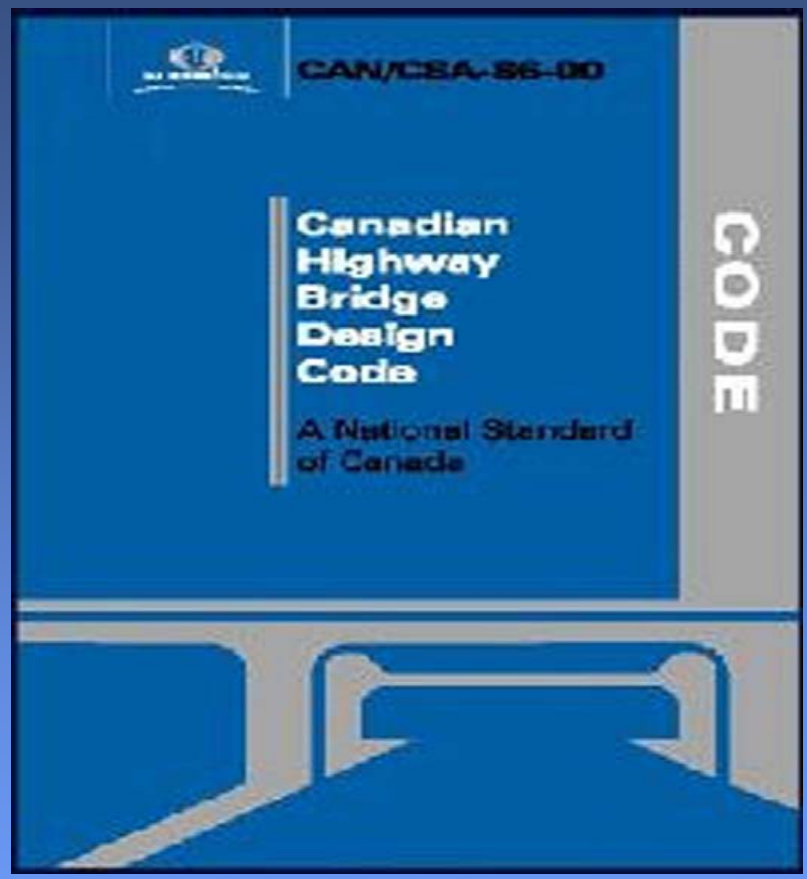
- **ACI 440.3R-03**
  Recommended Test Methods For FRP Rods And Sheets

- **ACI 440.4R.04**
  Prestressing Concrete Structures with FRP Tendons

Canadian Codes

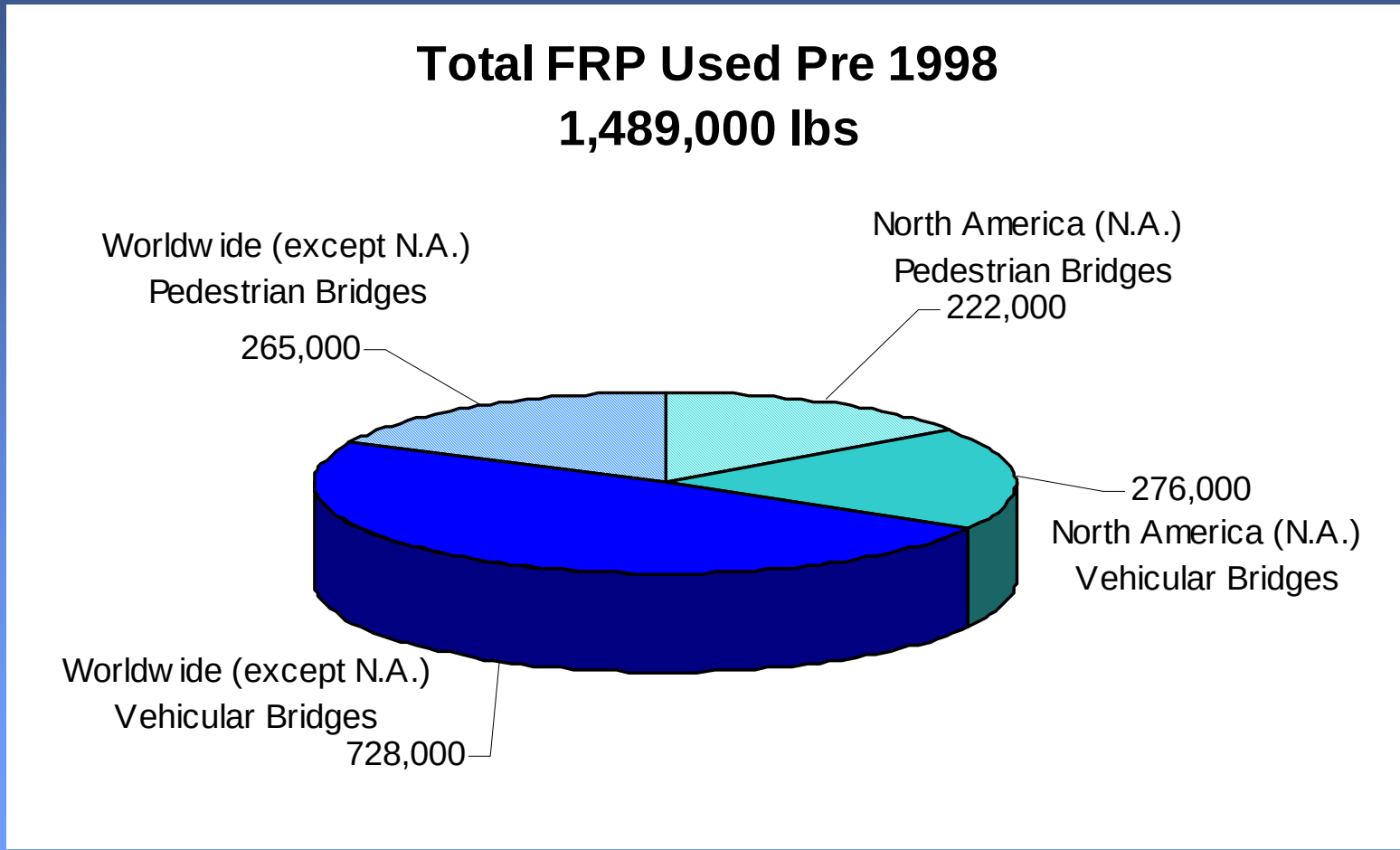


Canadian Standard Association (CSA) Design and Construction of Building Components with FRP (S806-02)

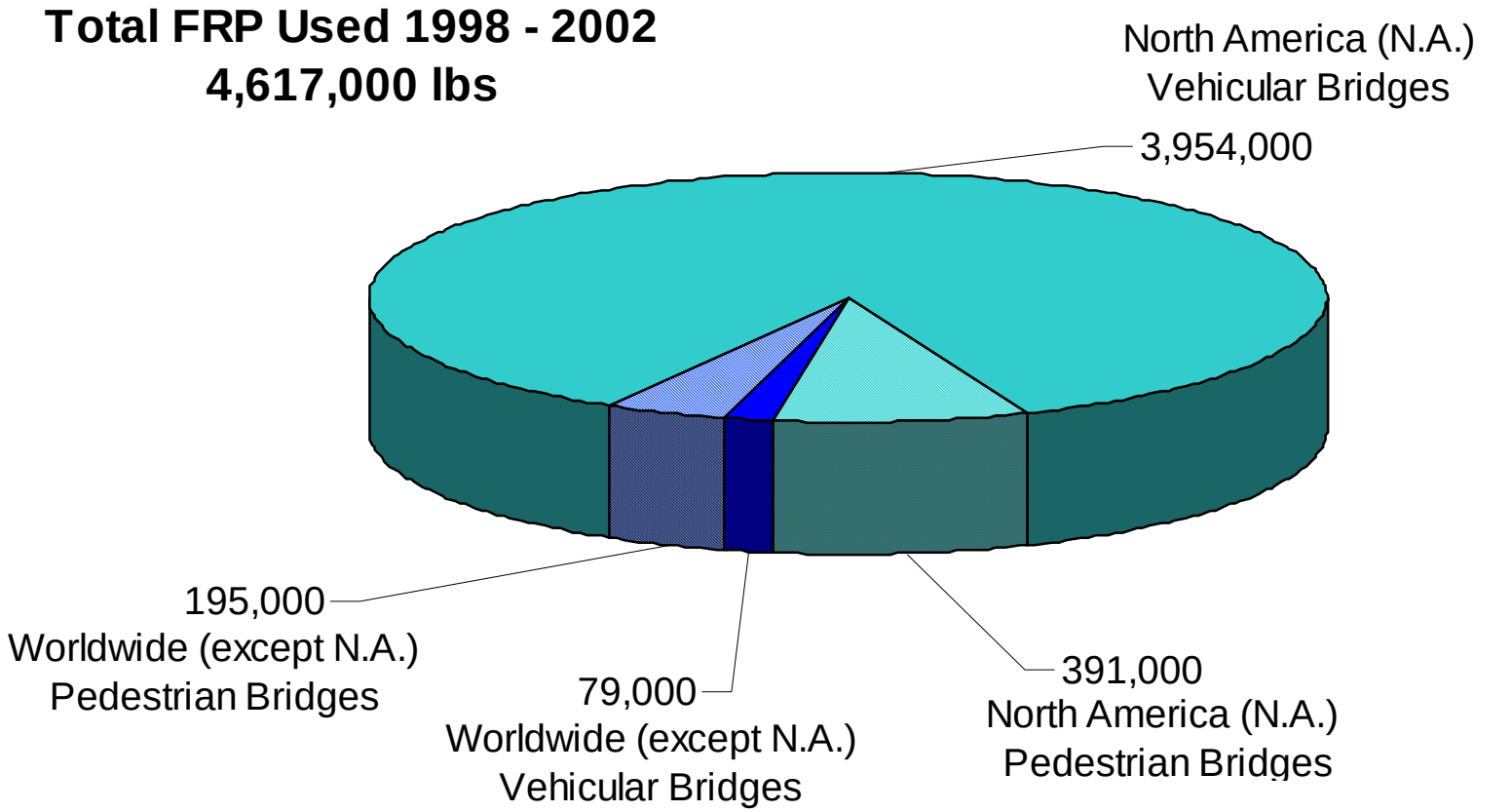


Canadian Highway Bridge Design Code (*CHBDC*): Fibre Reinforced Structures Section 16

Worldwide Usage – Pre 1998



Worldwide Usage – 1998-02



Quick Facts

- 350+ installations worldwide that use FRP composites in bridge applications
- Majority of the installations are in North America, many since 1994
- USA installations were influenced by Congressional Legislation by the Innovative Bridge Research and Construction Program

FRP Deck for Highways

FRP Deck for Highways

Light-weight

panels can often be shipped as entire units, thus lowering the installation time at the site.

Shipping of a complete 39’ x 17’ bridge panel

FRP Deck for Highways

Ohio's First All-Composite Bridge

Tech 21 Bridge over Smith Creek, OH, USA

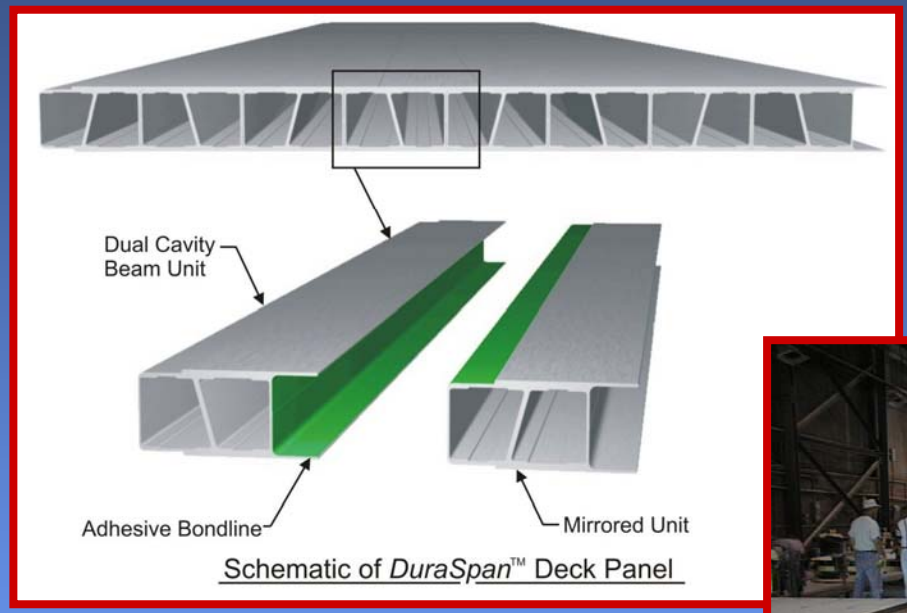
FRP Deck for Highways

Past

Tyler Road Bridge

Present

FRP BRIDGE DECKS



Panels fabricated indoors and shipped to site

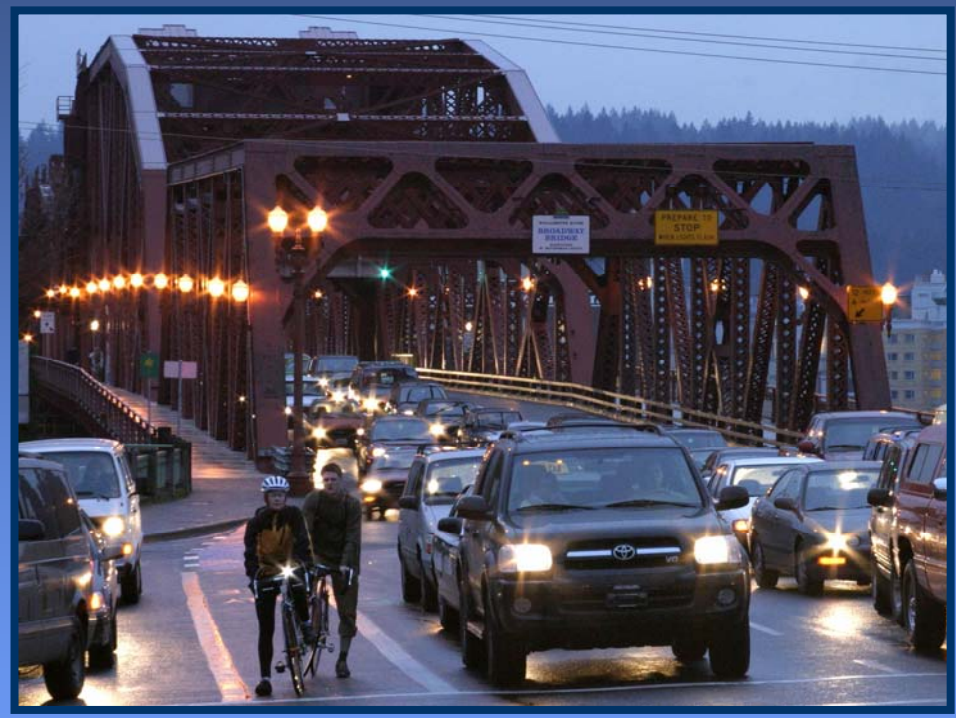
Case Study

Broadway Bridge:

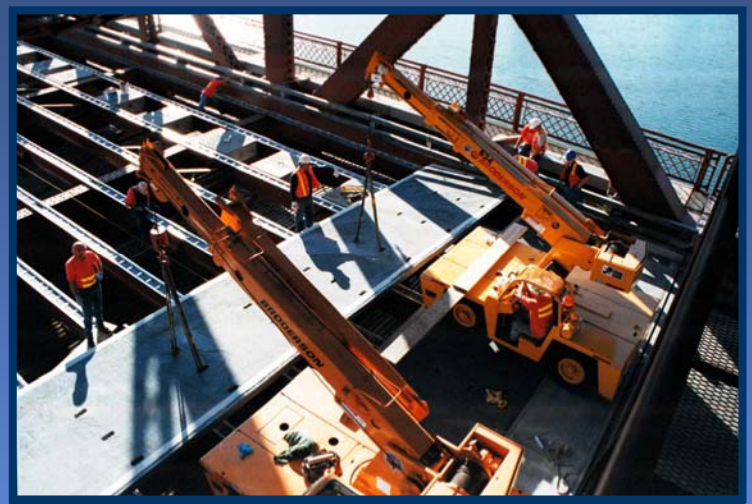
Portland, Oregon

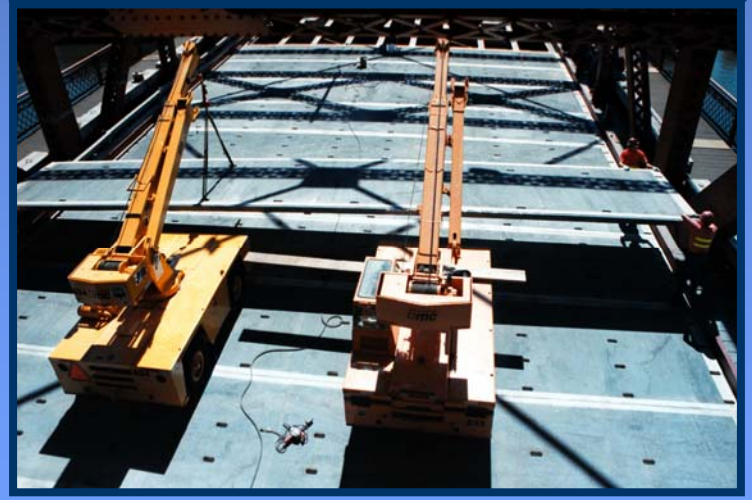
Broadway Bridge

- Located in the heart of the Portland harbor
- 30,000 vehicles per day
- Vital to all types of traffic
  - Vehicular
  - Pedestrian
  - Marine



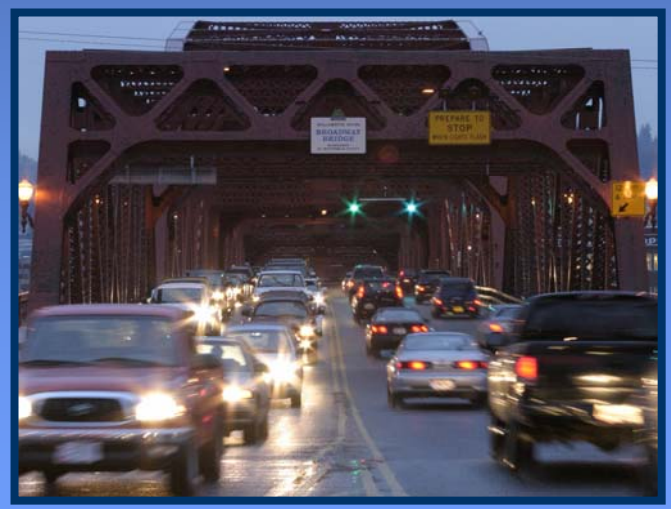
Installation – Place Panels





Results

- One of largest & most traveled FRP decks
  - Nearly 12,000 sf [1,110 sq m]
  - All panels placed **in 2 shifts**
- Completed miscellaneous tasks on 3rd shift
- Ready for bascule opening on 4th day



FRP Rebar for Decks / Approach Slabs

Sierrita de la Cruz Creek Bridge, USA

Pierce Street Bridge, Lima, Ohio, USA

Taylor Bridge, Manitoba, Canada

Wotton, Québec, Canada

FRP Rebar for Decks / Approach Slabs

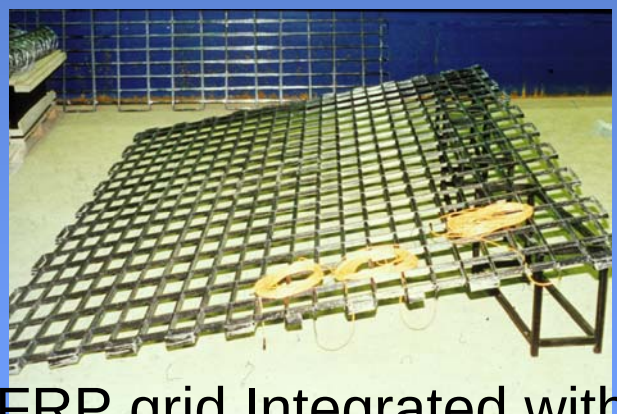
First continuous span steel free bridge deck

Crowchild Trail Bridge
Calgary, AB, Canada

First bridge deck entirely reinforced with CFRP Grid

Rollins Road Bridge
Rollinsford, NH, USA

FRP Rebar for Decks / Approach Slabs



CFRP grid Integrated with fiber optic sensors

Sidewalk Replacement

Reinforcement of the deck slab before casting

Joffre Bridge, Sherbrooke, Québec, Canada

Fond Du Lac, WI 151 by-pass over Denevue Creek

- Single 130’ Span
- 44’ Wide
- 2 lanes of traffic
- 7 pre-stressed wide flange bulb tee girders
- 2 twin bridges
- 180000 ADT

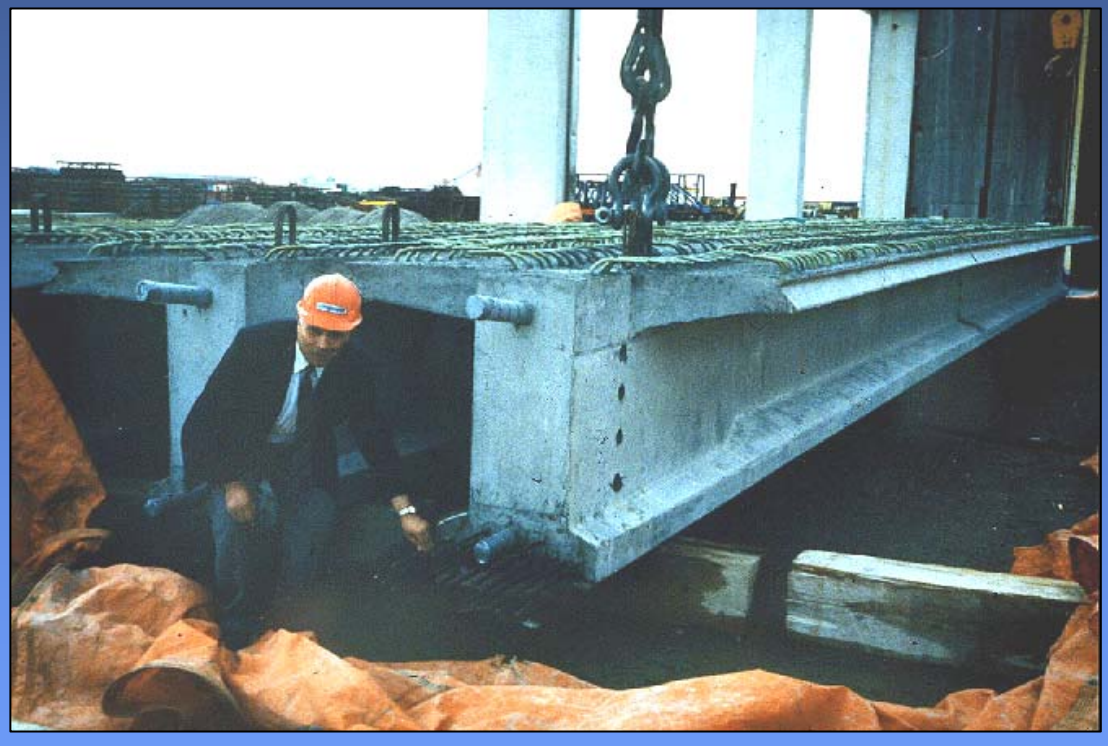
Double-layer Gratings at Bridge Site

Placement of Individual Double-layer Grating on Bridge

Double-layer Gratings in Place Prior to Concrete Pour

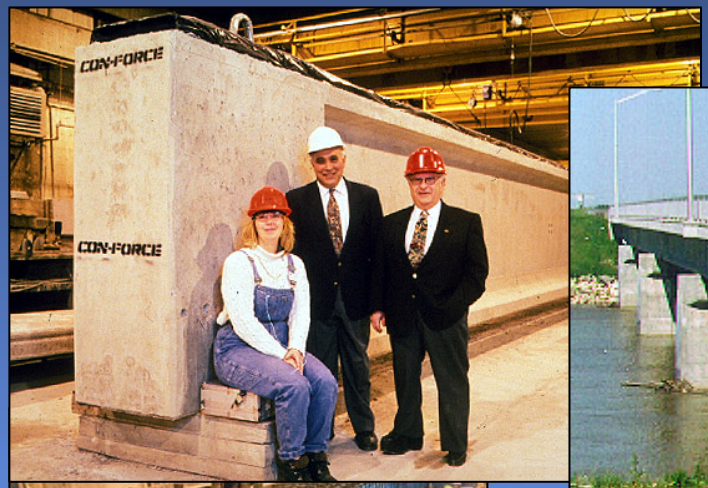
Bridge Girders

First Bulb-Tee bridge girder pretensioned with CFRP tendons, CFRP stirrups, and monitored by FBG sensors

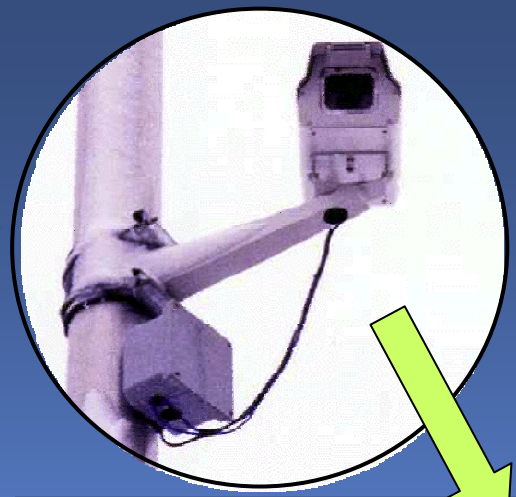


Beddington Trail Bridge, Calgary, Alberta, Canada

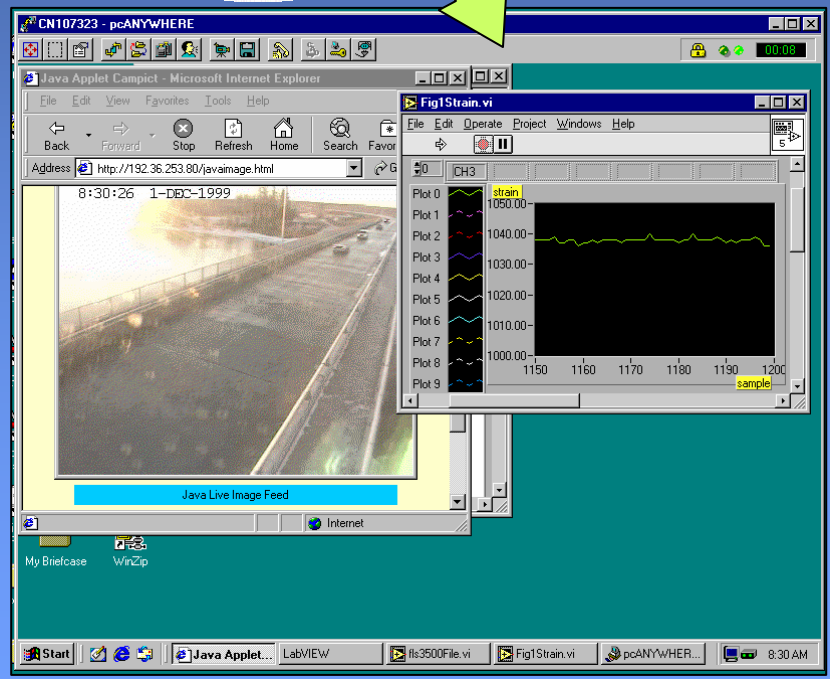
FRP Tendons:Bridge Girders



Taylor Bridge, Headingley, Manitoba, Canada



Taylor Bridge, Headingley, MB, Canada



San Patricio Bridge - Texas

Beams in transit

Beam weight ~ 3000 pounds

- Brace bars are visible near the top of the beams

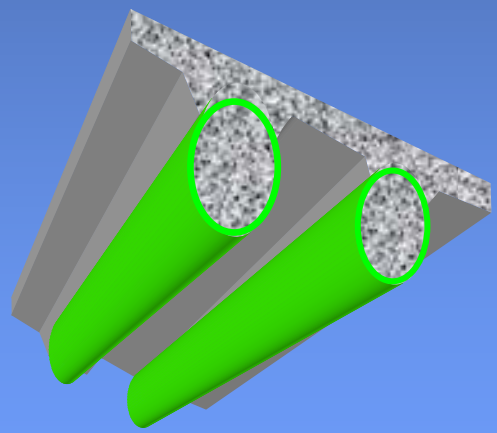
Concrete Filled FRP Tubes

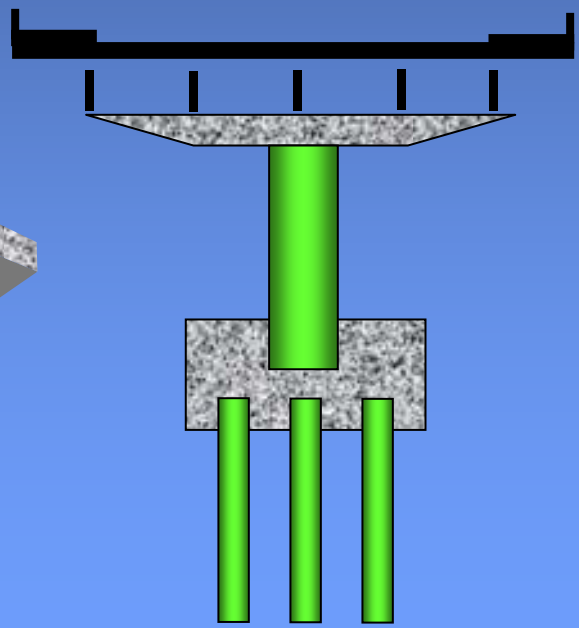
FRP Tube:

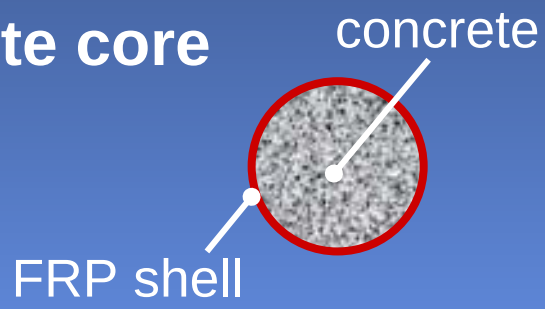
Stay-in-place permanent formwork

Longitudinal and hoop reinforcement for confinement

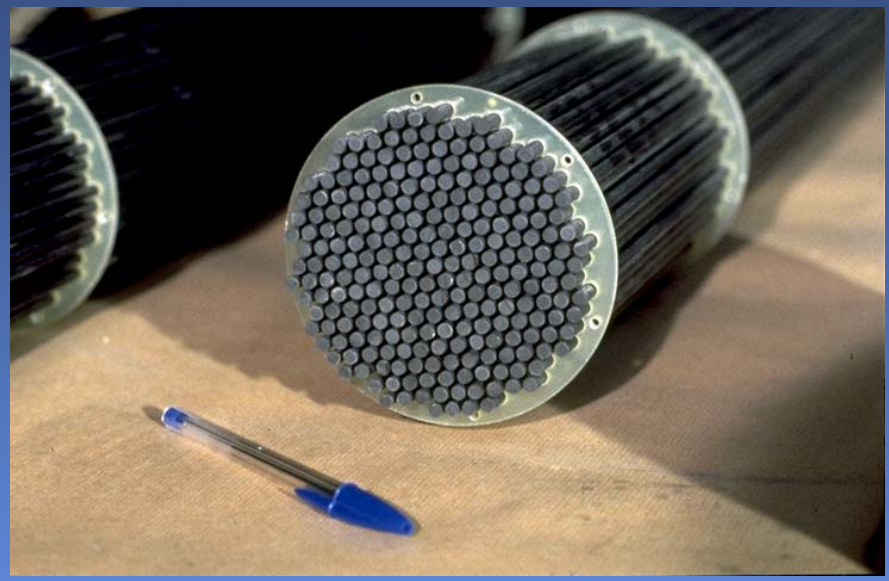
Non corrosive and protects concrete core







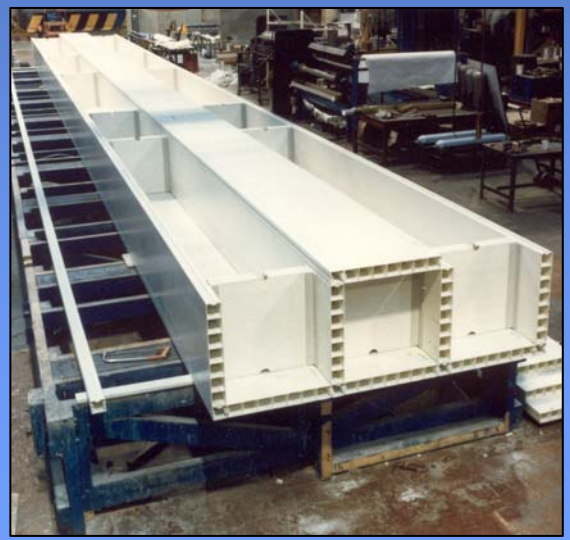
FRP Tendons: Cable-Stayed Bridges



Stork bridge (124 m span, 2 lanes)

241 wires (each 0.2 in)
ultimate load: 2700 kips

FRP Pedestrian Bridges



First All-Composite Bridge – Aberfeldy, Scotland - 1993

FRP Pedestrian Bridges

1950's

1960's

1970's

1980's

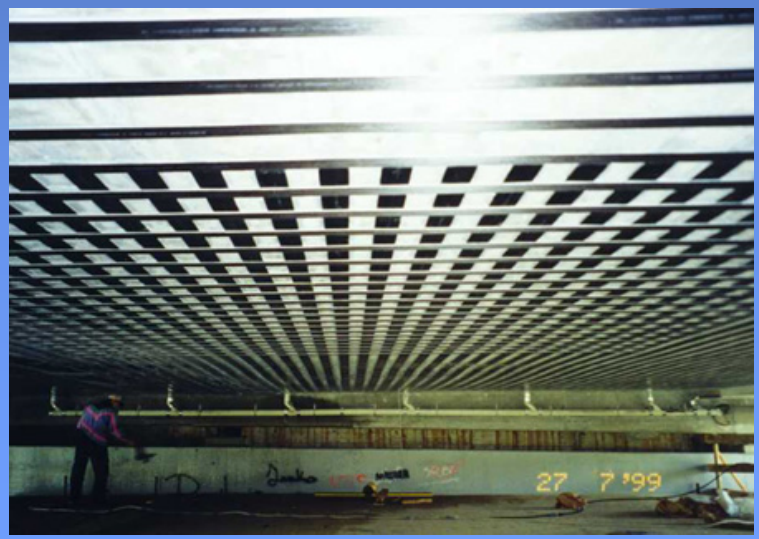
1990's

2000's

Repair/Strengthening/Retrofit

FRP Strengthening

- Composite plates or fabrics bonded with epoxy
- Provides passive reinforcement
- Utilized since 1990's



1950's

1960's

1970's

1980's

1990's

2000's

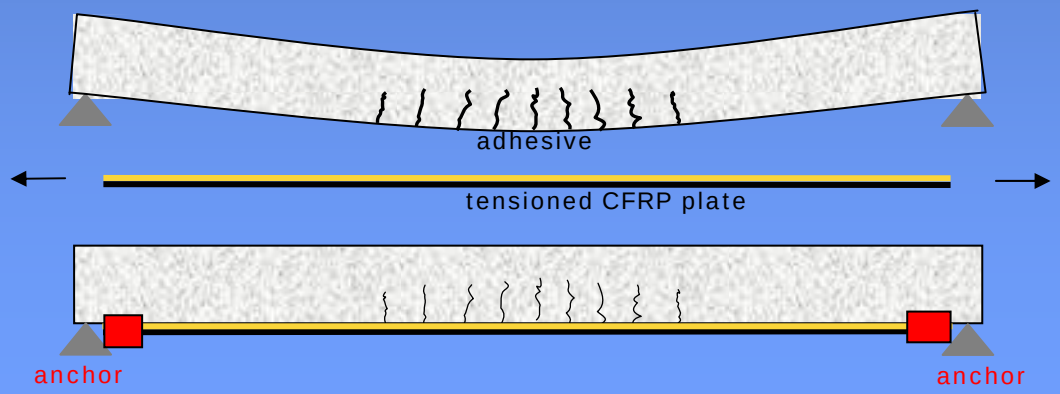
Repair/Strengthening/Retrofit

Post-tensioned CFRP Plates

- Tensioned carbon fiber plates
- Provides active reinforcement
- Installed as either bonded or unbonded system
- Utilized since 2000's

Post-tensioning with CFRP

- Optimal use of high material properties of carbon fibers
- Reduces tensile strain in existing steel reinforcement
- Increases live load capacity of member
- Non-corrosive material



Case Study

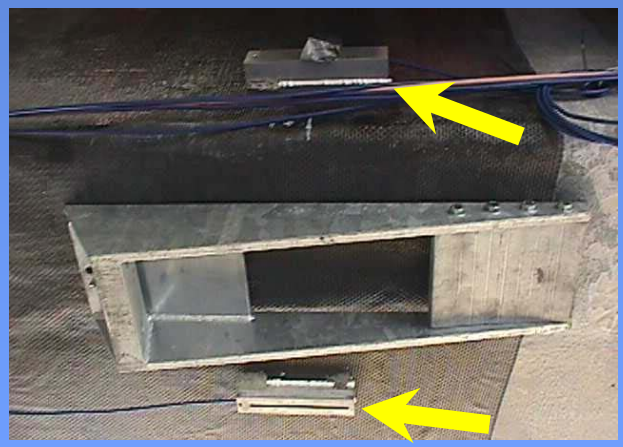
Hopkins & Clinton Street Bridges
Defiance, Ohio

Fixed Anchor Post-tensioned Strip

Applying Post-tensioning Force

Analysis of Repair

- A total of 11 beams were strengthened with plates ranging from 19 to 40 ft. in length
- Diaphragm capacity was critical for strengthening project
- One post-tensioned CFRP strip replaced two deteriorated steel strands
- Strain gages were installed to monitor long term effectiveness of repairs



Repair/Retrofit: Mechanically Fastened Composites

Vision

- Composites address the needs of aging and posted movable bridges
- Broader use of rebar and tendons in concrete applications for new construction
- Repair applications will continue to encourage innovation for composites
- Structures built with blast protection
- New applications in strengthening steel
- Nanocomposites are developing to a point of being economical – higher strength composites
- Combining composites with other materials technologies for “system solutions”

Composites Challenges

- Developing convincing examples of cost effective solutions that can be used by engineers
- Developing “FRP design guides” demonstrating viable, long-lasting solutions using FRP
- Educating engineering professionals on FRP technology and product systems

Composites Challenges

- The FRP composites industry must be unified
  - Present the technology and
  - The **tools** design engineers need to help them to specify and apply FRP technology solutions
- Attention to quality and repeatability
- Need to be conservative – life safety
- Promote, promote, promote
- Educate, educate, educate

Final thoughts

- Future installations will demonstrate new applications of FRP technology
- Development of uniform design guides will accelerate the specification of FRP (decks, bridges, buildings, etc.)
- FRP used for Blast mitigation is quietly expanding
- Innovation will influence numerous applications – but can the composites industry absorb concurrent development

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Thank you!

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