Outline

- About ACMA
- Overview of Field Applications
- FRP Materials
- Case Studies
- Standards & Specifications
- Conclusions
About ACMA

- The American Composites Manufacturers Association
  - Largest composites trade association in the world
  - Represents the composites supply chain
    - Material Suppliers
    - Distributors
    - Manufacturers
    - Consultants & Academia
- Represents an industry of:
  - 3000+ companies
  - 280,000+ employees
ACMA Industry Councils & others

- ACMA Industry Councils represent the many markets composites actively engage
  - Transportation Structures Council
  - FRP Rebar Manufacturers Council

- Other FRP Composites Groups
  - ACI Committee 440 – FRP Reinforcement
  - PCI Committee – FRP Composites
  - AASHTO Bridge Committee T-6
  - TRB AFF80 – FRP Composites
FRP Products Used in Infrastructure

- Vehicular Deck Panels, Pedestrian Decks/Bridges
- Deck Superstructures
- FRP Rebar
- Girders/Beams
- Concrete Strengthening Systems (blast mitigation)
  - Thousands of installations (column, bent, slab, girder)
  - Blast hardening of cables
- Marine Piles (fender, bearing, sheet)
- Cables, tendons (carbon fiber)
- Other: Dowel bars, Parapets, Sidewalks, Guardrails, Bridge Enclosures/Fairings, drainage pipe
FRP Composites Installations Today

- Nearly 400 installations in North America
- In the U.S., FRP composites in bridges
  - >190 installations
  - >50 installations where FRP bars are used in bridge decks
  - 15 states (CO, FL, IA, IN, KY, MO, NC, NY, OH, OR, TX, UT, VT, WI, WV) use FRP bars in bridge decks
- In Canada, FRP composites in bridges
  - >195 installations that use FRP composites
  - 190 installations use FRP bars in bridge decks, parapets, barriers, sidewalks
Composites Installations Today

Composite Products in the U.S.

Number

0
1
2
3
4
5
10
15
20
30

ACMA
American Composites Manufacturers Association
Why are composites different?
Fiber Reinforced Polymer Materials

**What is FRP?**

**Fibers**
- Provide strength and stiffness
- Carbon, glass, aramid

**Matrix**
- Protects and transfers load between fibers
- Polyester, Epoxy, Vinyl Ester, Urethane

**Composites**
- Creates a material with attributes superior to either component alone!
- Fibers and matrix both play critical roles in the composites material...
Factors Affecting Material and Composites Characteristics

- Type of fiber / core reinforcement
- Fiber volume
- Type of resin
- Fiber orientation
- Type of manufacturing process
- Quality control procedures during manufacturing
- Rate of curing
- Void content
- Service temperature
Composites Products for Prefabricated Bridge Elements & Systems (PBES)

- FRP composites deck panel systems
  - Full thickness, pultruded, 1-piece, bonded panel joints
  - 2-piece, pultruded, mechanically fastened
  - Sandwich construction, vacuum infusion (foam/structural reinforcement, balsa)

- FRP composites deck superstructure systems
  - Sandwich construction (foam/structural reinforcement)

- Girders (pultruded structural shape, box)

- FRP rebar reinforced precast concrete panels

- FRP grid reinforced concrete structural stay-in-place panel systems
FRP Composites Benefits

- Prefabrication of deck panels
  - Manufacturing in a plant to ensure quality
  - Minimizes installation on site

- High strength
  - Design loads can be tailored to meet the requirements of the job

- Lightweight
  - Reduces installation time
  - Reduces the number of trucks to carry products to site as more products can be transported per truck
  - Lighter duty equipment needed to lift and place panels
FRP Composites Benefits

- Corrosion resistance
  - Long durable life
- Design flexibility
  - Infinite shapes and sizes can be designed to meet the requirements of the job
- Color matching
  - Meet needs of blending into surrounding environment
- Enhanced Safety
  - Solid surface for traction
  - Non-skid surface for safety of pedestrian traffic
- Lower Life Cycle Costs
  - New requirement – MAP 21 Transportation Bill
Current Installations - superstructure

1997 – TECH 21, Butler County, Ohio
Pavement – **GOOD**

Crack at abutment joint - **TYPICAL**
Rail connection to deck – **GOOD**

FRP superstructure fascia – **GOOD**, **WATERTIGHT**, **NO** indication of **MOVEMENT** between deck & beam
Abutment joint – beginning to LEAK

Beam seat and abutment face will continue to DETERIORATE
Current Installations – FRP Deck Panels

1999 – Salem Avenue, Dayton, Ohio
Pre-cast haunch at beam to deck interface, provided UNEVEN BEARING
Salem Ave. – 2000

Manufacturing detail

Representative skin DELAMINATION (W.Va bridge)

Interior of core, NO BOND (Salem Ave.)
Salem Ave. – February 2007

Design detail

Wearing surface DELAMINATION
## Deck / Beam / Girder Manufacturers

### Deck Panel
- Zellcomp, Inc. (Raleigh, NC)
- Composite Advantage (Dayton, OH)
- Strongwell (Bristol, VA)
- Baltek, Inc. (Colfax, NC)

### Beam/Girder
- Strongwell (Bristol, VA)
- HC Bridge (Wilmett, IL)
- Creative Pultrusions, Inc. (Alum Bank, PA)
Bridge deck - Broadway Bridge, 2010

- Located in the heart of the Portland harbor
- 30,000 vehicles/day
- 7th longest Bascule bridge
- Vital to all types of traffic
  - Vehicular
  - Pedestrian
  - Marine (4 shifts)

Solid Surface FRP Deck Replaces Steel Grating on High Volume Bridge
Full depth, pultruded bonded panels

Schematic of DuraSpan Deck Panel
Broadway Modifications

- Aug 2010
- Light Rail System installed
- FRP deck cut out
- New deck replaced between the rails

Courtesy of ZellComp, Inc.
2-piece Deck Panel Design

Prefabricated & Pre-Engineered

= Low-cost & Easy to Assemble

(5 Inch Deck ~ 16 Lbs/sf   7 inch Deck ~ 18 Lbs/sf)

Top Sheet Pultruded
Broadway Modifications

- Two-piece Design
- Top sheet affixed with fasteners

 Courtesy of ZellComp, Inc.
Morrison Bridge – Portland 2011

- Six-lane bridge, 760 ft in length
- Over 50,000 ADT
- Replacing open steel decks with solid surface decks
- 17,000 sq ft, largest FRP deck panel replacements in the U.S. and one of the largest in the world
- Required to keep the bridge open to both car and truck traffic on the bridge and watercraft traffic beneath it.
- For traffic on the bridge, county devised a staged construction plan to ensure that two lanes were always kept open.
Morrison Bridge – Portland 2011

- Advantages – Traction, Noise, & Maintenance
- No replacement of counter-balance system

Courtesy of ZellComp, Inc.
Morrison Bridge – Portland 2011

Lightweight material is easier to handle and faster to install.

Courtesy of ZellComp, Inc.
Morrison Bridge – Final

Courtesy of ZellComp, Inc.
**Belle Glade, FL**
- Lift Bridge - Steel Framed Girders
- 78 ft wide x 37 ft long with 28° Skew
- 5 inch ZellComp Deck
- ½” Polymer Concrete WS (Kwik Bond Polymers)

**Tippecanoe County, IN**
- 1 Span Steel Girder Bridge
- 28 ft wide x 58 ft long with a Crown and Steel Guardrails attached to the ZellComp Deck
- 7 inch ZellComp Deck
- ½” Polymer Concrete WS (Kwik Bond Polymers)

**Redstone Arsenal, US Army Corps**
- 4 Span Steel Girder Bridge
- 20 ft wide x 200 ft long with Concrete Barriers attached to the ZellComp Deck
- 7 inch ZellComp Deck
- ½” Polymer Concrete WS (Tamms)
Sandwich Construction

- **Superstructure**
  - Weight 26 - 40 psf (depending on lengths of 20 to 50 feet)
  - $150 - 240/sf
Sandwich Construction

- Vehicular Deck
  - Weight: 15 - 20 psf that generally scale with the deck depths of 5 - 8 inches.
  - $80 to $120/sf
- Pedestrian Deck (thinner deck)
  - Weight: 4 - 10 psf
  - $35 to $65/sf
• Panels placed in less than 9 hours
• Bonded/bolted together
• Diaphragm rebar connected
Wolf Trap National Park
Vienna, Virginia

- Pedestrian bridge connecting parts of the park
- Crosses main access to Dulles Airport
  - Ten lanes of highway and one passenger rail line
- Safe access to amphitheater from one parking lot
- Visitors were walking on vehicle bridge with minimal sidewalk
FRP Deck Enables Accelerated Construction of Truss Bridges

- Enabled fully assembled spans to be erected with minimal road closure
  - No deck installation over the road
  - Precast concrete would have added 74,000 lb to the 132,000 lb lift
- 15 minutes in the middle of the night is Minimal
- FRP Benefits
  - Prefabricated Elements
  - Ease of installation - Light Weight
Hybrid Composite Beam

“Tied Arch in A Fiberglass Box”

A structural member using several different building materials resulting in a cost effective composite beam designed to be stronger, lighter, and more corrosion resistant

- Compression Arch - SCC Concrete
- Tension Reinforcement - Galvanized P/S Strand - Fiberglass Cloth
- FRP Shell
- Galvanized Shear Connectors

Tension Reinforcement - Galvanized P/S Strand - Fiberglass Cloth
Cedar Grove, NJ Installation

Route 23 - Bridge over Beckman’s Brook in Cedar Grove Township, Essex, NJ.

This is a highway bridge with a 32-foot span and a 66-foot deck width.

Light Weight Speeds Up Installation

Courtesy of HC Bridge, LLC
Knickerbocker Bridge – Boothbay, ME

- 540 ft. Overall Length – 8 Span Continuous
- 2 Spans @ 60 ft., 6 Spans @ 70 ft. 33” box beams
- No more expensive than a conventional concrete box beam bridge

Courtesy of HC Bridge, LLC
B0439 – Missouri

 Courtesy of HC Bridge, LLC

Rte 76 Over Beaver Creek
3 Spans of 60 ft. - October 2011
Safe & Sound Bridge - B0410, Missouri

- 60 in. HCB’s – Pre-Filled, Ready to Ship
- Double Web up to 120 ft. spans

Courtesy of HC Bridge, LLC
Bridge in a Backpack

- Carbon Fiber shell, prefabricated arch made in the plant
- Shipped to site – installed – lightweight, carried by workers - concrete poured
- Finished with composites panels
Lightweight

- Transportation
- Assembly
- Handling
Final Bridges

Farm Access Underpass
Caribu, ME

NHDOT Maintenance Lot,
Pickham’s Grant, NH
Tie Arches to foundation to create an assembly
FRP Rebar Manufacturers

- BP Composites (TUFF-Bar)
- Composite Rebar Technologies, Inc.
- Hughes Brothers, Inc. (AslanFRP)
- Marshall Composite Technologies, Inc. (C-Bar)
- Pultrall, Inc. (V-Rod)
Emma Park Bridge, Pleasant Grove, Utah DOT, 2009
Emma Park Bridge

- Full Depth Precast – top & bottom mat
- Cost premium in 2009 to use GFRP over Epoxy bar
  - 14% greater deck cost – due in large part to additional girders
  - On a 1:1 basis, GFRP bars equal in unit price to epoxy steel
Noden Causeway, Ontario, Canada

- Prestressed / precast deck
- The pre-cast deck panels mainly used #5 (16m) and #6 (19m) GFRP bars
- #4 CFRP bars were used for pre-stressing the panels

Courtesy of Pultrall, Inc.
Sunshine Creek, Thunder Bay, Canada

GFRP rebar/precast
CFRP bar / prestress

Courtesy of Pultrall, Inc.
Sunshine Creek

- Bridge converted from a monolithic design to a box-girder type bridge
- High strength concrete was used to fill the gaps between the box girders

Courtesy of Pultrall, Inc.
Prefabricated FRP stay-in-place panels

Double-layer stay-in-place (SIP) reinforcing panels pre-assembled using off-the-shelf pultruded GFRP components

- 1.5” I-bars (4” o.c. perpendicular to traffic)
- Three-part cross rods (4” o.c. parallel to traffic)
- Vertical connectors
- 1/8” thick epoxy bonded form plate

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Deck construction, Missouri

➢ Setting Panels of Reinforcement
Standards & Specifications

Translating research into industry standards
AASHTO design guides

- New AASHTO LRFD design guide specifications published 11/2009
- Bridge decks and traffic railings, glass FRP (GFRP) bars
- Specific properties of GFRP reinforcement, design algorithms and resistance factors, detailing, material and construction specifications
Canada - Highway Bridge Design Code

- Technology transitioned from government-subsidized research projects to actual commercialization
- Experience gained on viability of construction management practices where FRP reinforcement is adopted through traditional bid letting processes and competitive bidding from multiple FRP bar suppliers
ACI - rebar

- Design principles well established through extensive research
- Guideline documents published in North America, Europe, Japan
- In US, ACI 440.1R-06 guidelines from green to blue (no longer “emerging technology”)
- Non-mandatory language
ACI – rebar, materials

- Draws from ACI 440.6-08 (standard document)
- Provisions governing testing and evaluation for certification and QC/QA
- Describes permitted constituent materials, limits on constituent volumes, and minimum performance requirements
ACI – rebar, construction

- Draws from ACI 440.5-08 (standard document)

- GFRP bar preparation, placement (including cover requirements, reinforcement supports), repair, and field cutting
Pre-Standard released 2010

- Ch. 1 General Provisions
- Ch. 2 Design Requirements
- Ch. 3 Tension Members
- Ch. 4 Compression Members
- Ch. 5 Flexural and Shear Members
- Ch. 6 Combined Forces & Torsion
- Ch. 7 Plates and Built-Up Members
- Ch. 8 Bolted Connections
Conclusion – 1

- Many applications in the field, FRP is no longer a demonstration project.
- Multiple sources of product.
- FRP materials are very **DURABLE** relative to other bridge components.
- **DETAILS** of the system are **CRITICAL** to the overall durability of the bridge.
- Due to poor details, there is a potential for higher maintenance of some components of bridges.
Surface preparation is very important to whatever wearing surface is applied.

Joints and connections need to incorporate a “systems thinking” when using composites.

Composites are Engineered Systems.

Prefabricated components, factory built, quality controlled.

Reduces the need for large, heavy, expensive equipment during installation.
Conclusion – 3

- Increases safety on site
- Lighter Weight for Reduced Shipping, Handling and Erection Time and Costs (Accelerated Bridge Construction)
- Reduced Carbon Footprint
- Greater Corrosion Resistance than Conventional Materials Providing Service Lives Beyond 100 Years
- LOWER OVERALL BRIDGE COST!
- COMPOSITES: Multiple Strengths, Infinite Possibilities
Composites Conference

www.compositesshow.org

COMPOSITES 2013

• January 29-31, 2013
• Orange County Convention Center, Orlando, FL
• Sessions on infrastructure and construction
• Over 4,000 attendees
• Expo with suppliers and manufacturers
Thank You!

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