ADVANCED INFRASTRUCTURE TECHNOLOGIES

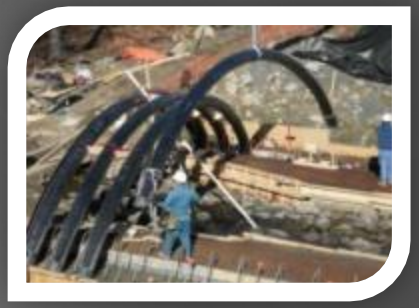
Concrete Filled, Fiber Reinforced Polymer (FRP) Composite Tubes

" Bridge-in-a-Backpack "

A collaborative innovation together with:

MaineDOT

AEWC Advanced Structures & Composites Center



What is the " Bridge-in-a-Backpack " System

Fiber Composite + Concrete Arch Superstructure

" A Hybrid bridge system combining benefits of high-performance composites with durability and cost savings of cast-in-place concrete"

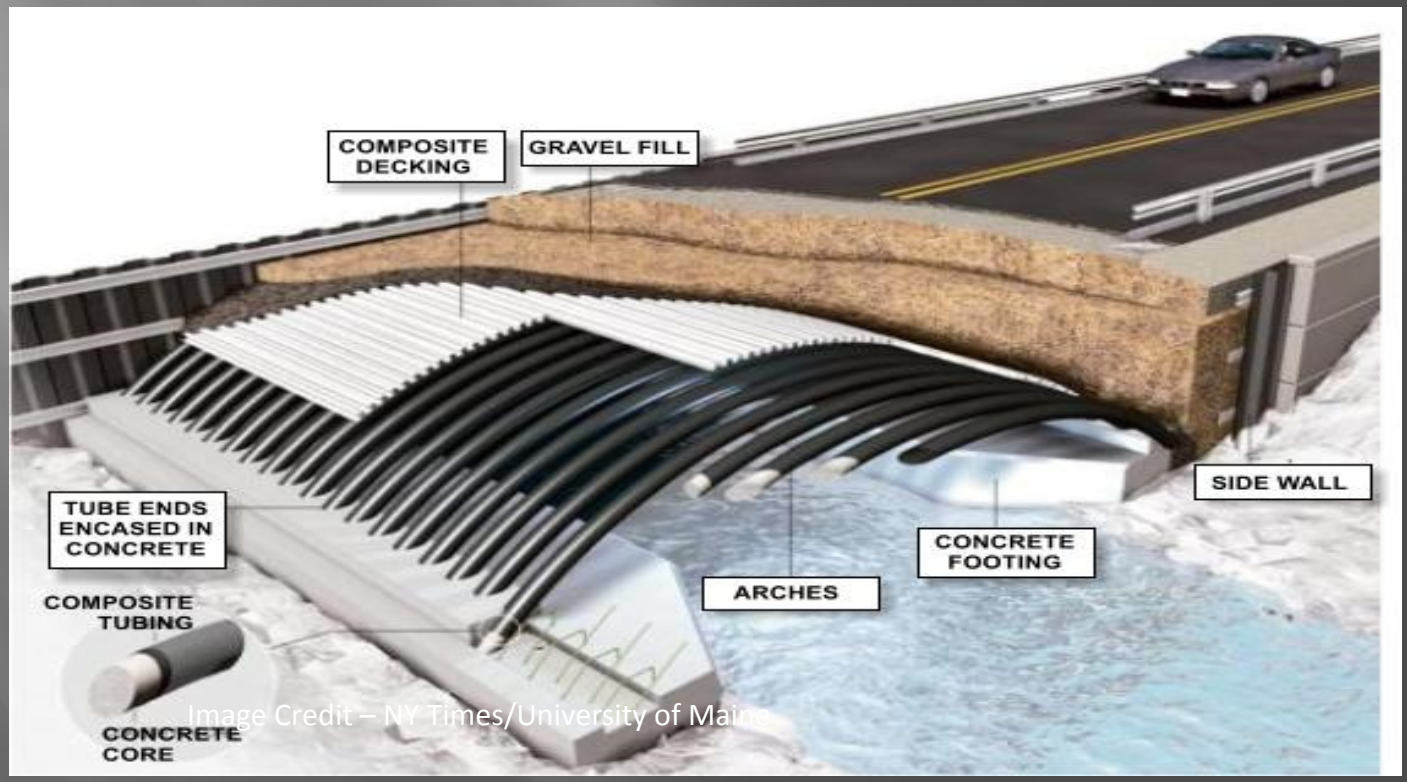


Image Credit – NY Times/University of Maine

Innovation

- **UMaine AEWC Composites Center**
  - **87,000 ft² facility**
  - **Researching Hybrid Composite Systems since 1996**
  - **Nearly 12 years development of Bridge-in-a-Backpack**

Secretary of Transportation Ray LaHood Speaks about Bridge-in-a-Backpack at UMaine Press Event

National Recognition for Bridge-in-a-Backpack

AASHTO Technology Implementation Group

ACMA American Composites Manufacturers Association
The Composites Connection

ACEC American Council of Engineering Companies
100 Years of Excellence

Engineering Excellence Award Royal River Bridge, Auburn, ME
(Along with Maine DOT & Kleinfelder | SEA)

ASCE

American Society of Civil Engineers 2011 Charles Pankow Award for Innovation

Product featured in:
Engineering News Record,
The NY Times,
Concrete International,
Popular Science,
Popular Mechanics,
The Boston Globe

Development & Testing at University of Maine

- Develop & patent manufacturing process
- Model development

2001 →

- Structural testing
- Model refinement
- Material optimization

2005 →

- Demonstration project
- System refinement

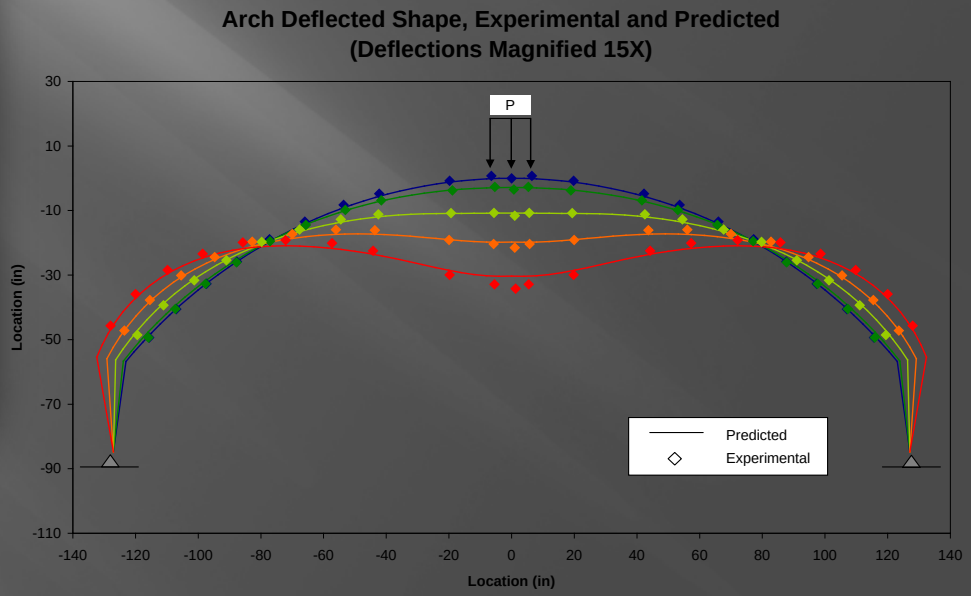
2008 → *Ongoing*

Manufacturing of 60′ Span Arch

Arch Structural Testing

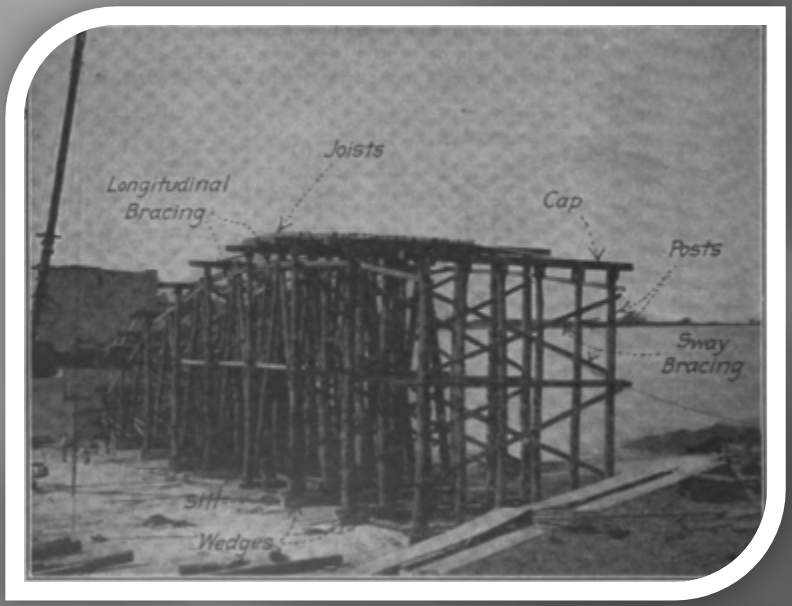
Performance Testing: Arch Testing

- Deflections measured using 3D digital image correlation system
- FE model predictions compared with experimental response



Three Functions of the FRP Arch Tube

1. Stay-in-place form for concrete



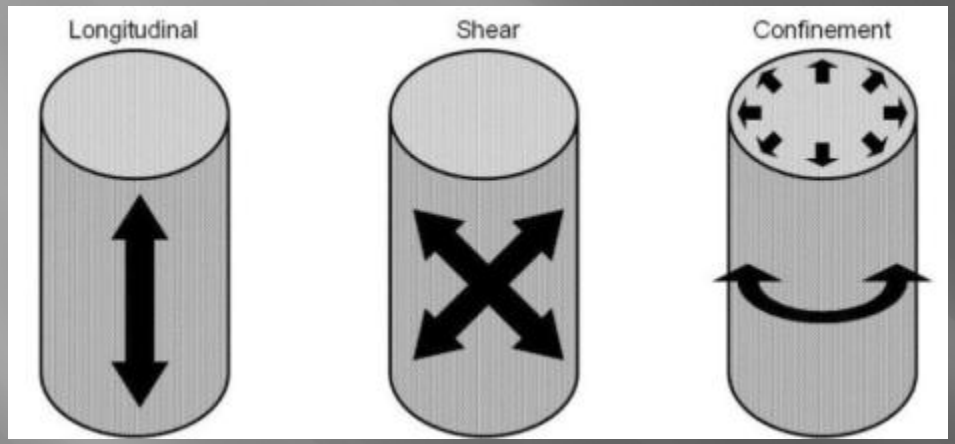
Temporary Formwork for Arches
Concrete Engineers Handbook,
McGraw-Hill, 1918

Arches and decking are the only formwork needed to stabilize the structure

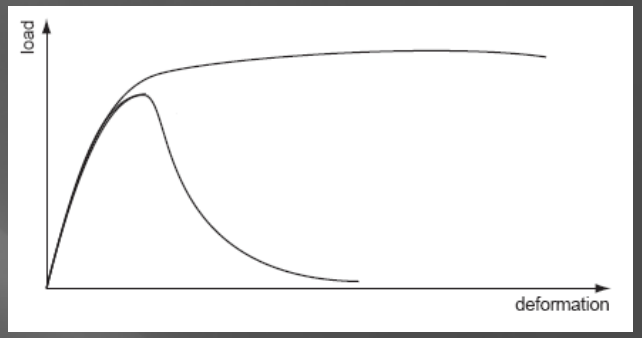
Eliminates need for temporary formwork

Three Functions of the FRP Arch Tube

2. *"Structural reinforcement"* for concrete confinement



Three Components of FRP Reinforcement



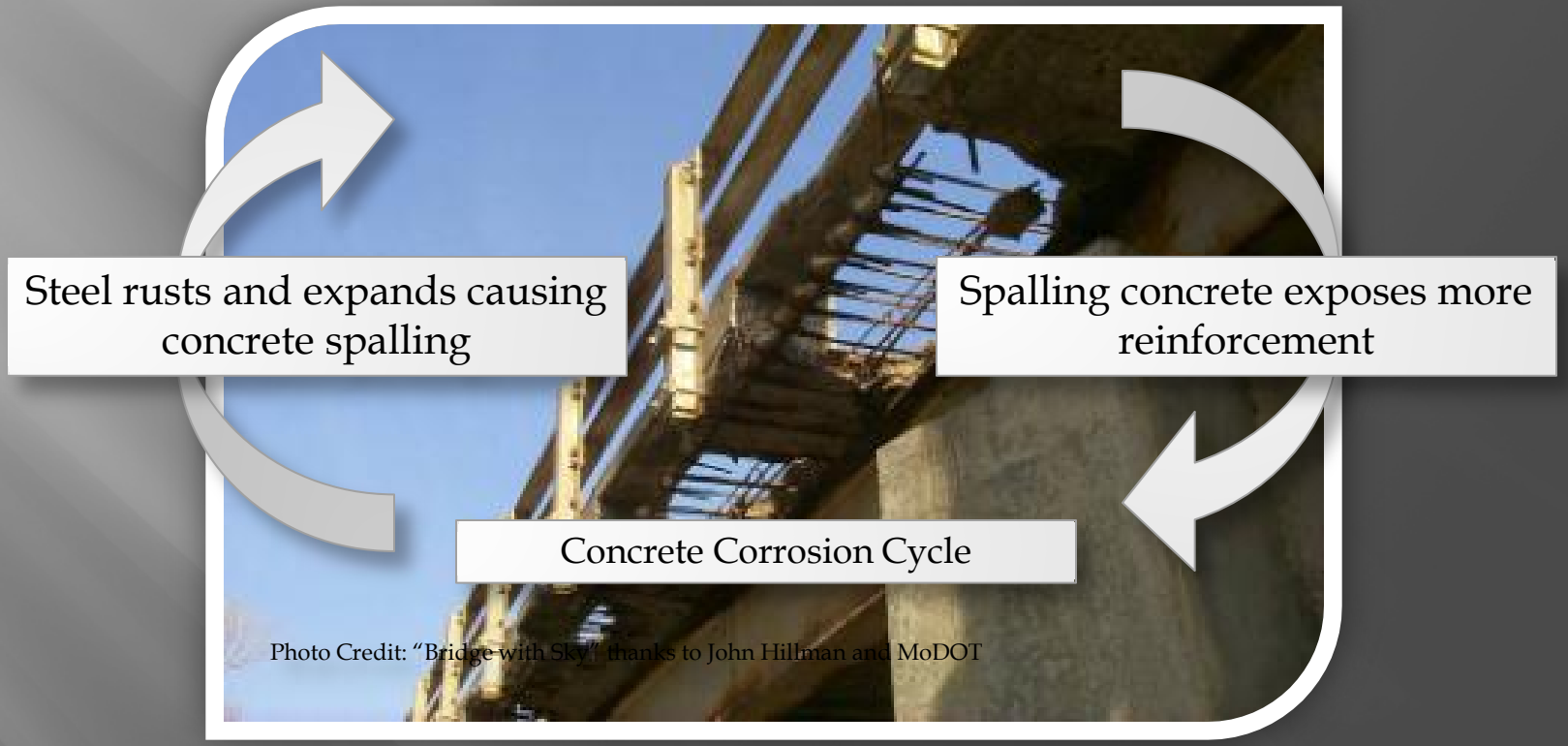
Confined concrete demonstrates significant ductility over unconfined

Eliminates need for rebar installation, no steel rebar in superstructure

Enhances concrete performance for safety & structural redundancy

Three Functions of the FRP Arch Tube

3. Environmental protection for concrete



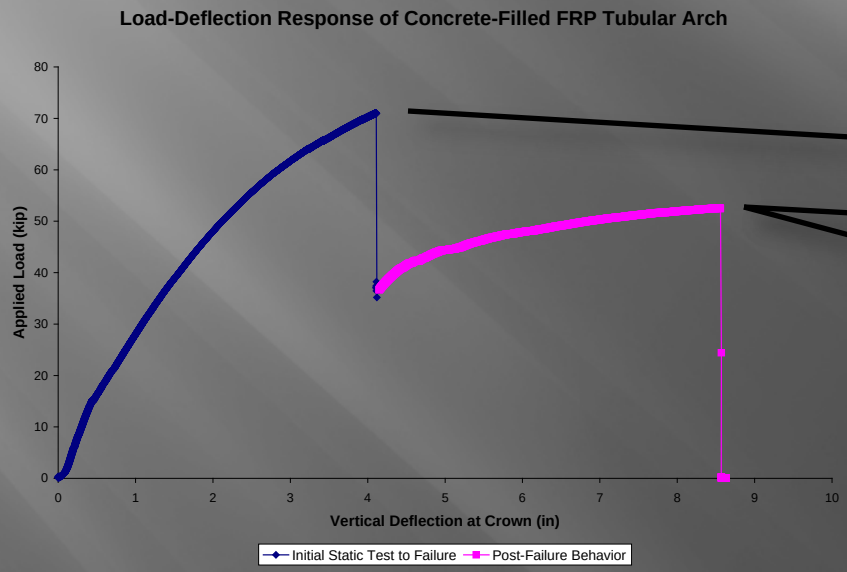
Drastically reduces maintenance requirements

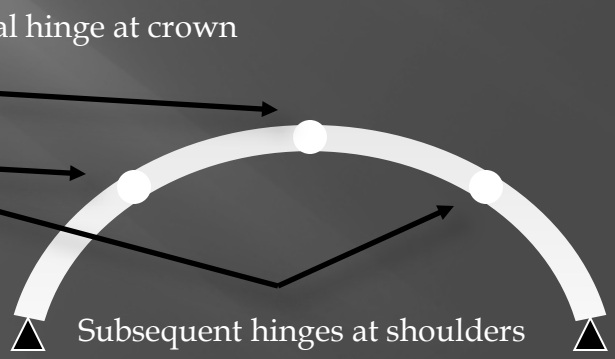
Performance Testing: Arch Testing

Performance Testing: Arch Testing

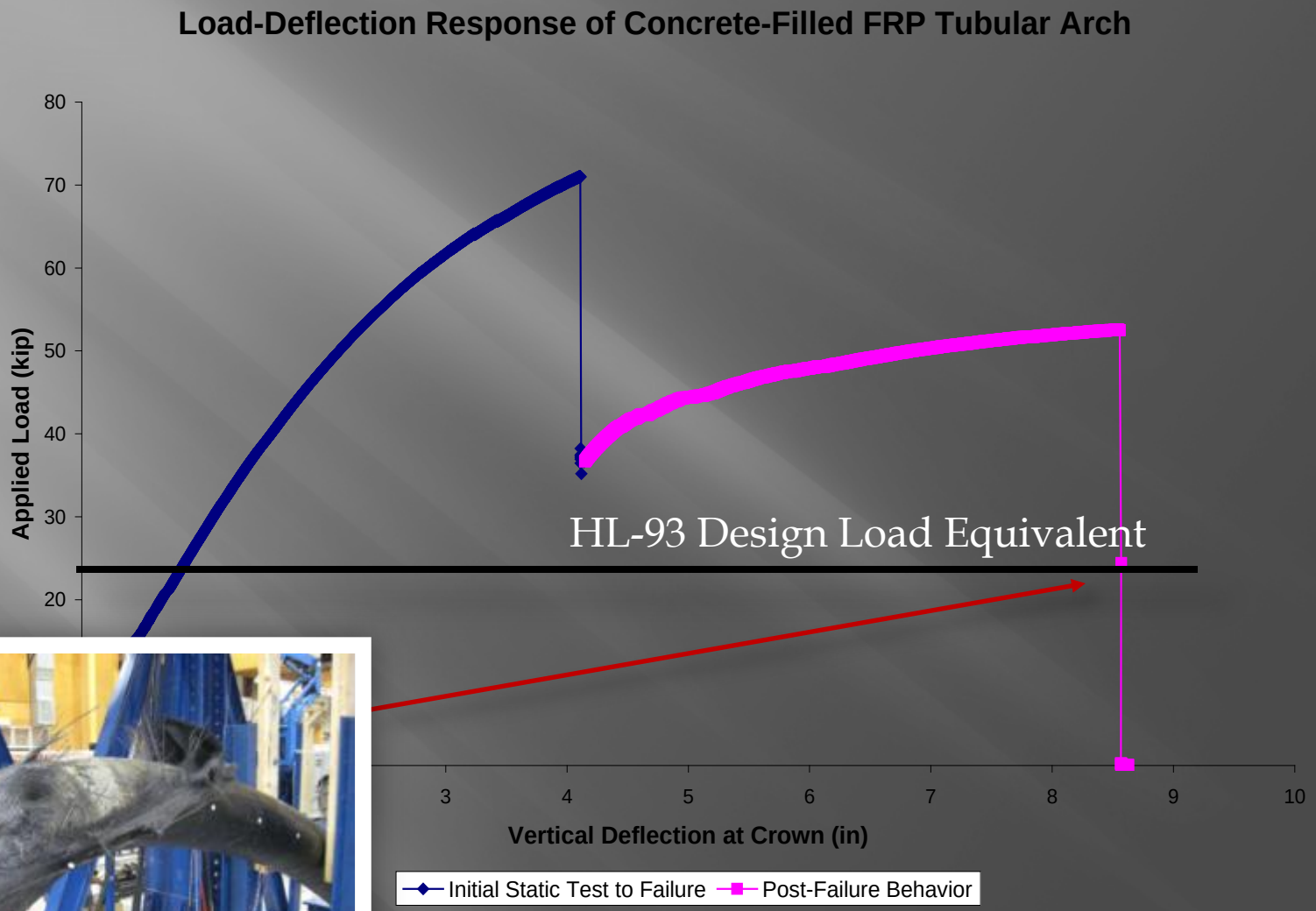
Experimental & Predicted Capacity

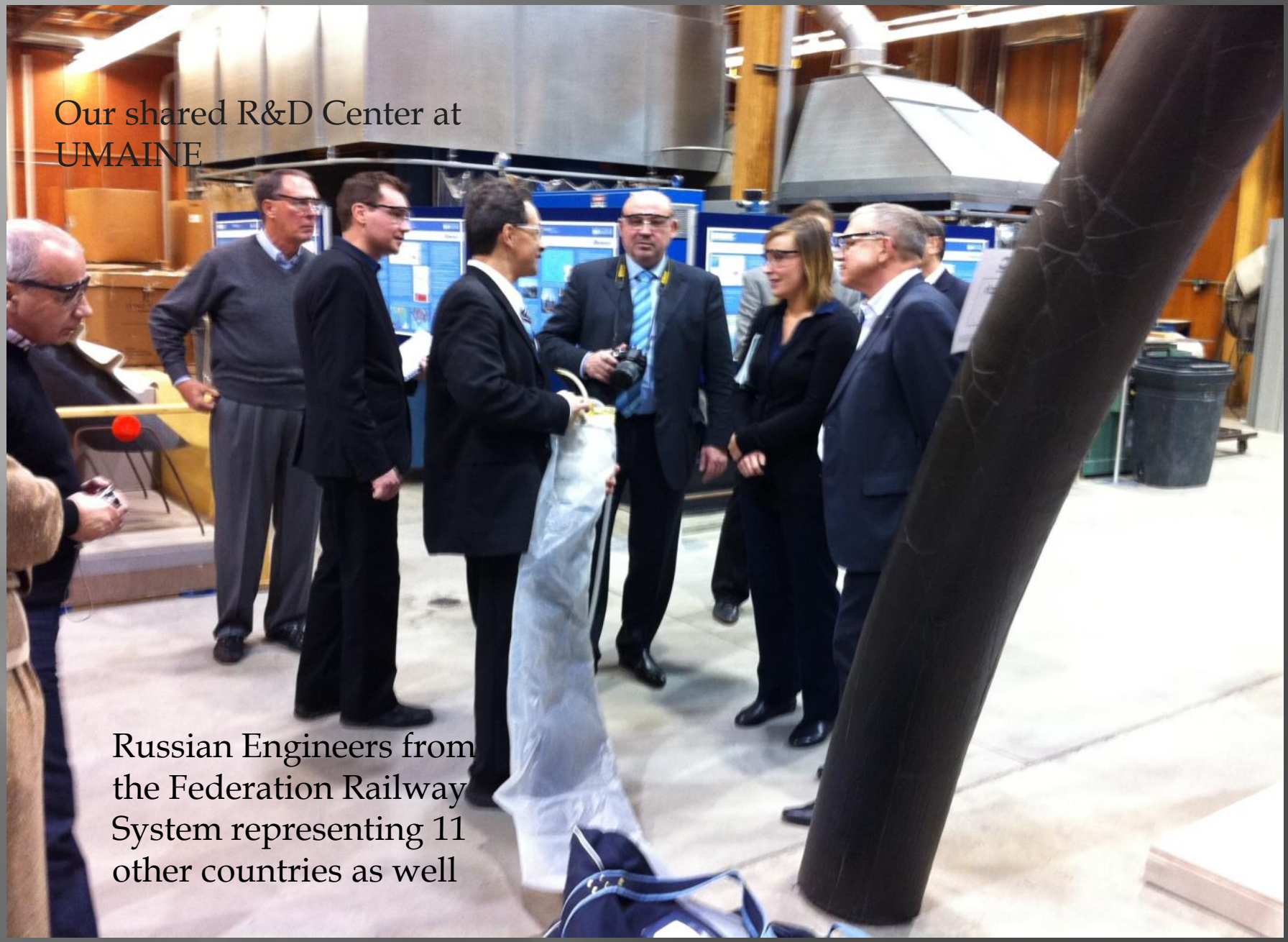
		Failure Load (kip)	COV	No.	Percent Diff.
Initial	Experimental	72.0	2.55%	3	4.14%
	Predicted	69.0	--------	--------	
Secondary	Experimental	57.6	7.75%	3	1.10%
	Predicted	57.0	--------	--------	



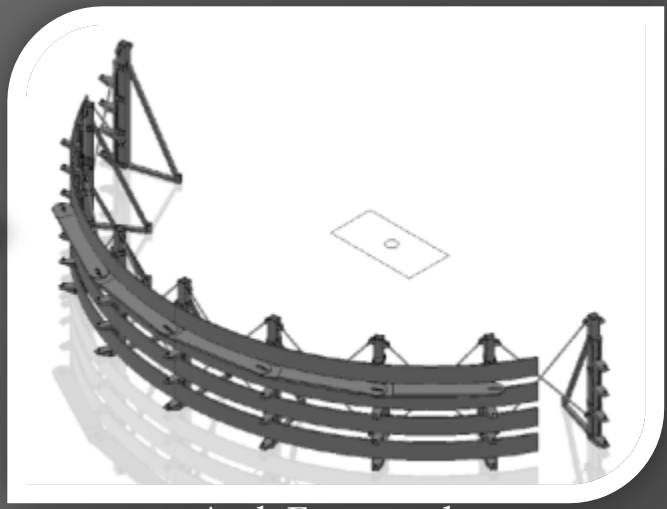


Performance Testing: Arch Testing




Our shared R&D Center at UMAINE
Russian Engineers from the Federation Railway System representing 11 other countries as well

Composite Arch Production Process



Arch Formwork

1. *Tubes assembled/packaged*
2. *Inflate tubes*
3. *Bend around arch form*
4. *Infuse with resin*

Within hours, arches can be removed from form for installation


ROAD CLOSED TO THRU TRAFFIC
DETOUR
TRANSCRAFT EAGLE
OVER SIZE LO

Arch delivery/unloading

- AIT's arches arrive on site ready for installation
- Can be unloaded quickly with hand labor

M 25 Harbor Beach

M 25 Harbor Beach

M 25 Harbor Beach

M 25 Harbor Beach

M 25 Harbor Beach

Arch Concrete Filling

- Filled with Self Consolidating Concrete (SCC)
- Simple procedure, no rodding/vibration required
- AIT provides standard specifications for concrete mix

Pumping concrete into arches

Funnel boxes direct flow, prevent overflow

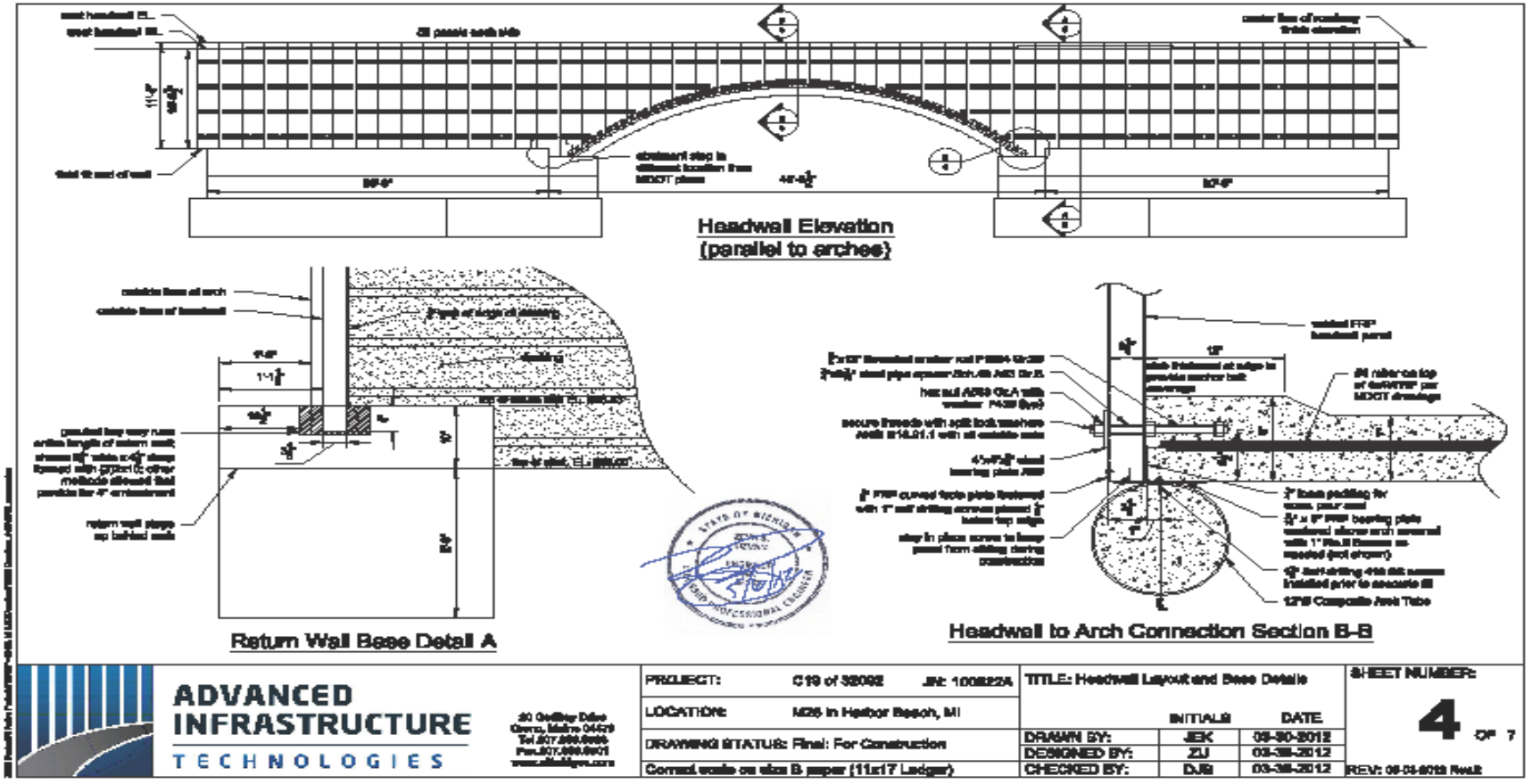
A Note on Self Consolidating Concrete (SCC)

- SCC is a concrete that uses High Range Water Reducers (HRWR), or superplasticizers, to achieve high *flowability*

- In our mix we also include
  - Hydration Stabilizer (retarder)
  - Shrinkage Compensating Admixture (SCA)
  - 3/8" pea stone aggregate

M 25 Harbor Beach

M 25 Harbor Beach



M 25 Harbor Beach

M 25 Harbor Beach

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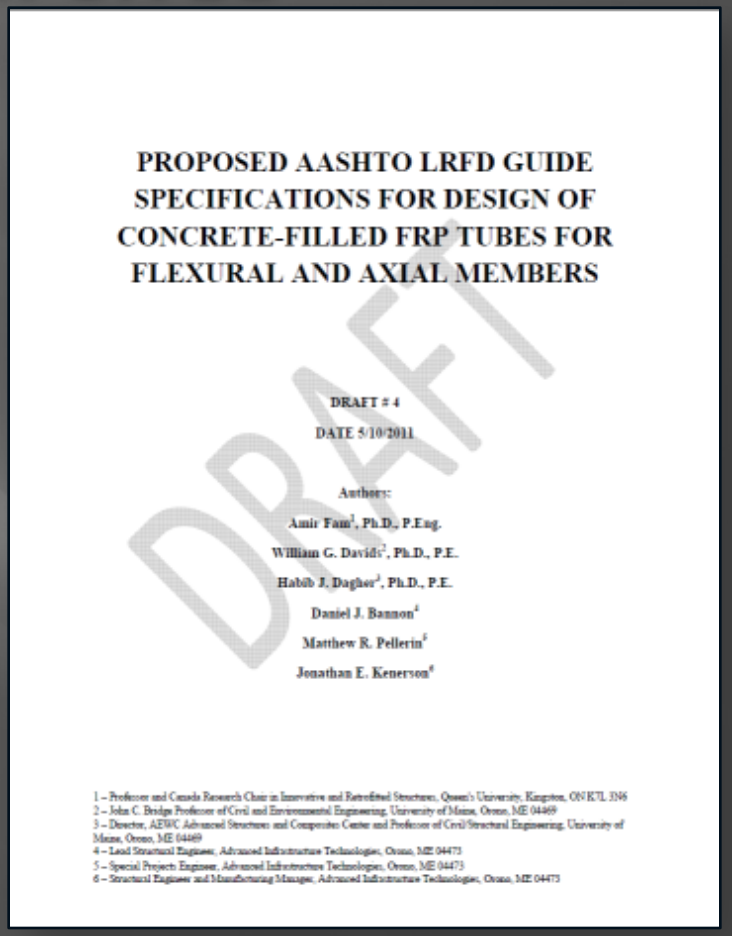
M 25 Harbor Beach

Design of Concrete-Filled FRP Tubular Arches

- *Proposed AASHTO LRFD Guide Specifications for Design of Concrete-Filled FRP Tubes for Flexural and Axial Members*
- Closed-form, simplified method for design of Concrete-Filled FRP Tubes (CFFT's)
  - Bending (φMn), Axial (φPn) , Shear (φVn)
  - Combined Axial and Bending (interaction diagrams)
  - Connection detailing
- Generic in nature – applies to all CFFT's
- Presented to AASHTO's T-6 (FRP) Committee in May 2011
- T-6 plans to put forward for ballot to SCOBS in July 2012



PROPOSED AASHTO LRFD GUIDE SPECIFICATIONS FOR DESIGN OF CONCRETE-FILLED FRP TUBES FOR FLEXURAL AND AXIAL MEMBERS

DRAFT

DRAFT # 4

DATE 5/10/2011

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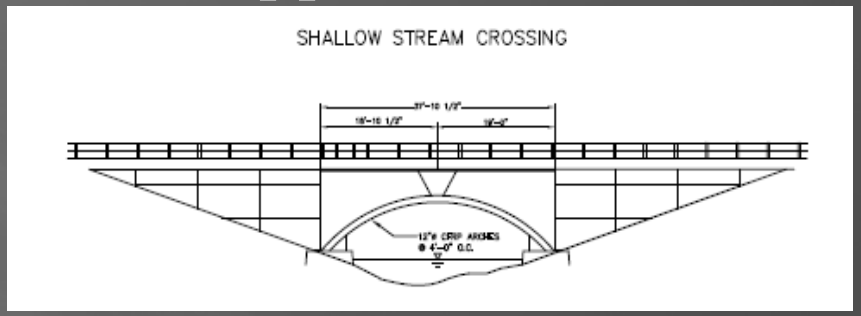
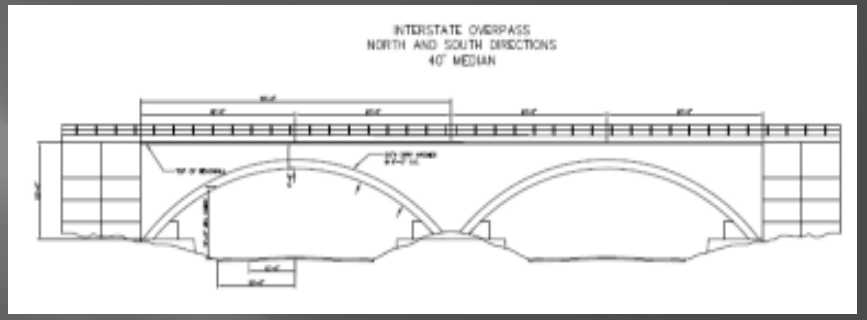
Design Options – Numerous Applications

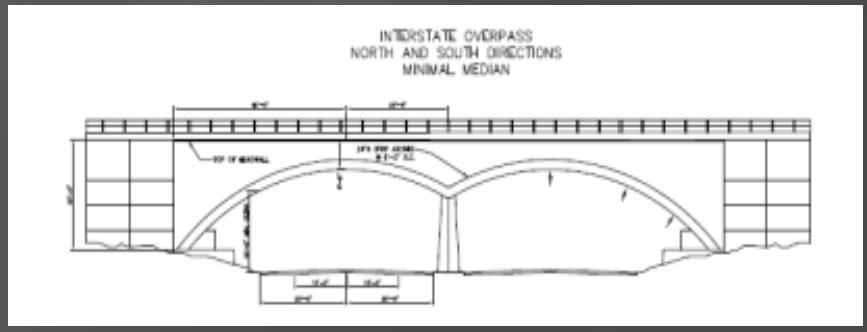
Highly Customizable Geometries

Spans up to 75’

- Single or Multiple Spans
- Skewed designs
- Standard geometries or customized for specific sites
- Deep soil cover (45’ and greater)
- Water/stream crossings, Roadway overpass/underpass, Railway, Pedestrian, Tunnels



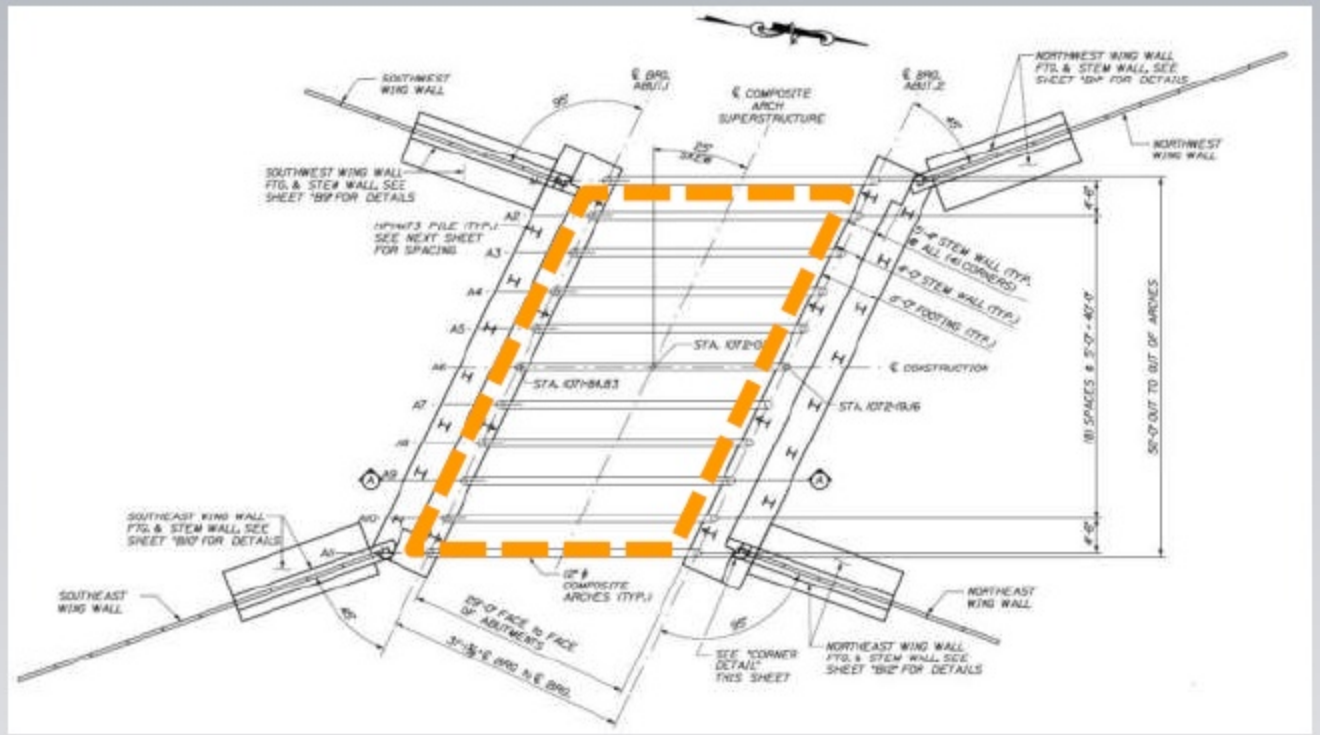




Inexpensive, Quick Installation, Long-term Reliability

Save on Skew – AIT Arch Advantages

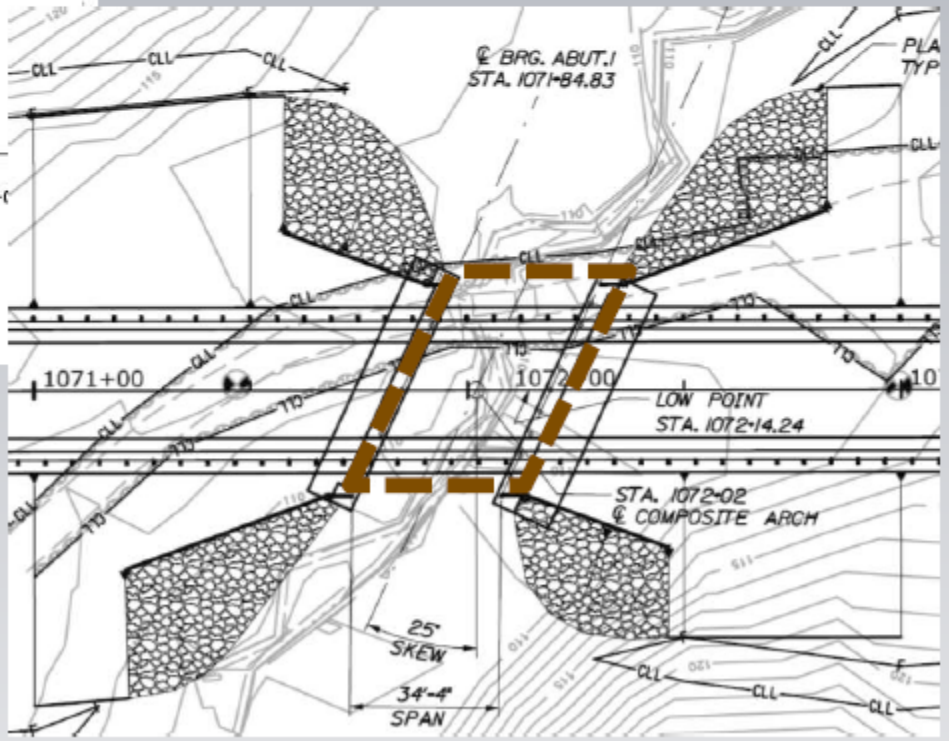
- Orienting the arches and headwalls parallel the roadway
- Reduce total footprint of structure
  - Both width or span
- Reduce or eliminate right-of-way impacts
- Soften horizontal curves in the roadway alignments

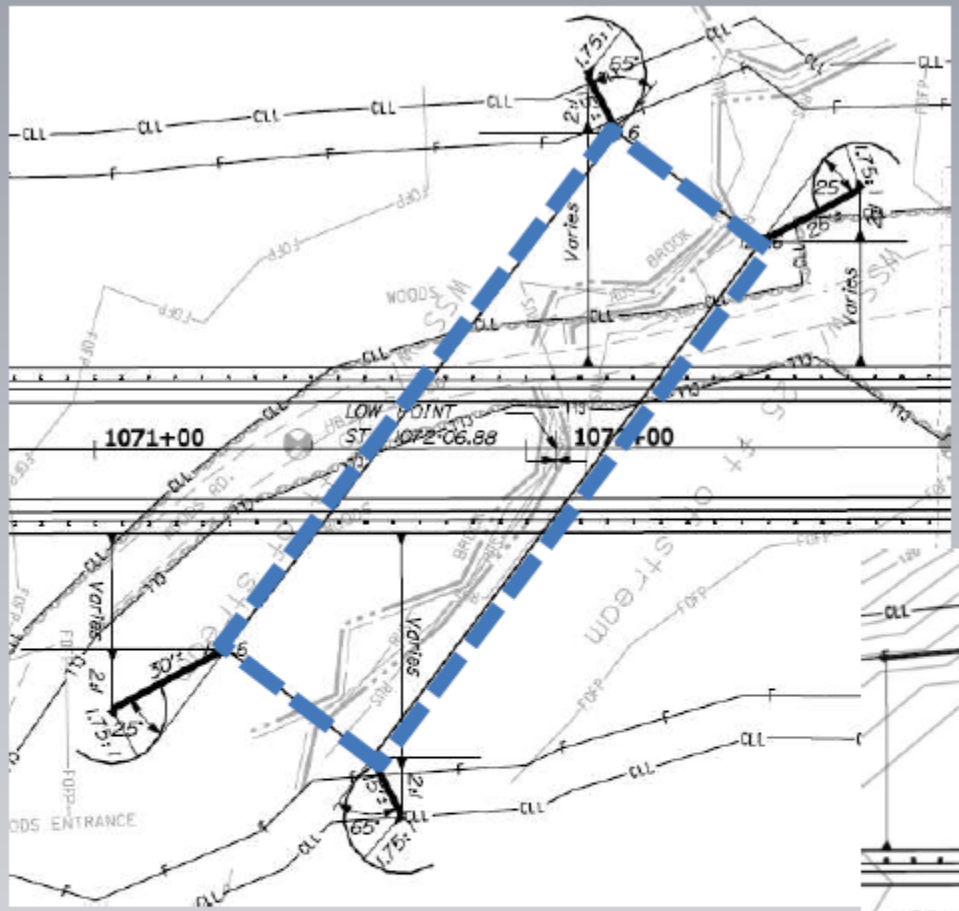


Ellsworth Maine -- Maine DOT Skew Bridge Example

38% footprint reduction compared to precast concrete

Option B (Chosen) – AIT Arch Bridge: Skewed Alignment (~1775 sq. ft.)





Option A Initial Design– Precast Concrete Arch: Square Alignment (~2870 sq.ft.)

Skewed Bridges -- AIT Arches Savings Example

Benefits from our ability on skews:

- Reduced superstructure area
- Reduced substructure length
- Less earthwork
- Less right-of-way impact
  - Less legal issues
  - Less permitting issues
- Less environmental impact
  - Simpler permitting process
- Ability for staged construction

40 foot Span Bridge		
Reduction in Area, Skewed vs. Square		
Skew Angle (degrees)	2 - Lane Bridge	4 - Lane Bridge
10^0	13%	9%
15^0	19%	13%
20^0	23%	16%
25^0	26%	18%
30^0	28%	20%
35^0	30%	22%
40^0	31%	22%
45^0	31%	23%
50^0	31%	22%
55^0	30%	22%
60^0	28%	20%
65^0	26%	18%
** call for more detail on specific		

Design Options - Headwalls

Multiple options to meet the Engineering, Economic, and Aesthetic requirements of the site

- FRP Panel Walls
  - MSE or Through-Tied Configurati
  - Compatible with skewed bridges
  - Lightweight, easy to install
  - Durable, and cost competitive

- Concrete – Precast or CIP
  - MSE, Through-Tied, or Gravity
  - PC Panel, PCMG Units, Cast-in-place
  - Versatile design options
  - More conventional aesthetic

Design Options - Aesthetics

Architectural facades, details, rails, can be incorporated for improved aesthetic qualities

Images courtesy of various arch bridge suppliers


Tom Frost Memorial Bridge

Summary and Quick Facts on CFFT Arch Bridges

Innovative Product Application

- Rapid fabrication
- Hybrid composite-concrete system improves material performance
- Steel free superstructure
- Reduced carbon footprint

Performance Tested

- Design/tested to exceed AASHTO load requirements
- Superior redundancy – safe system
- Corrosion resistant materials
- Field load testing indicates even greater levels of safety

Cost Effective and Fast Installation

- Light weight product– reduces equipment transportation needs
- Erected with a small crew, no skilled labor
- Performs up to 2x lifespan of conventional materials
- Accelerated Bridge Construction
- Rapid design, fabrication, and delivery

CONCRETE BRIDGES - CONCRETE SAVINGS.

Advanced Infrastructure Technologies

- Product
  - AIT designs & manufactures FRP composite tubes for construction
  - Ability to supply a complete engineered bridge system
  - Packages: FRP arches + composite decking, modular FRP headwalls
- Structural Design
  - AIT's engineers design the composite arch bridge superstructure
  - Can design the bridge substructure, internally or with consultants
  - Optimization to maximize efficiency of structure
  - Local manufacturing and installation
- Carbon Fiber Bridge Superstructures
  - Safe, Fast, Designed with Redundant Strength Characteristics

Concrete Bridges Concrete Savings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