Hillman Composite Beams

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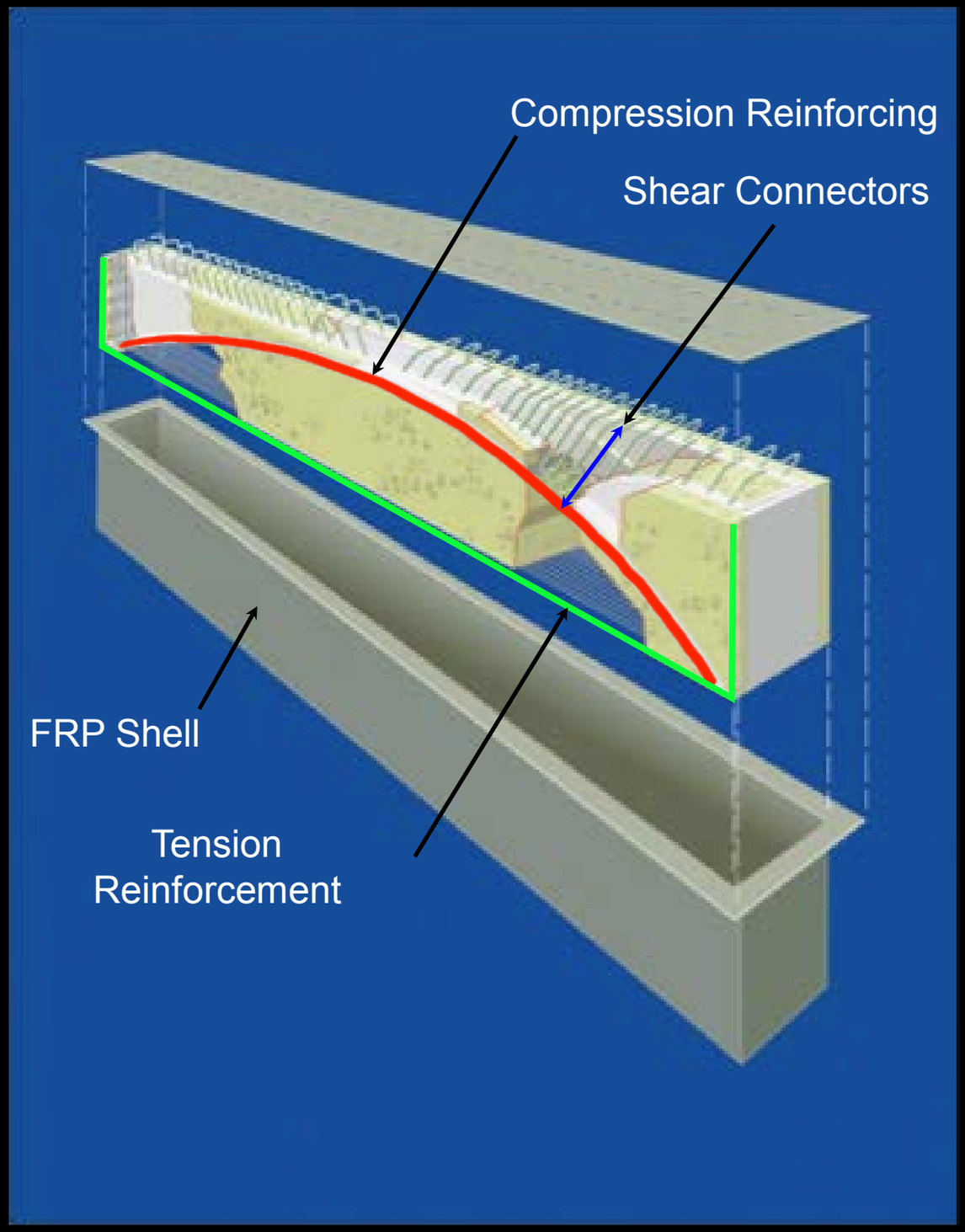
ACMA – Bristol, RI June 2016

No HCBs were harmed in the making of this video!

HCB

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



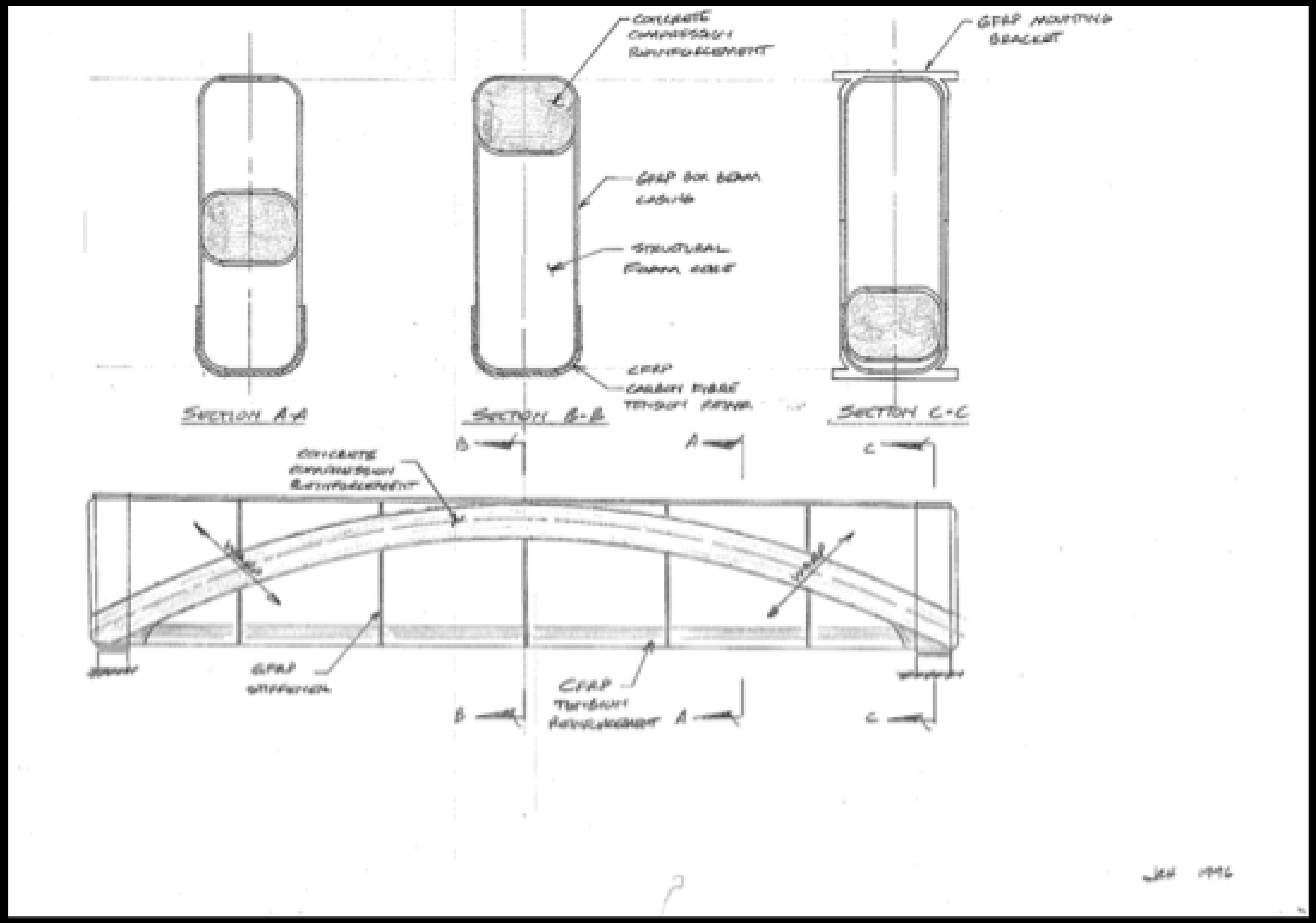
Benefits of HCB Technology

- Lighter Weight (reduces foundations)
- Reduced Carbon Footprint
- Optimization of every material used
- Sustainable (greater corrosion resistance)
- Simplicity in Design, Fabrication and Erection
- Provide the public with “SAFER” bridges

The Benefits of HCB

- Reduce the burden of infrastructure maintenance on future generations

From Concept - 1996

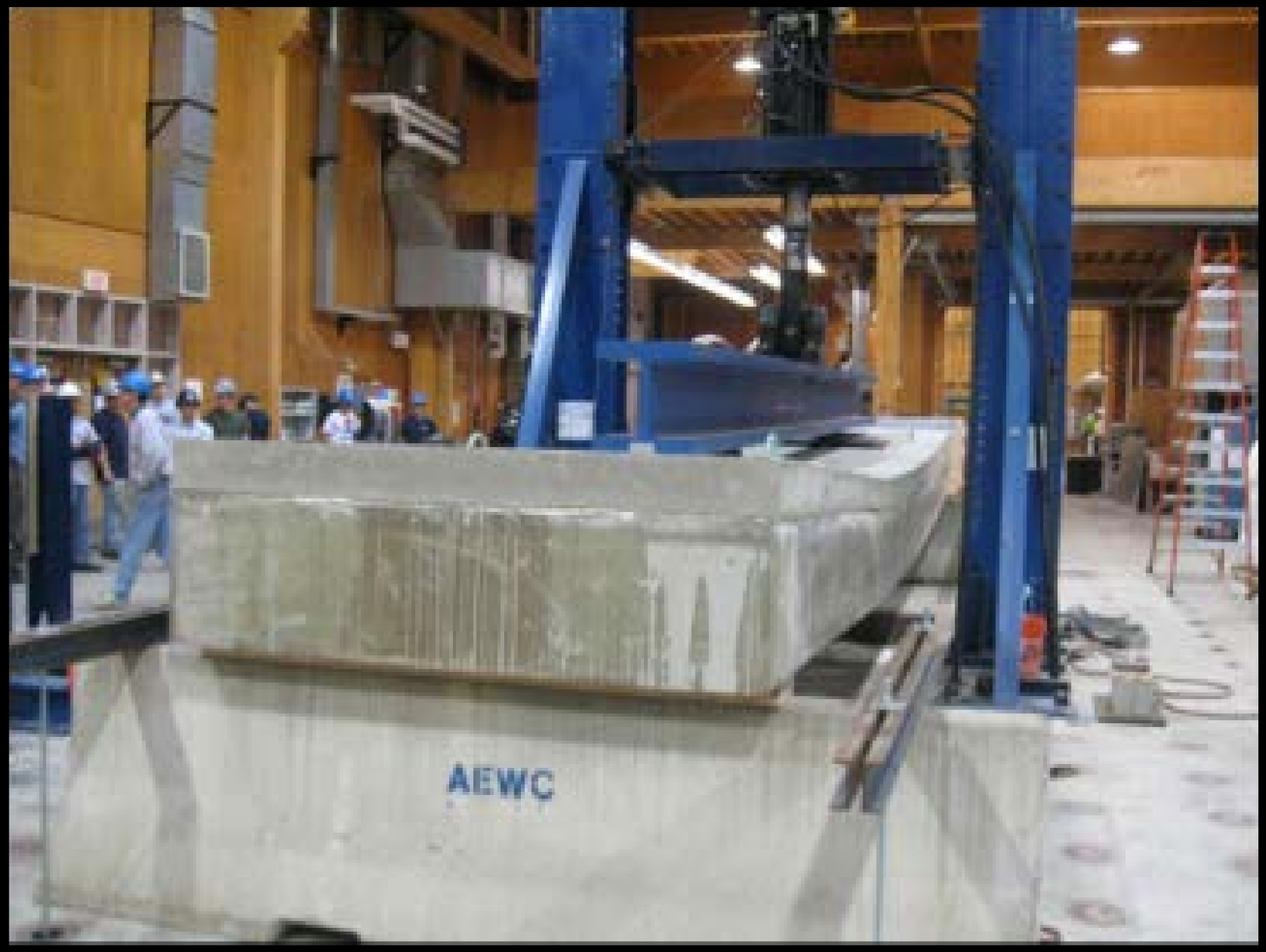


Original Sketches

To Reality - 2007

1st HCB Installation - TTCI - Pueblo, CO
9.1m (30 ft.)

Laboratory Testing



- Inventory Rating = 2.68 (HS-54)
- Operating Rating = 3.47 (HS-69)

Ultimate Capacity of 30 ft. RR Bridge

2.6 x Union Pacific Big Boy

High Road Bridge - Lockport Township, IL
18m (57 ft.) Span - August, 2008

Route 23 Bridge, Cedar Grove, NJ
9.4m (31 ft.) Span - October 2009

Knickerbocker Bridge - Boothbay, ME
165m (540 ft.) - 8 spans @ 21.3m (70 ft) - Oct. 2010

B0410 - Lockwood, MO - July 2012
32.3m (106 ft.) span w/1524mm (60 in)
HCB Double Web Box

Standard Railroad Bridge Construction

1st HCB Railroad Revenue Service - Fernie, BC
10m (33 ft.) - Canadian Pacific Railway, Oct. 2014

I know the HCB works But!

- How do I know the HCB is properly filled?
- What if the strands are damaged?
- What happens if a truck hits the bridge?
- How am I going to repair an HCB?

Standard HCB Construction

How do I know the HCB is properly filled?

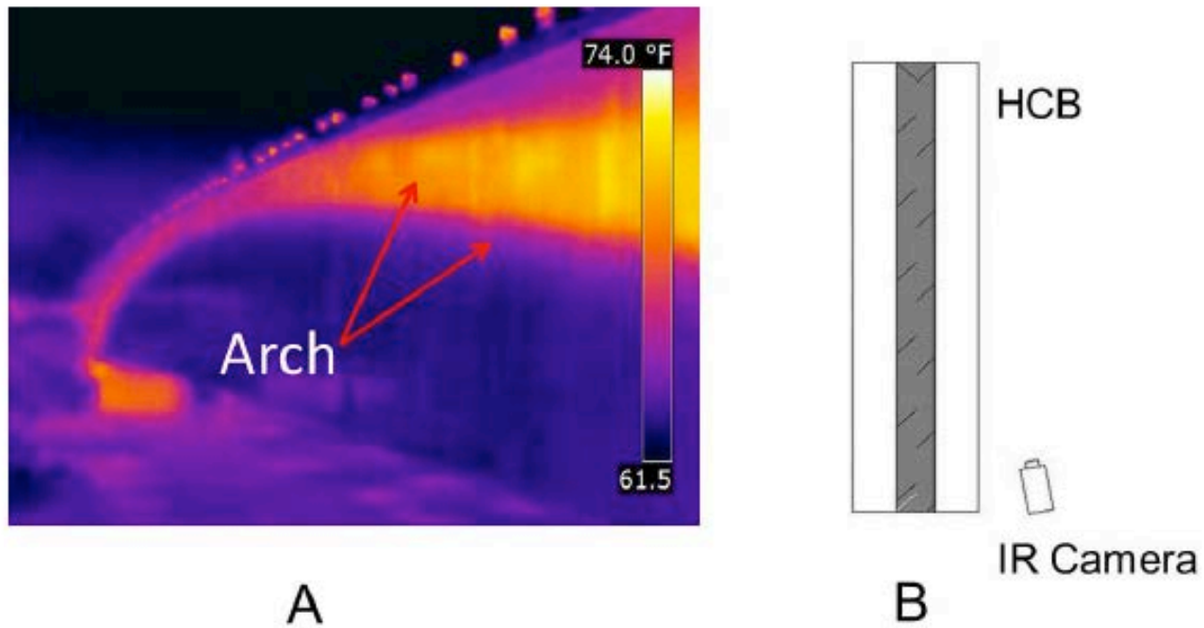
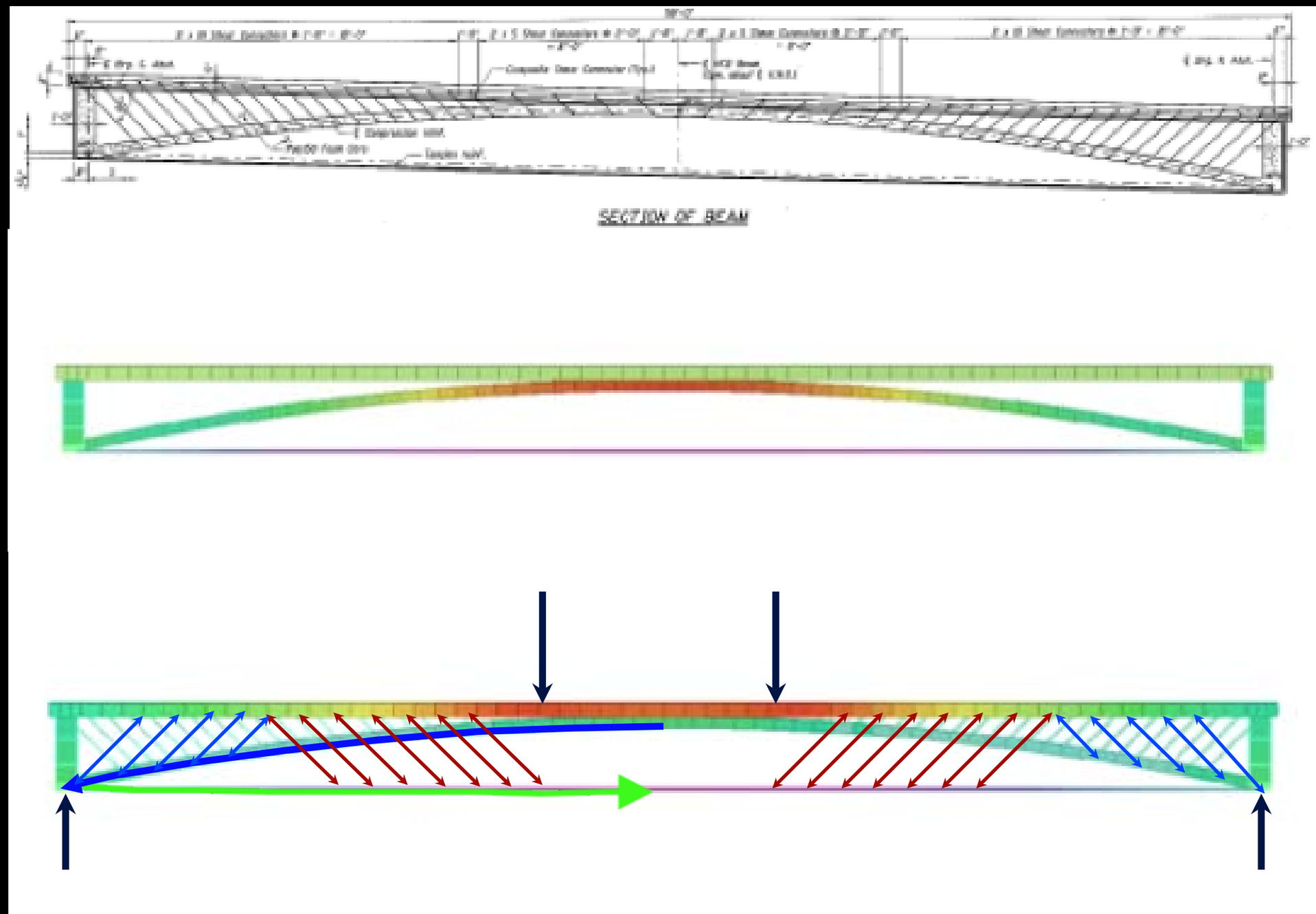


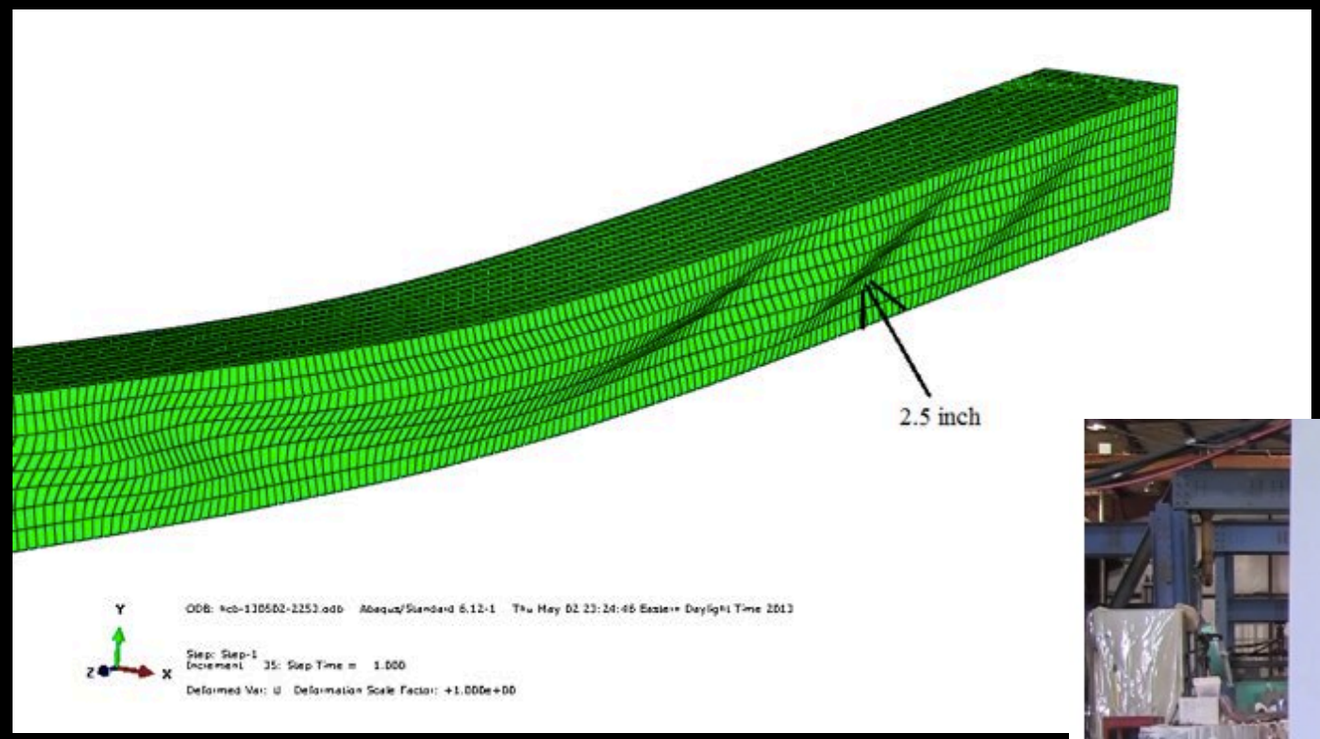
Figure 4-10 (A) IR Picture of HCB Length in B0478 and (B) Diagram of Corresponding Camera Location

Figure 4-7 Mock-Up Beam (one day after pour)



Basic Structural Behavior of an HCB

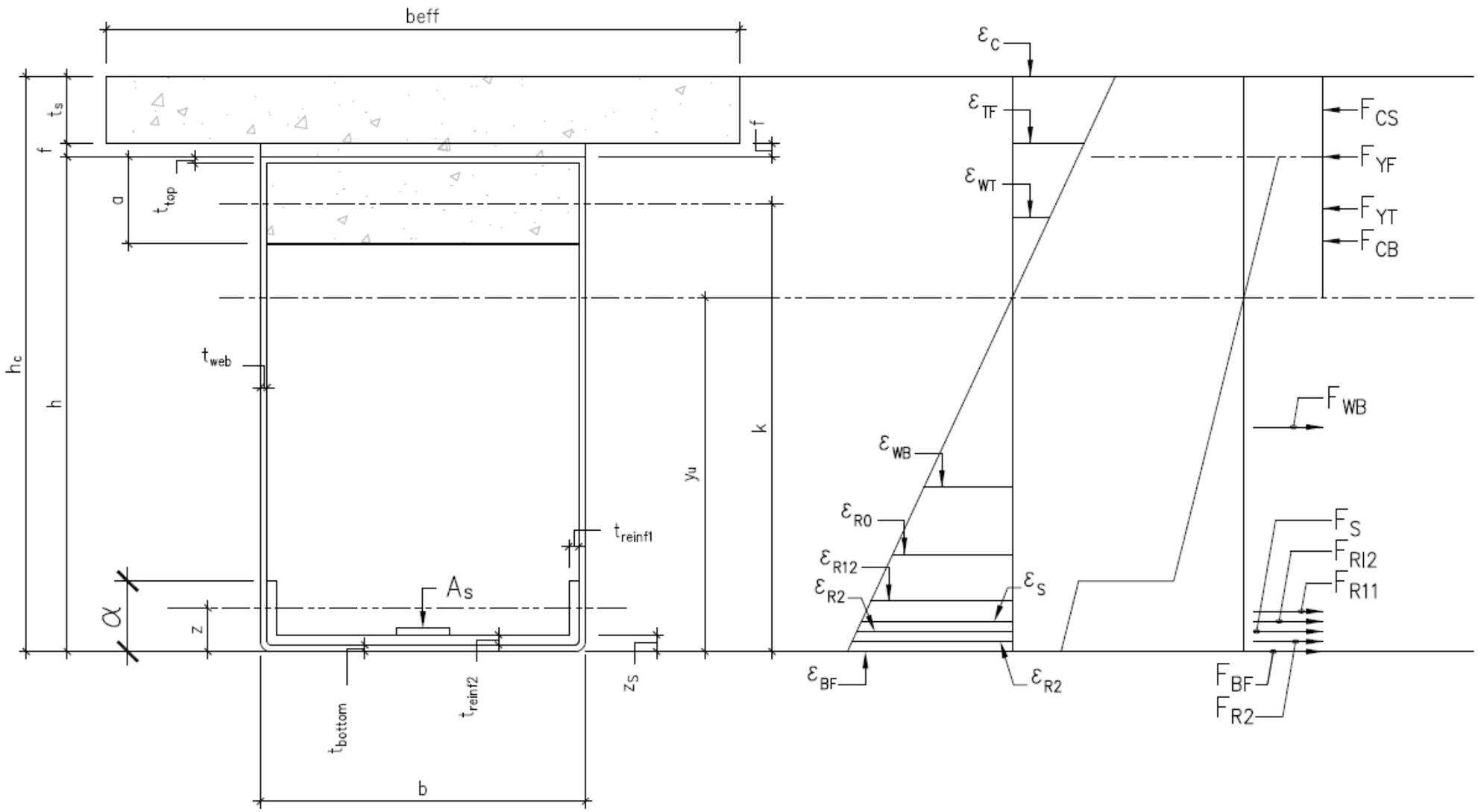
HCB – Shear Behavior



Images courtesy of Virginia Tech

Tension Field Action - (TFA)
Experimental vs. ABAQUS

HCB – Bending Behavior



Strain Compatibility - Force Equilibrium

Solving for Neutral Axis

Once all of the horizontal force components in the HCB are known, the exact location of the plastic neutral axis can be found directly from force equilibrium on the section with the simple equation:

$$\Sigma F = F_{CS} + F_{CB} + F_{TF} + F_{WT} + F_{WB} + F_{BF} + F_{R2} + F_{R11} + F_{R12} + F_s = 0$$

Knowing all of the force equations for each component and normalizing each component to the properties of the FRP shell, it is now possible to return to the force equilibrium equation and solve directly for the plastic neutral axis using the following equation:

$$\bar{y}_u = \frac{\left[bt_{top}h + t_{web}h^2 + \frac{0.85h_c(f'_{CS}t_s b_{eff} + f'_{CB}ab)}{E_w\epsilon_c} + 3n_R t_{Reinf1}g^2 + n_s z_s A_s\right]}{\left[bt_{top} + 2t_{web}h + \frac{0.85\left(f'_{CS}t_s b_{eff} + f'_{CB}ab\right)}{E_w\epsilon_c} + bt_{bottom} + n_R bt_{Reinf2} + 2n_R t_{Reinf1}g + n_s A_s\right]}$$

What if the strands are damaged?

Tides Mill - Colonial Beach, VA - Feb 2013
13.5m (44 ft.) span 45 degree Skew 21 in. HCB

- $C=T$
- $C=0.85f_c'ab$
- $\Phi M_n=\Phi C(d-a/2)$

What happens if a truck hits an HCB?

4.5 Ton concrete mass accelerated to produce no less than 100 kJoules of energy at impact

No HCBs were harmed in the making of this video!

Only damage to HCB was cosmetic

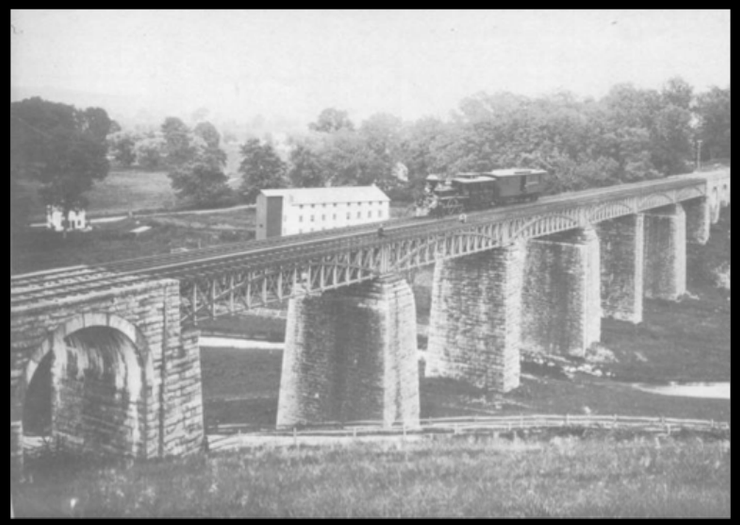
Same test apparatus – traditional building material

How am I going to repair an HCB?

FRP bonds to FRP better than to concrete

What do these 3 objects have in common?

What do these 3 objects have in common?



“Thomas Jefferson’s views on patents should not surprise those who are aware of his views about democracy and equality. He opposed patents strongly because he considered it an unfair monopoly. He would later become more in favor when he discoved the power they had to encourage invention.” Jefferson was subsequently instrumental in helping to pass the Patent Act of 1790.

Thomas O.
Jewett

Almost every great paradigm shift in the evolution of bridge engineering resulted from a patented intellectual property, including:

- Trusses for Wooden Covered Bridges
- Iron & Steel Trusses (catalogue bridges)
- Drawn iron for wire ropes
- Spinning mechanisms for suspension bridges
- Reinforced concrete
- Almost every type of movable bridge
- Prestressing & Post-tensioning systems

“The bucolic covered bridge; the ethereal appearance of prefabricated metal trusses thrown across numerous streams; traditional arch and girder forms appearing in the garb of a new material, reinforced concrete – these altogether elicited more than eight hundred patents during the first century of the U.S. Patent Office.”

Kemp, Emory, L. *American Bridge Patents – The First Century 1790-1890,* West Virginia University Press, 2005

Some of the more Famous Patented Metal Trusses of Iron & Steel "Catalogue Bridges"

- Howe
- Pratt
- Whipple
- Warren
- Murphy
- Fink

“These “catalogue bridges” appeared on the scene after the Civil War and became a ubiquitous feature on the American landscape. Arguably, they had a more profound effect on the development of the American highway system than the justly famous landmark bridges by luminaries such as John. A. Roebling, James B. Eads, Theodore Cooper, or James Finley.”

Emory L. Kemp

If you're going to lose sight of land, which boat are you going to chose?

The Traditional “Least Cost” Materials

When it comes to Safety

Performance is more important than tradition!

They don’t build them like they used to!
Why do we?

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