Building Better Bridges with Hybrid-Composite Beams

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October 26, 2010

What is Innovation?

To make something better through positive change.

Why Innovate?

"What's Money? A man is successful if he gets up in the morning and goes to bed at night and in between does what he wants to do."

Bob Dylan

Things you get to do as an innovator

- Engineer
- Scientist
- Patent Attorney
- Proposal Writer
- Fabricator
- Purchasing Agent
- Lab Technician
- Academic
- Contractor
- Accountant
- Public Relations
- Business Man
- Travel Agent
- Therapist

"Failure is easier to accept than success."

"Of course there is no formula for success except perhaps an unconditional acceptance of life and what it brings."

Arthur Rubenstein

The story of HCB (*slightly abridged*)

Before HCB

Dreaming of Innovative Bridges?

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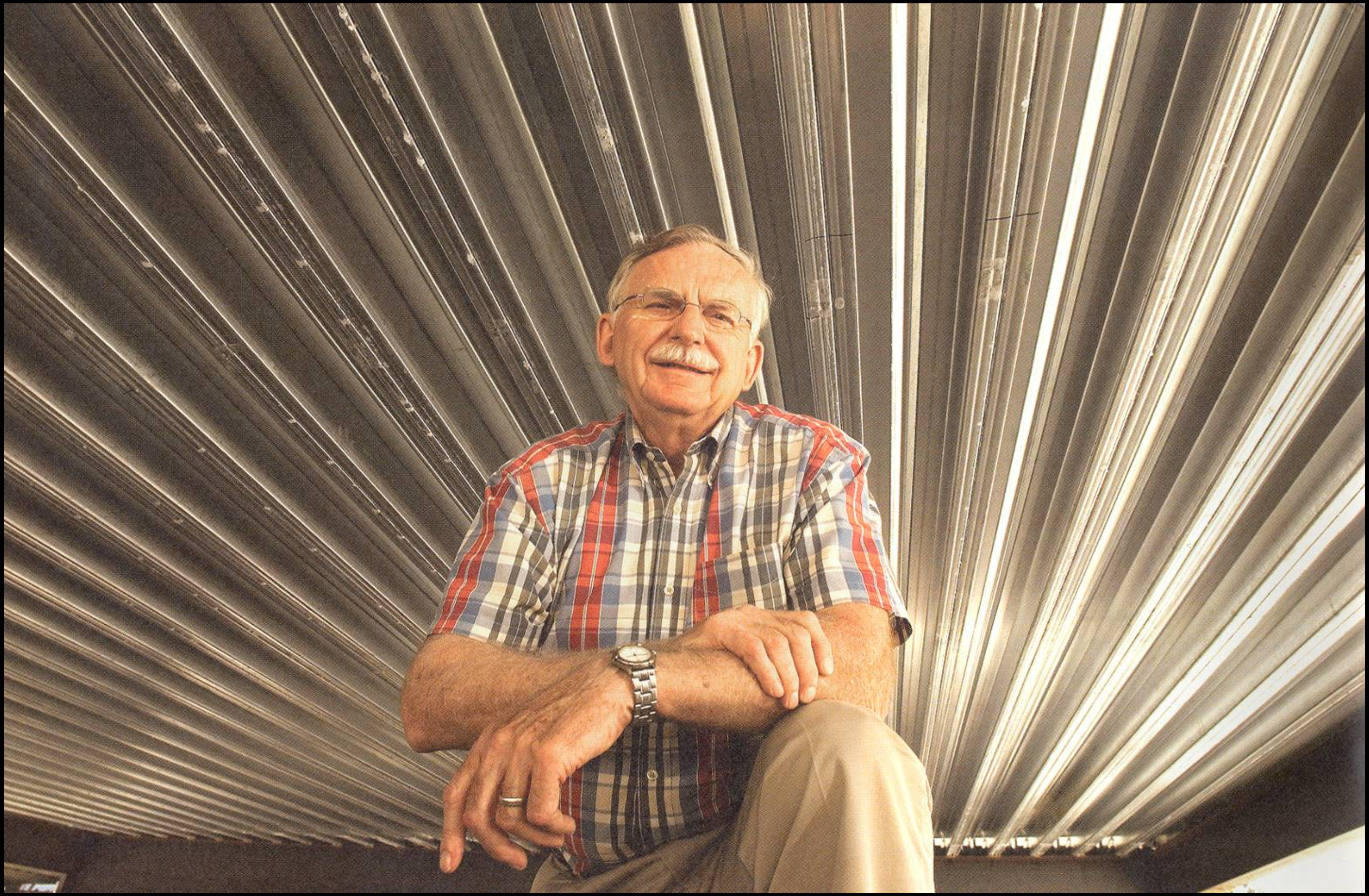
Inventing Floor Systems @VT



Apprentice to Tom Murray

Launching Bridges in Puerto Rico

Apprentice to the Master Jean Muller

Confederation Bridge

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The Beauty of the Arch

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Inventing HCB

US006145270A

United States Patent [19]
Hillman

[11] **Patent Number: 6,145,270**
[45] **Date of Patent: Nov. 14, 2000**

[54] **PLASTICON-OPTIMIZED COMPOSITE BEAM SYSTEM**

[76] Inventor: **John Hillman**, 1521 Lake Ave., Wilmette, Ill. 60091

[21] Appl. No.: **09/065,191**

[22] Filed: **Apr. 23, 1998**

Related U.S. Application Data

[60] Provisional application No. 60/050,612, Jun. 24, 1997.

[51] **Int. Cl.**[7] **E04C 3/02**
[52] **U.S. Cl.** **52/731.1**; 52/737.1; 52/174; 52/223.8; 52/650.1; 52/730.2; 14/6; 14/73; 14/74.5
[58] **Field of Search** 52/87, 174, 223.8, 52/223.11, 263, 650.1, 650.2, 732.1, 730.2, 730.4, 731.1, 731.2, 737.1, 737.6, 738.1, 223.6, 223.9, 223.1; 14/6–7, 73, 73.5, 74.5

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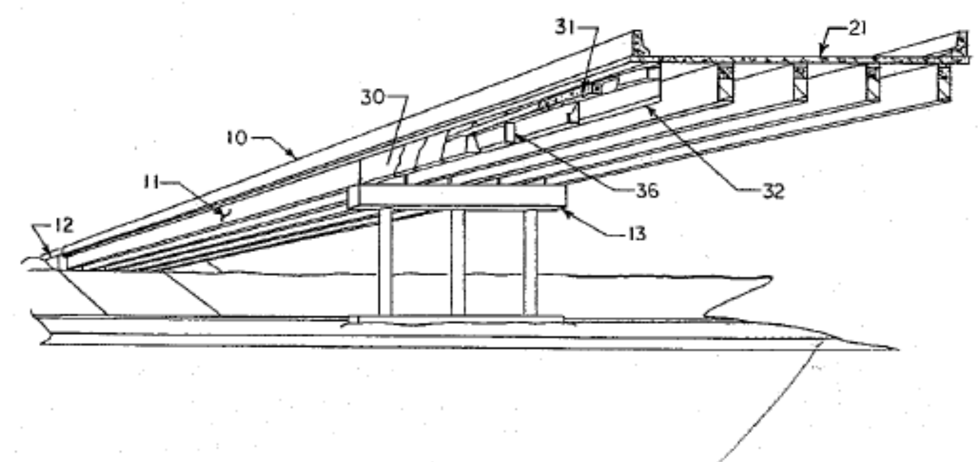
Primary Examiner—Carl D. Friedman
Assistant Examiner—Winnie Yip
Attorney, Agent, or Firm—Marshall, O'Toole, Gerstein, Murray & Borun

[57] **ABSTRACT**

A composite beam system that can be used for the framing system in bridges or buildings and provide enhanced corrosion protection includes a fiber reinforced plastic beam shell with compression and tension reinforcement. The compression reinforcement consists of portland cement concrete which is pumped into a profiled conduit within the beam shell. The conduit for the compression reinforcement is profiled to optimally resist the internal forces in the composite beam for a particular loading. The tension reinforcement consists of carbon, glass or steel fibers anchored by wrapping around the ends of the compression reinforcement. The positioning of the tension reinforcement is optimally designed to equilibrate the internal forces in the compression reinforcement. Each composite beam has a series of internal vertical stiffeners which are perpendicular to the sides of the beam shell. The composite beams can be used in the construction of bridges and buildings using conventional erection techniques. The compression reinforcement can be installed into the beam after it is erected. This results in a very light weight structural member for transportation and erection.

16 Claims, 6 Drawing Sheets



Purpose and Need

- Infrastructure decaying at a rate outpacing rehabilitation
- "40 percent of all bridges are more than 40 years old. When these bridges were constructed, design life was often 50 years."
- "Congestion Relief" is necessary to promote economic growth
- Safety of traveling public at risk

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Limited Service Life

Fundamental Principals of Structural Behavior

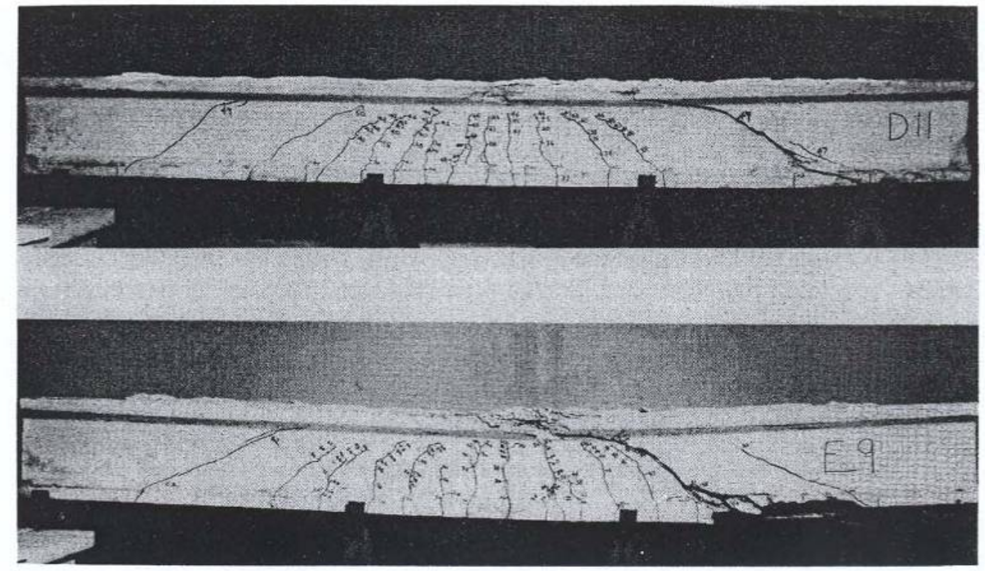
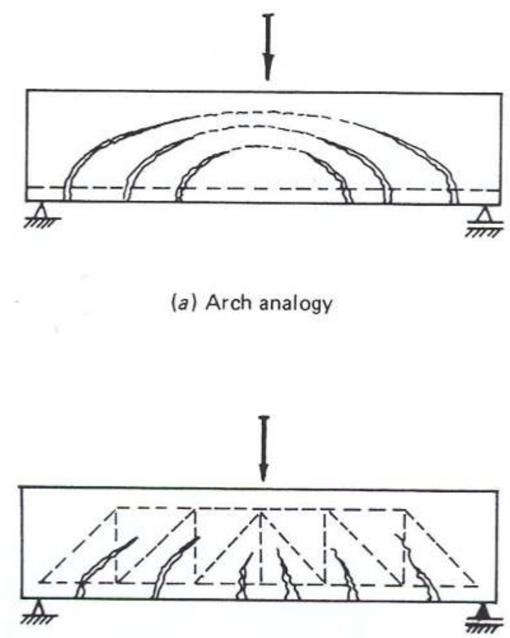


Figure 6.7 Typical shear failure in prestressed beams without web reinforcement. *(Courtesy Prestressed Concrete Institute.)*



(*a*) Arch analogy

(*b*) Truss analogy

Figure 6.8 Typical analogies for shear failure mechanisms.

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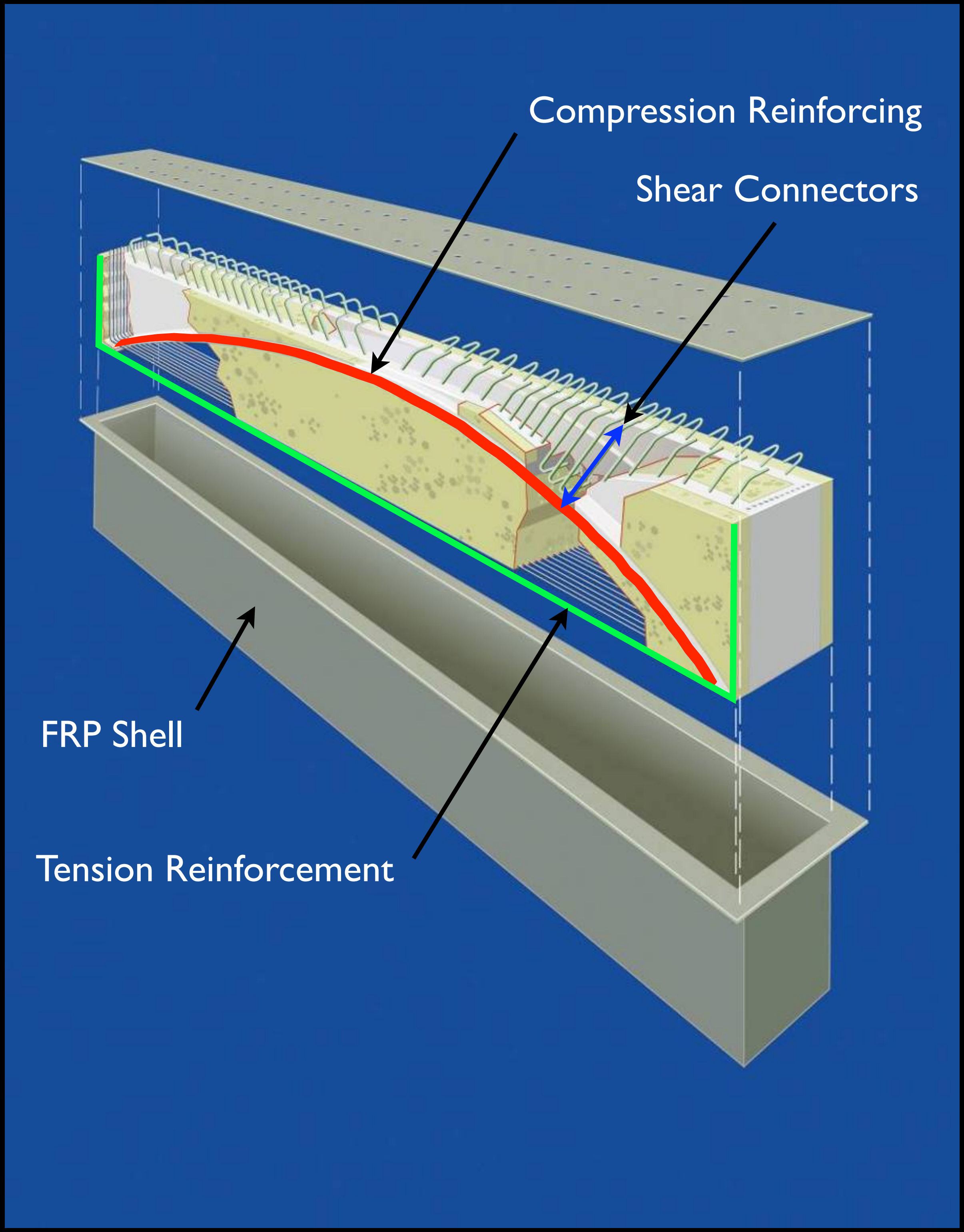
A structural member using several different building materials resulting in a cost effective composite beam designed to be stronger, lighter and more corrosion resistant



Benefits of HCB Technology

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

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The Benefits of HCB

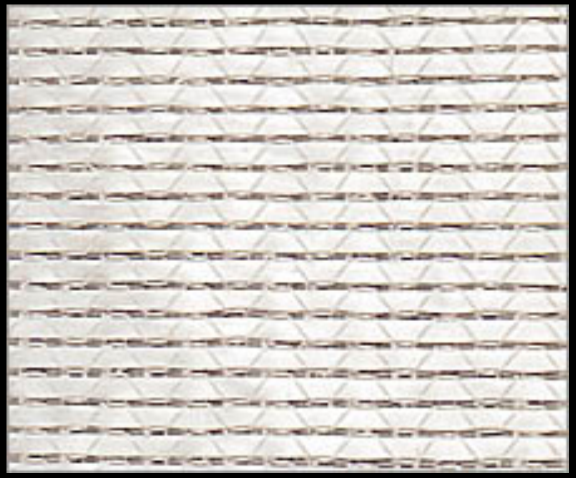
- Reduce the burden of infrastructure maintenance on future generations

Stealing Ideas from the Past

The First Hillman Bridge

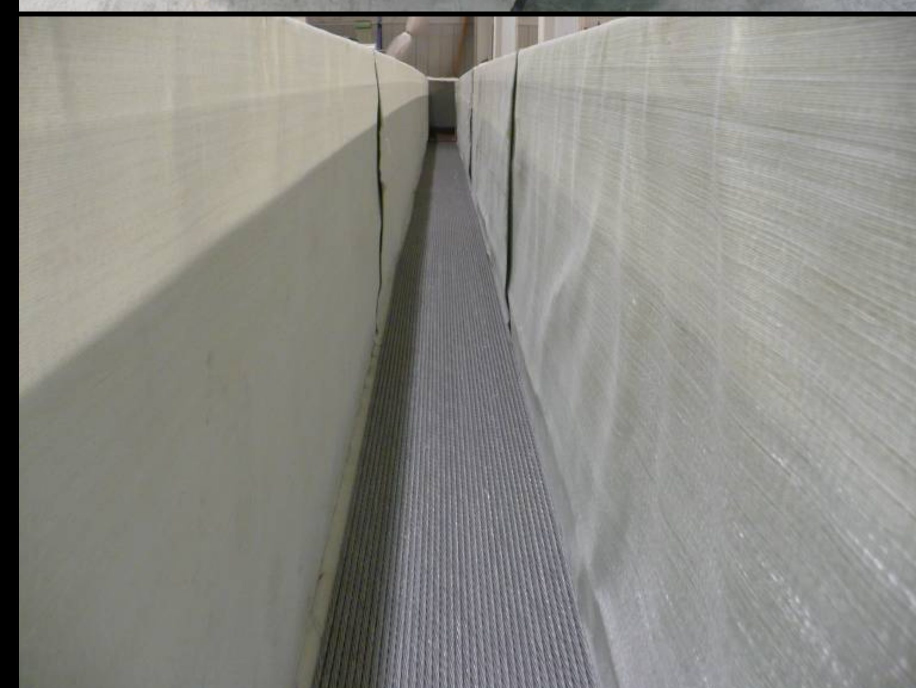
Fiberglass Box (FRP Shell)

- Balanced quad-weave fabric with fibers that are horizontal (0^0), vertical (90^0) and ($\pm$ 45^0)
- infused in an epoxy vinyl ester resin matrix



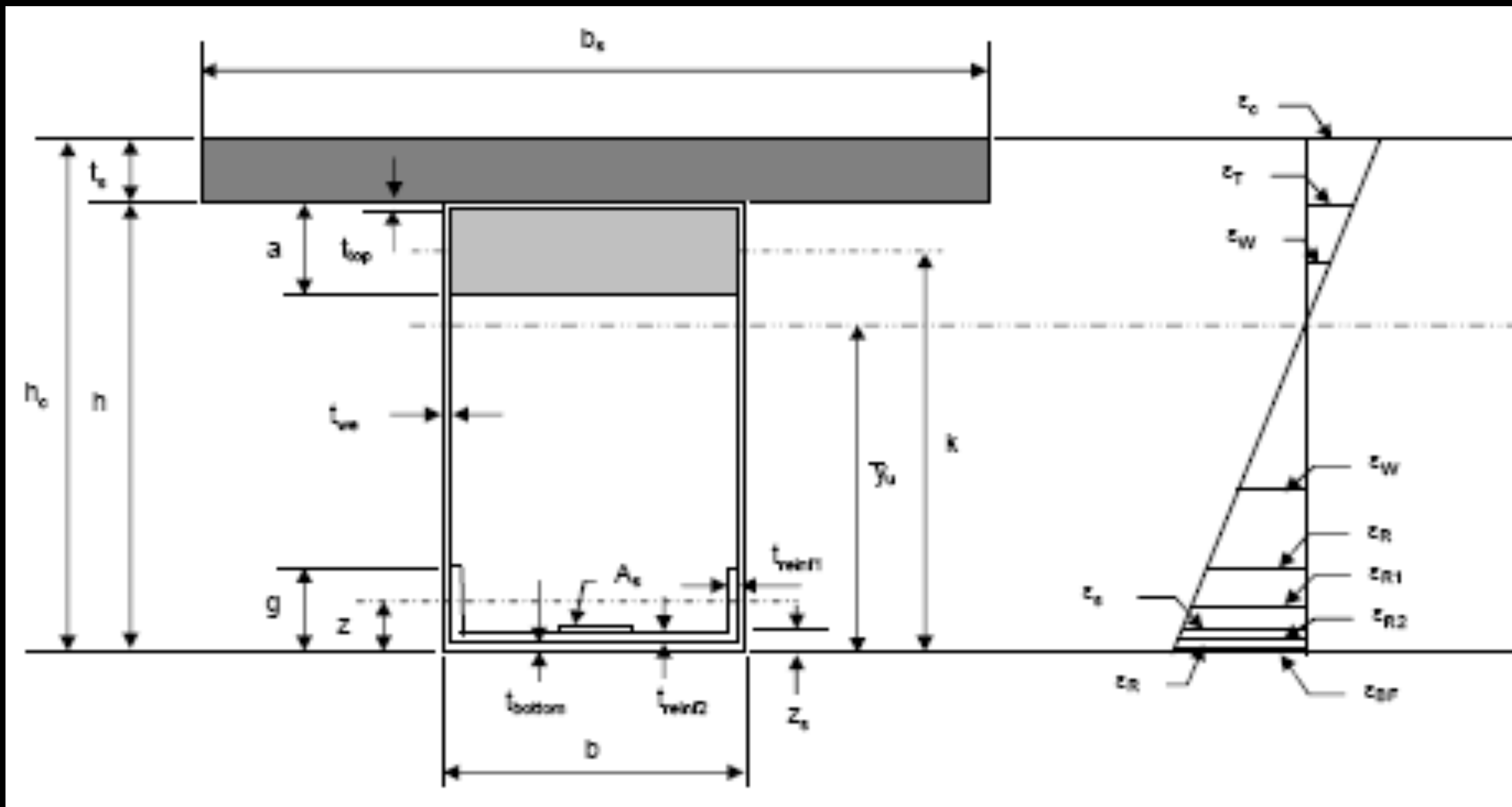
Tension Reinforcing

- Tension reinforcing consisting of 270 ksi galvanized prestressing strand along bottom of beam



Compression Reinforcing - SCC

- Compression reinforcing consisting of 6,000 psi Self-Consolidating Concrete (SCC) pumped into internal arch-shaped conduit



Strain Compatibility - Force Equilibrium

Strain Compatibility Equations

$$\varepsilon_{TF} = \varepsilon_c \frac{h-\bar{y}_u}{h-t_{top}-\bar{y}_u}$$

$$\varepsilon_{WT} = \varepsilon_c \frac{h-\bar{y}_u}{2\left(h-t_{top}-\bar{y}_u\right)}$$

$$\varepsilon_{WB} = \varepsilon_c \frac{\frac{1}{2}\left(t_{R2}-\bar{y}_u\right)}{h-t_{top}-\bar{y}_u}$$

$$\varepsilon_{BF} = \varepsilon_c \frac{t_{R2}-\bar{y}_u}{h-t_{top}-\bar{y}_u}$$

$$\varepsilon_{R2} = \varepsilon_c \frac{\bar{y}_u}{h-t_{top}-\bar{y}_u}$$

$$\varepsilon_{RO} = \varepsilon_c \frac{g-\bar{y}_u}{h-t_{top}-\bar{y}_u}$$

$$\varepsilon_{R1} = \varepsilon_c \frac{g/2-\bar{y}_u}{h-t_{top}-\bar{y}_u}$$

$$\varepsilon_s = \varepsilon_c \frac{z_s-\bar{y}_u}{h-t_{top}-\bar{y}_u}$$

$$d_{TF} = -\left(h-\bar{y}_u-t_{top}/2\right)$$

$$d_{WT} = -\tfrac{2}{3}\left(h-\bar{y}_u\right)$$

$$d_{WB} = \tfrac{2}{3}\left(\bar{y}_u-t_{R2}\right)$$

$$d_{BF} = \bar{y}_u-t_{R2}-t_{bottom}/2$$

$$d_{R2} = \bar{y}_u-t_{R2}/2$$

$$d_{R0} = \bar{y}_u-g/2$$

$$d_{R1} = \bar{y}_u-g/3$$

$$d_S = \bar{y}_u-z_S$$

where $\bar{y}_u$ = position of the plastic neutral axis, PNA with respect to the bottom of the beam

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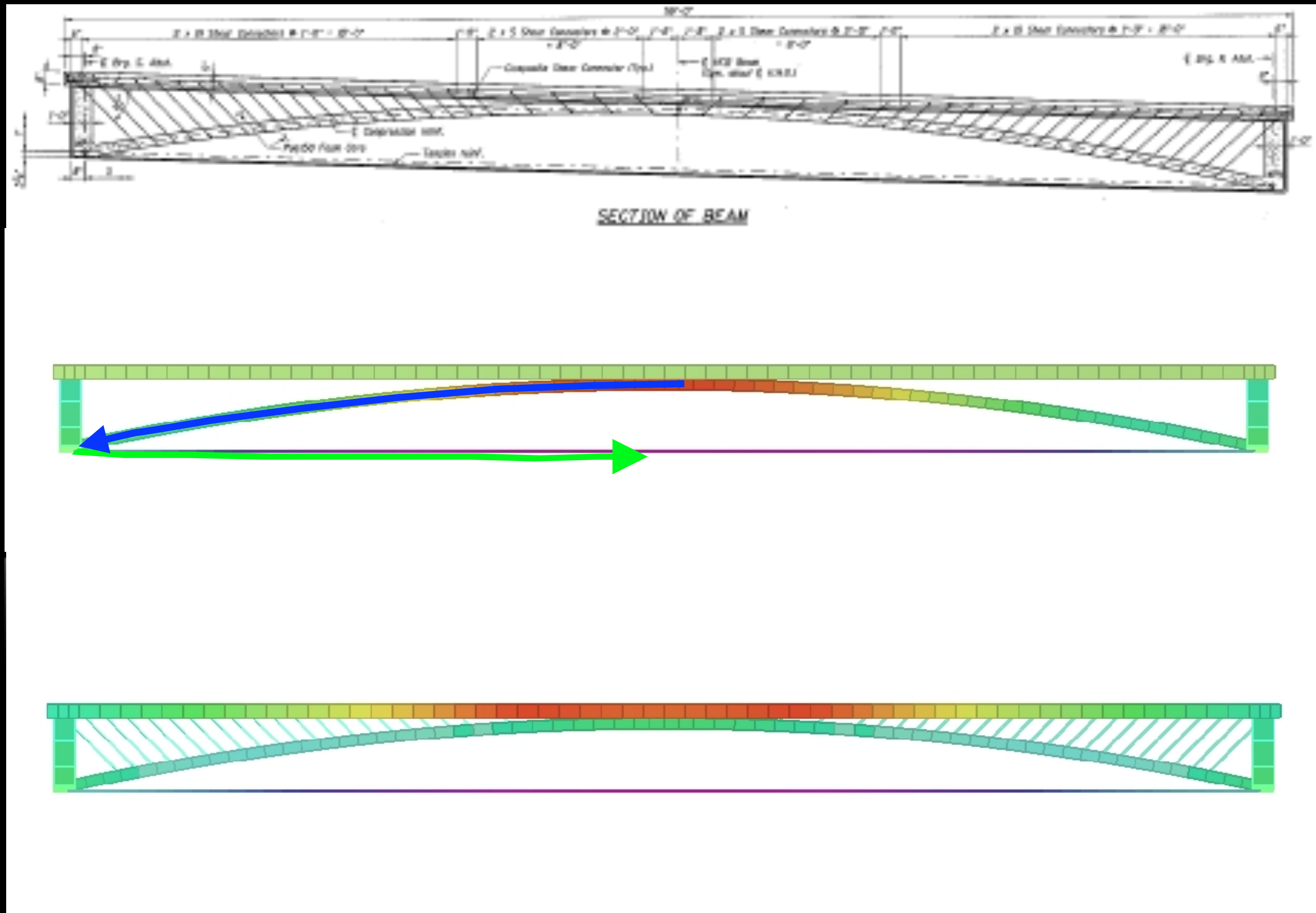
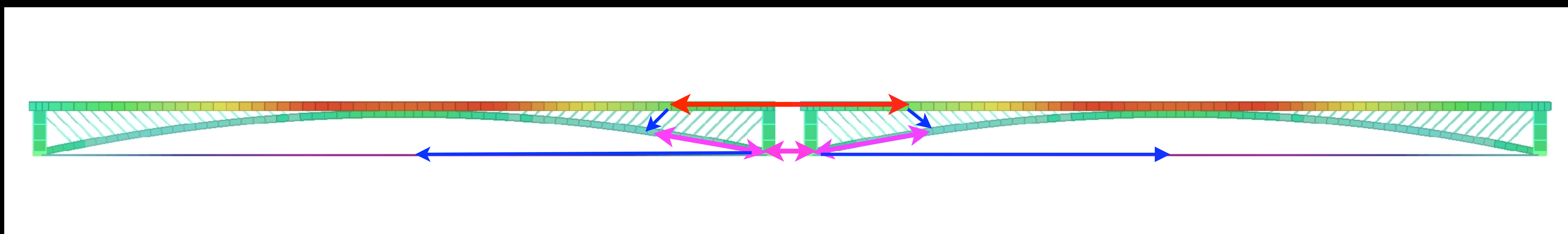
Solving for Neutral Axis

$$\bar{y}_u = \frac{\left[bt_{top}h + t_w h^2 + {0.85f'_c ab\left(h - t_{top}\right)}\Big/{E_w \varepsilon_c} + t_w t_{R2}^2 + bt_{bot}t_{R2} + n_R t_{R1} g^2 + n_S A_S z_S \right]}{\left[bt_{top} + 2t_w h + {0.85f'_c ab}\Big/{E_w \varepsilon_c} - 2t_w t_{R2} + bt_{bot} + n_R bt_{R2} + 2n_R t_{R1} g + n_S A_S \right]}$$

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



Stress History



Continuous Structures

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

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High Road Bridge - Lockport Township, IL
57 ft. Span - August, 2008

Route 23 Bridge, Cedar Grove, NJ
31 ft. Span - October 2009

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Knickerbocker Bridge - Boothbay, ME
540 ft. - 8 spans @ 70 ft., October 2010

1st HCB Installation - TTCI - Pueblo, CO
30 ft. span - Class 1 RR (320k), November 2007

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“The point of the journey is not to arrive.”

Neil Peart

It's lonely at the top!

Duane & John Under Pressure

Precast Planks? Fuggedaboutit

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If the Super's happy, everyone's happy!

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It's also lonely at the bottom.

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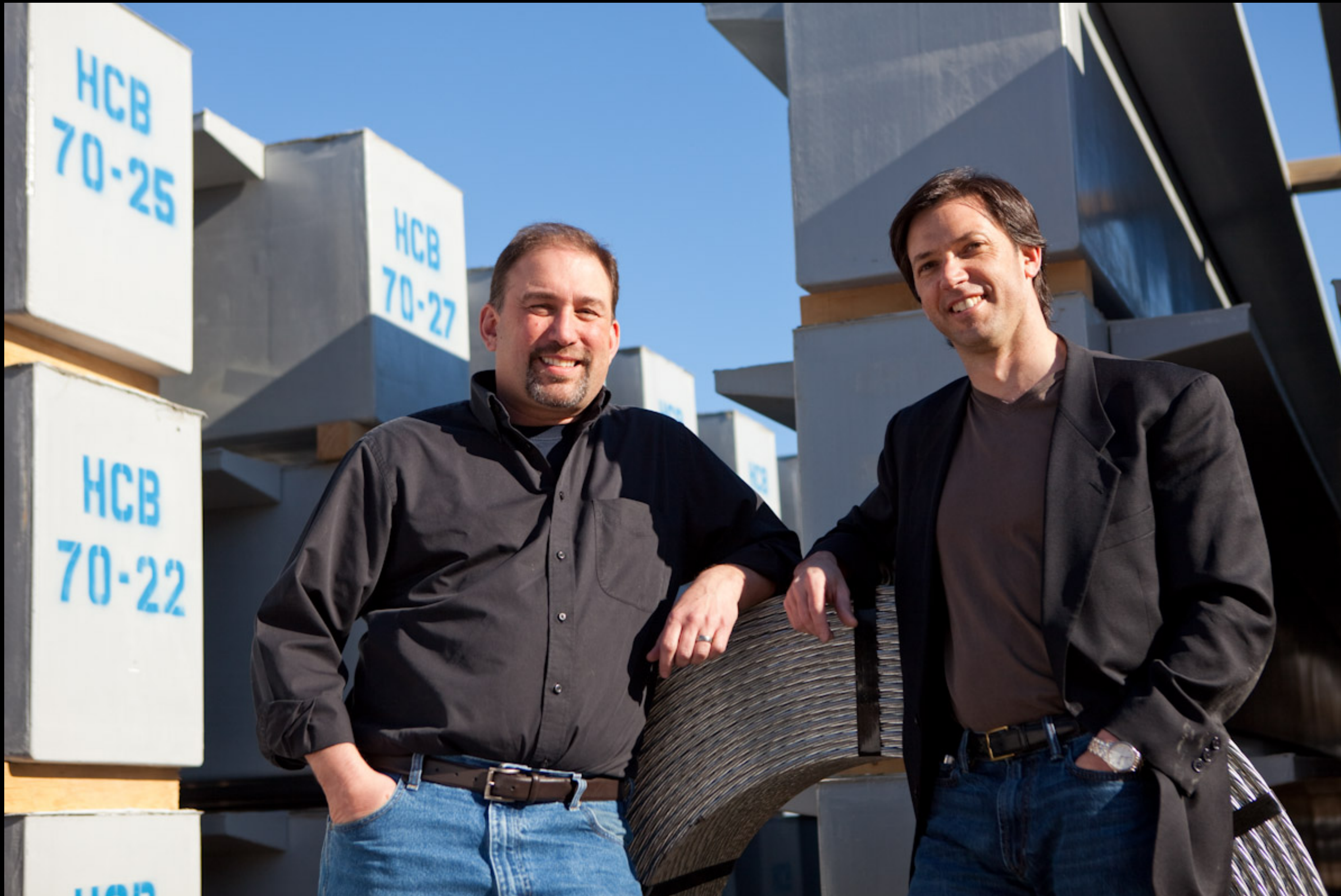
The Objective

- To create a paradigm shift in bridge construction through the deployment of safe, sustainable structures that can withstand extreme environmental conditions at a better value through the deployment of advanced composite materials.

- "Build Better Bridges"

"It's not the mountain that we conquer, but ourselves."

Sir Edmund Hillary



It’s no fun to climb mountains by yourself!

"Ambition is self defeating,
Passion is contagious."

"Success is not the result of spontaneous combustion. You must set yourself on fire."

Reggie Leach

Questions?

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