Building Better Bridges with Hybrid-Composite Beams

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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?
Inventing Floor Systems @ VT
Apprentice to Tom Murray
Launching Bridges in Puerto Rico

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Apprentice to the Master
Jean Muller
The Beauty of the Arch
Inventing HCB
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
Limited Service Life
Fundamental Principals of Structural Behavior

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

Figure 6.8 Typical analogies for shear failure mechanisms.
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
- 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
Stealing Ideas from the Past
The First Hillman Bridge
Fiberglass Box (FRP Shell)

• Balanced quad-weave fabric with fibers that are horizontal (0°), vertical (90°) and (± 45°)

• 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

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

\[ \varepsilon_{WT} = \varepsilon_c \frac{h - \bar{y}_u}{2(h - t_{top})} \]

\[ \varepsilon_{WB} = \frac{1}{2} t_{R2} \]

\[ \frac{\bar{y}_u}{h - t_{top}} - \bar{y}_u \]

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

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

\[ \varepsilon_{RO} = \varepsilon_c \frac{\bar{y}_u}{h - t_{top}} - \bar{y}_u \]

\[ \varepsilon_{R1} = \varepsilon_c \frac{\bar{y}_u}{h - t_{top}} - \bar{y}_u \]

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

\[ d_{TF} = -\left( \frac{h - \bar{y}_u - t_{top}}{2} \right) \]

\[ d_{WT} = -\frac{2}{3} (h - \bar{y}_u) \]

\[ d_{WB} = \frac{2}{3} (\bar{y}_u - t_{R2}) \]

\[ d_{BF} = \frac{\bar{y}_u - t_{R2}}{2} \]

\[ d_{R2} = \frac{\bar{y}_u - t_{R2}}{2} \]

\[ d_{R0} = \frac{\bar{y}_u - g}{2} \]

\[ d_{R1} = \frac{\bar{y}_u - g}{3} \]

\[ d_S = \bar{y}_u - z_S \]

where \( \bar{y}_u \) = position of the plastic neutral axis, PNA

with respect to the bottom of the beam
Solving for Neutral Axis

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

\[ \left[ \frac{b_{\text{top}} + 2t_w h + 0.85f'_c a b}{E_w \varepsilon_c} - 2t_w t_{R2} + b_{\text{bot}} + n_R b_{R2} + 2n_R t_{R1} g + n_S A_S \right] \]
\[ C = T \]
\[ C = 0.85 f_c' ab \]
\[ \Phi M_n = \Phi C (d - a/2) \]
Stress History
Continuous Structures
• Inventory Rating = 2.68 (HS-54)

• Operating Rating = 3.47 (HS-69)
High Road Bridge - Lockport Township, IL
57 ft. Span - August, 2008

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

Neil Peart
It’s lonely at the top!
Precast Planks? Fuggedaboutit
If the Super’s happy, everyone’s happy!
It's also lonely at the bottom.
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