Sandwich composite structures in bridge building – short-lived trend or opportunity for the future?

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Corfou, October 11th 2010

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2) 3A Composites, Lausanne/Steinhausen, Switzerland
Outline

1. Introduction to sandwich composites
2. Examples of applications in use
3. Sandwich composites in bridge construction – state of the art
4. Our approach & ongoing projects
5. Conclusions & perspectives
Sandwich Structures
An Intelligent and Efficient Material Approach

- Highest stiffness-to-weight ratio for a structure exposed to flexural load
- High strength/stiffness faces taking up compression- and tensile loads
- Low-density core material keeping faces apart and transferring shear stresses from one face to another
Structural behaviour of a simply supported sandwich panel

(a) Simply supported sandwich panel
(b) Shear force diagram
(c) Bending moment diagram
(d) Low-strength adhesive allows faces to slip relative to each other
(e) Low shear strength and stiffness of core allows shear failure or reduces sandwich action
(f) Local buckling (wrinkling) of upper face
(g) Tensile yield of lower face
### The Sandwich Effect

<table>
<thead>
<tr>
<th>Single Skin - t</th>
<th>Sandwich - 2t</th>
<th>Sandwich - 4t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight: 1</td>
<td>Weight: 1</td>
<td>Weight: 1</td>
</tr>
<tr>
<td>Strength: 1</td>
<td>Strength: 6</td>
<td>Strength: 12</td>
</tr>
<tr>
<td>Stiffness: 1</td>
<td>Stiffness: 12</td>
<td>Stiffness: 48</td>
</tr>
</tbody>
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Examples of Possible Core Materials

- Foam core
- Foam with bubbles
- Corrugated sheet
- Tube core
- Balsa core
- Balsa core with tubes
- Balsa vertical beam
- Honeycomb core
Shear Properties vs. Density for Some Typical Core Materials

- Balsa endgrain
- PVC foam
- PET foam

shear modulus, $G$ [Mpa]
density, $\rho$ [kg/m$^3$]
Examples of Face Materials

- **Metal (Aluminum, steel)**
  - Isotropic
  - Intermediate specific stiffness and strength
  - Corrosive
  - Relatively low-cost

- **Carbon Fibre Reinforced Polymers**
  - Anisotropic
  - High specific stiffness and strength
  - Non-corrosive
  - High cost

- **Glass Fibre Reinforced Polymers**
  - Anisotropic
  - Intermediate specific stiffness and strength
  - Non-corrosive
  - Relatively low-cost

<table>
<thead>
<tr>
<th>Specific modulus</th>
<th>Specific strength</th>
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<tbody>
<tr>
<td>Alu 25</td>
<td>Alu 0.08</td>
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<tr>
<td>Steel 25</td>
<td>Steel 0.06</td>
</tr>
<tr>
<td>CFRP approx. 30-85 (quasi-isotropic vs. Unidirectional)</td>
<td>CFRP approx. 0.4-1.15 (quasi-isotropic vs. Unidirectional)</td>
</tr>
<tr>
<td>GFRP approx. 10-25 (quasi-isotropic vs. Unidirectional)</td>
<td>GFRP approx. 0.08-0.22 (quasi-isotropic vs. Unidirectional)</td>
</tr>
<tr>
<td>Concrete 8</td>
<td>Concrete 0.01 – 0.03</td>
</tr>
</tbody>
</table>
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Sandwich Structures in Architecture

Sandwich Composite Cladding System – DIAB

Alucobond – 3A Composites
Sandwich Structures in Transportation

Future SBB intercity train – Bombardier

Westport 130 Yacht
Wind Energy
Typical Wind Blade Construction

- Glass fibre reinforced polymer (GFRP) widely used for the skins
- Carbon fibre reinforced polymers (CFRP) increasingly used for very large blades to reduce weight
- Various types of core materials along the blade (PET, balsa) depending on local requirements
- Infusion, vacuum-assisted resin transfer molding (VARTM) and Prepreg in open molds are the dominant manufacturing technologies today
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General overview

- Approx. a dozen of composite bridge manufacturers worldwide
- First composite bridge deck installed in 1996 by Kansas Structural Composites*
- Mainly 2 technologies used so far, namely (i) structural foam reinforced by shear webs, and (ii) pultruded decks

*) Keller T, de Castro J. Development of a FRP sandwich bridge deck – preliminary study. Lausanne, August 2010
- More than 30 bridge „DuraSpan“ decks installed in the US*
- Made from pultruded glass fibre composites
- Decks carrying transversal load, adhesively bonded on steel girders carrying the longitudinal load

*) Keller T, de Castro J. Development of a FRP sandwich bridge deck – preliminary study. Lausanne, August 2010
Shear-Web Reinforced Foam Cores
Example of FiberCore Europe

- 23 bridge decks installed by end of 2009*, both pedestrian and vehicular (mainly in NL)
- Core material using structural foam and FRP shear webs
- Similar approach used by companies like HardCore Composites, WebCore Technologies, and Composite Advantage

*) Foster M. FiberCore. Conference „Development in FRP bridge design“. London, February 2010
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New Customer Needs in Bridge Construction
Opportunities in Various Market Segments

- Solutions for deck replacement and/or widening of vehicular bridges with minimum changes to existing sub-structure
- Shorter installation time to cut cost occurring from traffic interruption
- Easy-to-install short-span bridges with increased durability in remote areas
- Structures requiring less maintenance (e.g. no corrosion issues)
Our Solution: A Composite Sandwich Structure

1. Lightweight concept with structural sandwich
2. Fiber reinforced composites faces
3. Novel detailing solutions
Composite Bridge in Louisiana DOT
A First Feasibility Study

- Louisiana Department of Transportation → durability & easy to install
- Baltek developed a solution based on balsa core materials with GFRP/metal grid faces
- Equipped with structural health monitoring
- Installed in Pierre Part, LA, September 2009
The Chancy Bridge Project

- Replacing the bridge deck, with the aim of reducing the bridge’s dead load by 6 kN/m²
- Thus increasing the allowed live load with the aim of meeting current standards
- Temporary lightweight pedestrian bridge hung onto main substructure
- Construction summer/fall 2011
The Avençon Bridge Project

- Total bridge replacement with focus on minimum traffic interruption
- Thus fast installation by lifting in lightweight composite deck
- Construction summer/fall 2011
### The Project Partners

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<tr>
<th>CORE COMPETENCY</th>
<th>PROJECT PARTNER</th>
<th>KEY ROLE</th>
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<tr>
<td><strong>MATERIALS</strong></td>
<td>3A Composites</td>
<td>• Candidate materials for core and faces</td>
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<tr>
<td><strong>STRUCTURE</strong></td>
<td>CCLAB</td>
<td>• Composite processing → samples &amp; manufacturing at large scale</td>
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<td><strong>DESIGN</strong></td>
<td>ingénierie</td>
<td>• Structural concept – testing and modeling</td>
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<td><strong>DETAILING</strong></td>
<td>Sika</td>
<td>• New FRP composite slab</td>
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<td>• Connection to national and international road authorities</td>
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<td>• Conception and design of FRP bridges</td>
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<td>• Implementation of first concept at national level</td>
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<td></td>
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<td>• Connection to cantonal road authorities</td>
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<td></td>
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<td>• Suggest/develop solutions for</td>
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<tr>
<td></td>
<td></td>
<td>i. Sealing and surfacing</td>
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<td>ii. Adhesive bonding</td>
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<td>iii. Detailing</td>
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