About Owens Corning

• Founded in 1938, an industry leader in glass fiber insulation, roofing and asphalt and glass fiber reinforcements
• 2009 sales: $4.8 billion
• 16,000 employees in 26 countries
• FORTUNE 500 company for 56 consecutive years

<table>
<thead>
<tr>
<th>Owens Corning Building Materials and Services</th>
<th>Owens Corning Composite Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Residential Insulation</td>
<td>• Composite Reinforcements</td>
</tr>
<tr>
<td>• Commercial &amp; Industrial Insulation</td>
<td></td>
</tr>
<tr>
<td>• Manufactured Stone Veneer</td>
<td>• OCV Reinforcements</td>
</tr>
<tr>
<td>• Residential Shingles</td>
<td>• OCV Technical Fabrics</td>
</tr>
<tr>
<td>• Roofing Asphalts</td>
<td>• OCV Non-Woven Technologies</td>
</tr>
</tbody>
</table>
Owens Corning History with the Military

- Structural Aircraft Parts (1942) – OC partnered with U.S. A.A.F. to develop plastic laminates.
- Beta® yarn (1963) – OC develops fiber for aerospace applications and use in NASA spacesuits.
- S-Glass® (1959-63) – Developed by OC under contract with U.S. Navy.
- Piedmont Products, Inc. (1979) – OC manages reinforcements plant under government contract
- ShieldStrand® Reinforcements (2007-2009)
  – MRAP, HMMWV
Market Transformation Opportunities

HARD Armor

- Personnel protection
  - Body armor inserts
  - Helmets
  - Shields
  - Anti-mine shoes, leg protection, ...

- Armored vehicles
  - Light vehicles
    - Ballistic panels for floor, door, bodywork, roof, interior armor ...
      - Cash in transit, ambulance,...
      - Law enforcement, Army: car, 4x4, hummer, van, truck ...
      - Civilian: VIP car, 4x4, limousine, ...
  
  - Heavy vehicles
    - Ballistic panels for military vehicles. External & internal armor
      - Tank, char, wheeled vehicle, tracked vehicle

- Armored aerial vehicles
  - Helicopters: floor, seat (panels), cockpit...
  - Aircraft: cockpit doors, seat, ...

- Armored marine vehicles
  - Submarine
  - Shipboard: bridge, compartment, ...

- Fixed structure
  - Ballistic panels for structural parts
    - Bank counter, prison, bridge, shelter, vulnerable building (embassy, airport,...)

SOFT Armor

- Personnel protection
  - body armor
  - Gloves
  - Clothes
Mobility & Lethality drives solution

- Fighter Jets
- Tactical Vehicles
- Personal Armor

- Helicopter
- Defense Vehicles
- Amphibious Assault Vehicles

- Homeland Security
- Bridges / Infrastructure
- Embassies

- Marine Deckhouses
- Marine Hull Components
- Coast Guard
- Battlefield ISO Shelters
History of Composite Vehicles

Functional Requirements

- weight (lighter)
- range of protection levels
- ballistic and blast performance
- damage tolerance
- structural performance
- fire performance
- Electromagnetic properties
- maintainability
- affordability

Technology Gaps:

- Lightweight Multifunctional Materials are needed
- Materials-by-design vs trial and error
- Multi-scale modeling across all length scales and loading rates
- Systems Approach for Design and Optimization

Monocoque

Appliqué

Integral

Structure (A) + Armor (B)
Industry Needs

Performance Drivers

• Protection against blast and fragmentation
• Performance improved with vehicle mobility
• Payload capacity increased
• Lighter, faster, more fuel efficient vehicles
• Higher survivability at affordable price
Design Drivers

Ballistic energy absorbing fracture mechanisms may be combined within same armor systems to meet requirements of different threats.

This combination is based on:

- Weight limitation
- Space constraints
- Structural role
- Environment (moisture, FST)
- Type of projectile(s)
- Need for single shot or multi-hit capability

And usually leads to armor systems which are based on multimaterials, multilayer arrangements, each providing a specific functionality.
Maximize energy absorption in composite integral armor **while** maintaining structural properties

- **Potential mechanisms in composite layer**
  - Delamination
  - Fiber and resin fracture/deformation
  - Fabric deformation effects
  - Fiber-matrix interphase damage
  - Frictional effects – interlaminar, fiber-matrix, etc.
Tailoring Composite Performance

- Interphase & thermodynamic effects
- Fiber design
- Enhancement of compressive strength
- Optimum Composites for Desired Properties
  - Ballistic
  - Structure
  - Durability
- Micromechanical Characterization
  - Energy Absorption
  - Strain Rate
  - Durability
- Effects of sizing & Resin Compatibility
- Grading of Interlaminar Region
- Control of Resin Permeability
Material Choices for Armor Protection

- Shieldstrand® (High Strength Glass Fiber)
- Aramid fiber
- UHMWPE fiber
- Ballistic nylon fiber
- Ceramics
- Steel
- Aluminum
- Titanium
Effectiveness vs. selected threats

<table>
<thead>
<tr>
<th>Projectile</th>
<th>Velocity Km/s</th>
<th>Material</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball</td>
<td>0.9</td>
<td>Al</td>
<td></td>
</tr>
<tr>
<td>Armor Piercing</td>
<td>0.9</td>
<td>Steel</td>
<td></td>
</tr>
<tr>
<td>Sabot-light AP</td>
<td>1.1</td>
<td>Aramid</td>
<td></td>
</tr>
<tr>
<td>Tungsten carbide AP</td>
<td>0.9</td>
<td>Shield</td>
<td>strand</td>
</tr>
<tr>
<td>AP Discarding sabot</td>
<td>1.2</td>
<td>Ceramic</td>
<td></td>
</tr>
<tr>
<td>Fragment simulating</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fragment simulating</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-forging fragment</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long rod penetrator</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High velocity KE</td>
<td>2+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shaped charge</td>
<td>7.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Effectiveness:
- :red:
- :orange:
- :green:
- :blue:
Benefits of ShieldStrand Armor Solutions

Tangibles - Mitigates Behind Armor Debris from Fragmentation and Overmatch Threats of IED, EFP

- Stronger & Lighter
- Thinner
- Durable
- Excellent Processing
- Affordable
- Consistent Supply Chain
- Phenolic Fire Resistance
- Ballistic Performance to Specifications for Composite Armor Systems MIL-DTL-64154
- Qualified for Spall Liner, Frag 5, Frag 6 and EFP
Benefits of ShieldStrand Armor Solutions

**Intangibles – Heritage of Proven Spall Liner Field Performance and Prototype Structural Armor Hull Performance for Aluminum and Steel Substitution**

- Depot / Field Installation Capable
- Battle Damage and Repair Field Maintenance Capable
- Flat or Curved Plate or Complex Shape Demonstrated
- Installs with Fastener Systems typical to Metals
- Surface ready for CARC or adhesive for Metal and/or Ceramic Bonding / Joining
- No Corrosion or galvanic corrosion
- Good Durability to Vehicle Environment
- Complies with FMVSS 302 Flammability
ShieldStrand® Enables Lightweight Composite Armor Affordability

Weight required to meet MIL-DTL-64154B (lbs/sf)

Cost ($/lb)

UHMWPE

Aramid/Phenolic

S-2 Glass®

ShieldStrand® S

Advantex® (E-glass)

5083 Al

RHA Steel
ShieldStrand® Offers the opportunity for Hybridization with other materials for Optimum Solution

Data shown for comparative purposes only and should not be construed as a guaranty or warranty of performance. Absolute performance will vary by resin system or process.
Integrated Structural Armor

**ShieldStrand® is making new armor solutions possible**

- The strength of ShieldStrand® provides structure as well as protection, allowing armor to be integrated into the vehicle structure, reducing overall vehicle weight.

- ShieldStrand® can be molded into large complex-shaped structural parts using proven large scale composite manufacturing technologies.

- ShieldStrand® has been tested in combination with a steel or ceramic strike face to provide protection when armor piercing and multi hit capability is required or an overmatched threat exists.
ShieldStrand® Armor Solutions for Blast and Multi-hit Fragmentation Performance

- Offers good performance in blast – structurally good with minimal global deflection
- Local Deflection with Large Fragments
- FR Vinylester ShieldStrand V-hull passed blast & full scale diesel fuel fire test
- Minimal secondary behind armor effects – V-hull vents Blast, Composite stops fragmentation, while structure absorbs Blast energy and dissipates shock.
# ShieldStrand® Phenolic Plate:
## Provides structure as well as protection

### Elastic Constants

<table>
<thead>
<tr>
<th>Property</th>
<th>Code</th>
<th>Modulus</th>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal Modulus</td>
<td>D3039, D638</td>
<td>3.5 - 4.6 PSI</td>
<td>1.5 - 4 %</td>
</tr>
<tr>
<td>Transverse Modulus</td>
<td>D3039, D638</td>
<td>3.5 - 4.6 PSI</td>
<td>0.7 - 2 %</td>
</tr>
<tr>
<td>Axial Shear Modulus</td>
<td>D3518</td>
<td>0.5 - 0.7 PSI</td>
<td>1.5 - 4 %</td>
</tr>
<tr>
<td>Axial Comp Modulus</td>
<td>D695</td>
<td>5.2 - 6.7 PSI</td>
<td>0.7 - 2 %</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>D3039</td>
<td>0.24 - 0.27</td>
<td>2 - 2.5 %</td>
</tr>
</tbody>
</table>

### Strength Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Code</th>
<th>Modulus</th>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal Tension</td>
<td>D3039, D638</td>
<td>60 - 100 PSI</td>
<td>1.5 - 4 %</td>
</tr>
<tr>
<td>Longitudinal Compression</td>
<td>D3410, D695</td>
<td>20 - 80 PSI</td>
<td>0.7 - 2 %</td>
</tr>
<tr>
<td>Transverse Tension</td>
<td>D3039, D638</td>
<td>60 - 100 PSI</td>
<td>0.7 - 2 %</td>
</tr>
<tr>
<td>Transverse Compression</td>
<td>D3410, D695</td>
<td>20 - 80 PSI</td>
<td>0.7 - 2 %</td>
</tr>
<tr>
<td>Normal Compression</td>
<td>D695</td>
<td>100 - 120 PSI</td>
<td>70 %</td>
</tr>
<tr>
<td>In-Plane Shear</td>
<td>D3518</td>
<td>17 - 30 PSI</td>
<td>0.470 - 0.530</td>
</tr>
<tr>
<td>Interlaminar Shear</td>
<td>D2344</td>
<td>1.9 - 4.0 PSI</td>
<td>0.019 - 0.020</td>
</tr>
<tr>
<td>Longitudinal Flexural</td>
<td>D790</td>
<td>20 - 45 PSI</td>
<td>4.6 - 5.4</td>
</tr>
<tr>
<td>Longitudinal Bearing</td>
<td>D953</td>
<td>35 - 80 PSI</td>
<td>0.072 - 0.074</td>
</tr>
</tbody>
</table>

### Physical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Code</th>
<th>Modulus</th>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber Volume</td>
<td>D2734</td>
<td>61 - 66%</td>
<td></td>
</tr>
<tr>
<td>Resin Weight</td>
<td>D2584</td>
<td>16 - 24%</td>
<td></td>
</tr>
<tr>
<td>Water Absorption</td>
<td>D570, D792</td>
<td>&lt;1.5%</td>
<td></td>
</tr>
<tr>
<td>Longitudinal Flexural, Wet Ret.</td>
<td>D790</td>
<td>&gt;70%</td>
<td></td>
</tr>
<tr>
<td>Thickness (in.)</td>
<td></td>
<td></td>
<td>0.470 - 0.530</td>
</tr>
<tr>
<td>Ply Thickness (in.)</td>
<td>25 ply</td>
<td>0.019 - 0.020</td>
<td></td>
</tr>
<tr>
<td>Areal Density (lb/sf)</td>
<td>25 ply</td>
<td>4.6 - 5.4</td>
<td></td>
</tr>
<tr>
<td>Density (lb/ci)</td>
<td>D792</td>
<td>0.072 - 0.074</td>
<td></td>
</tr>
<tr>
<td>Hardness (M scale)</td>
<td>D785</td>
<td>&gt;80</td>
<td></td>
</tr>
<tr>
<td>Thermal Transition</td>
<td>D4065</td>
<td>210 - 240</td>
<td></td>
</tr>
<tr>
<td>Flammability</td>
<td>UL 94</td>
<td>V0</td>
<td></td>
</tr>
<tr>
<td>Time to Ignition @50kW/sm (s)</td>
<td>E1354</td>
<td>500 - 600</td>
<td></td>
</tr>
<tr>
<td>Total Heat Release (MJ/sm)</td>
<td>E1354</td>
<td>25 - 60</td>
<td></td>
</tr>
<tr>
<td>MAHRE (kW/sm)</td>
<td>E1354</td>
<td>20 - 35</td>
<td></td>
</tr>
<tr>
<td>FIGRA</td>
<td>E1354</td>
<td>0.10 - 0.20</td>
<td></td>
</tr>
</tbody>
</table>

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Shieldstrand® Solution Case Histories

- HMMWV Spall Liner
- MRAP EFP Kit
- Integrated Structural Cab
- Frag 5 Door Kit
- Composite V-hull

- Spall liners
- Exterior armor modules
- V-hull
- Structural components

- Compression Molded Phenolic
- Infusion Molded FR Epoxy Vinylester
Shieldstrand® Solutions for Armor Protection

Shieldstrand® Fibers delivers optimum strength and stiffness

Ultimate energy absorption controlled by **strain to failure** of the fibres. Once fibres have ruptured the armour collapses and no further energy is absorbed.

<table>
<thead>
<tr>
<th></th>
<th>Shieldstrand®</th>
<th>Metal (Steel &amp; Al)</th>
<th>S-2 Glass</th>
<th>Aramid</th>
<th>UHMW Polyethylene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Assumes equal ballistic threat for all materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>++</td>
<td>+++</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Structural Capability</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Part thickness (thin is +)</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Resistance to acid and chemical attack</td>
<td>++</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Fire, Smoke and Toxicity</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Temperature Resistance</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

A balanced solution ½ weight of Steel and 1/3 cost of UHMWPE