UV Stable, Weather Resistant Sheet Molding Compound:
An Alternative Approach to Building Strong, Durable Transportation Components

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UV Stable, Weather Resistant Sheet Molding Compound:

• Part I: The Appearance Science Approach
• Part II: Durability Testing
• Part III: Mechanical Properties
• Part IV: Application
• Part V: Conclusions
Part I: The Appearance Science Approach
Part I: The Appearance Science Approach

- **Appearance is that aspect of an object which enables us to identify an object for what it is.**
  
  -- Richard S. Hunter, 1975
UV Stabilization
Weathering Failure!
Identified Causes of Weathering Failure:

- Resin selection
- Glass selection
- Filler selection
- Colorant type and quantity
- Low Profile Additive type and quantity
- Thickening profile
- Molding viscosity
- Initiator selection
- Inhibitor type and quantity
- Mold surface condition
- Mold performance
- Mold temperature and flow of material
A Common Cause of Failure:

• Failure to adequately cover or hide the glass
  • This can be due to dry glass
  • Lack of resin rich surface
  • Molding conditions
  • Behavior of low profile
  • Colorant often plays an important role in covering and hiding glass
Appearance Science

COLORANTS  ADDITIVES

 thượng

SUBSTRATE
Weathering Test Matrix:

- SAE J-2527, 4000 hours, quartz/boro filters, Q-Sun Xe-3-HSQ (Q-Panel).
- ASTM G-155 Cycle 3a using Q-Sun Xe-3-HSQ (Q-Panel).
- Outdoor direct exposure: ASTM G-147, 5° South, AZ and SF, 2 years.
- 1000 hours xenon arc \(\approx 1250 \text{ kJ} @ 340 \text{ nm} \approx 1 \text{ year} @ 5° \text{ south.}\)
- ASTM G-23 Sunshine Carbon Arc (SWOM), 1000 hours
- Evaluation of multiple textured surfaces – texturing plays a role in surface durability
Weathering Test Matrix:

- Testing conducted and results correlated by each of four (4) parties:
  - Chromaflo
  - Ashland
  - CSP
  - Honda
- High priority on understanding and correlating differences between test methods and facilities.
- Appearance measurement:
  - Color Sphere Spectrophotometer (e.g. X-Rite Color-Eye 7000A), Large Area View, 10° Observer, D65 Luminescence, CIEL*a*b* and CMC 2:1 color spaces.
  - 60° Gloss using glossimeter (e.g. Byk Micro-Tri-Gloss)
  - Each reading represents average of three (3) readings on each of multiple panels per reading interval
Comparison of L* Drift of 50% Glass UV Stable SMC in Accelerated (Ci4000 SAE J1960kJ boro/boro) vs Natural (SAE J1976 5° SOB) Testing

Years of Outdoor Exposure

L* (CIEL*a*b*)
Comparison of Gloss Retention of 50% Glass UV Stable SMC in Accelerated (Ci4000 SAE J1960kJ boro/boro) vs Natural (SAE J1976 5° SOB) Testing

- UV Stable SMC 50% Glass Ci4000
- UV Stable SMC 50% Glass 5° SOB South Florida
- UV Stable SMC 50% Glass 5° SOB Arizona
Color Drift of Black UV Stable Composite in South Florida Direct Exposure

Graph showing the color drift of a Black UV Stable Composite and a Paint over months of direct exposure in South Florida, 5° South.
Gloss Drift of Black UV Stable Composite in South Florida Direct Exposure

- **Composite**
- **Paint**

**Gloss 60°** vs. **Months Direct Exposure, 5° South**
Color Drift of Black UV Stable Composite in Artificial Accelerated South Florida Direct Exposure via Ci4000

Delta E* CIEL*a*b* vs Years Equivalent South Florida Exposure
Gloss Drift of Black UV Stable Composite in Artificial Accelerated South Florida Direct Exposure via Ci4000

![Graph showing the gloss drift of a black UV stable composite over years equivalent to South Florida exposure.](image-url)
Part II: Physical Durability Requirements and Testing
Honda Rock Drop Test:

https://www.youtube.com/watch?v=ayOhO3D_90Y
# DVP&R Test Summary:

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Test Number</th>
<th>UV SMC vs Painted SMC</th>
<th>UV SMC vs. Painted Steel</th>
<th>UV SMC vs. Thermoplastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gloss Polish Change</td>
<td>BI 010-02</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Scuff Resistance 10k cycles</td>
<td>BN 108-04</td>
<td>Same</td>
<td>Better</td>
<td>Same</td>
</tr>
<tr>
<td>Taber Abrasion 2000 cycle @ 1kg</td>
<td>BN 108-02</td>
<td>Appearance Worse</td>
<td>Better</td>
<td>Worse</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Performance Better</td>
<td>Better</td>
<td>Worse</td>
</tr>
<tr>
<td>Taber Abrasion 6000 cycle @ 1kg</td>
<td>BN 108-02</td>
<td>Appearance Same</td>
<td>Better</td>
<td>Worse</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Performance Better</td>
<td>Better</td>
<td>Worse</td>
</tr>
<tr>
<td>Taber Abrasion 2000 cycle @ 250 gm</td>
<td></td>
<td>Appearance Worse</td>
<td>Better</td>
<td>Worse</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Performance Same</td>
<td>Better</td>
<td>Worse</td>
</tr>
<tr>
<td>Soap / Washer Fluid / Oil</td>
<td>BI 113-01</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Acid (Sulfuric)</td>
<td>BI 113-02</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Fuel Resistance</td>
<td>BO 101-05</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Gravelometer</td>
<td>SAE J400</td>
<td>Appearance Better</td>
<td>Better</td>
<td>Better</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Performance Better</td>
<td>Better</td>
<td>Better</td>
</tr>
<tr>
<td>Thermal Shock</td>
<td>BI 107-05</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Mar Resistance</td>
<td>BI 161-01</td>
<td>Same</td>
<td>Better</td>
<td>Better</td>
</tr>
<tr>
<td>Environmental Cycle</td>
<td>BQ 104-07</td>
<td>Same</td>
<td>Same</td>
<td>Better</td>
</tr>
<tr>
<td>Scratch Resistance (7 fingers) 5+2</td>
<td>BN 108-13</td>
<td>Same</td>
<td>Same</td>
<td>Better</td>
</tr>
<tr>
<td>Water Immersion</td>
<td>BI 104-10</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>QCT (24 Hour Salt Spray)</td>
<td>BI 104-02</td>
<td>Same</td>
<td>Same</td>
<td>Same</td>
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</tbody>
</table>
Summary of Jury Evaluation

<table>
<thead>
<tr>
<th>UV SMC vs. Painted SMC</th>
<th>UV SMC vs. Painted Steel</th>
<th>UV SMC vs. Thermplastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same or Better (17 of 19 tests)</td>
<td>Same or Better (19 of 19 tests)</td>
<td>Same or Better (13 of 19 tests)</td>
</tr>
<tr>
<td>Worse (2 of 19 tests)</td>
<td>Worse (0 of 19 tests)</td>
<td>Worse (6 of 19 tests)</td>
</tr>
</tbody>
</table>

UV composite is more durable than painted steel.
## DVP&R Surface Durability:

<table>
<thead>
<tr>
<th>Material</th>
<th>Scratch Test</th>
<th>Gravelometer</th>
<th>Taber Scuff</th>
<th>Taber Abrader</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermoplastic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Painted Steel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Painted SMC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UV SMC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part III: Mechanical Properties
### Typical Properties: Multi-lot Analysis

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass Content</td>
<td>50</td>
<td>%</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.73</td>
<td>Rel. Density</td>
</tr>
<tr>
<td>Moisture Absorption</td>
<td>0.73</td>
<td>%</td>
</tr>
<tr>
<td>Flexural Strength, Mpa</td>
<td>266</td>
<td>MPa</td>
</tr>
<tr>
<td>Flexural Modulus, Mpa</td>
<td>11,700</td>
<td>MPa</td>
</tr>
<tr>
<td>Tensile strength, Mpa</td>
<td>140</td>
<td>MPa</td>
</tr>
<tr>
<td>Tensile Modulus, Mpa</td>
<td>12,300</td>
<td>MPa</td>
</tr>
<tr>
<td>CLTE(-30cto 30c), mm/mm/c</td>
<td>1.87E-05</td>
<td>mm/mm/c</td>
</tr>
<tr>
<td>Poisson Ratio</td>
<td>0.38</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Weathered Mechanical Properties

Analysis of Tensile Strength Retention over Time

- Tensile Strength MPa South Florida
- Tensile Strength MPa Arizona
Weathered Mechanical Properties

Analysis of Flexural Strength Retention over Time

Flexural Strength MPa

Years of Outdoor Exposure

Flexural Strength MPa South Florida
Flexural Strength MPa Arizona
Weathered Mechanical Properties

Analysis of Modulus Characteristics over Time

- **Tensile Modulus MPa South Florida**
- **Tensile Modulus MPa Arizona**
- **Flexural Tangent Modulus MPa South Florida**
- **Flexural Tangent Modulus MPa Arizona**

Years of Outdoor Exposure

Modulus Values MPa

- 0
- 2000
- 4000
- 6000
- 8000
- 10000
- 12000
- 14000
- 16000
- 18000

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5
Part IV: Commercial Utilization
Applications Requiring:

- UV Stability
- A Paint-Free Solution
- Structural Performance

+ Black Texture
## SMC Formulation

### Component Table

<table>
<thead>
<tr>
<th>Component</th>
<th>PPHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>AROTRAN® 805 Resin</td>
<td>104</td>
</tr>
<tr>
<td>Catalyst</td>
<td>1.5</td>
</tr>
<tr>
<td>Inhibitor</td>
<td>1.2</td>
</tr>
<tr>
<td>Filler</td>
<td>35</td>
</tr>
<tr>
<td>UVS-02610/AM-9033</td>
<td>24</td>
</tr>
<tr>
<td>Glass Reinforcement (% by weight)</td>
<td>55</td>
</tr>
</tbody>
</table>
Current Commercial Application:

- CSP started manufacturing as CSP 834UV in 2015
- Currently being used in molding of Honda Ridgeline Bed
- SMC is being produced at CSP-Van Wert, Ohio facility
- Parts are molded at CSP, Salisbury, NC facility
- Material has been validated and approved for use on visible, textured, structural exterior parts at Honda
- Approval status at GM: waiting for specification number
- Panels with short vertical walls mold well
- Panels with deep vertical wall may give some discoloration due to lack of pressure
Part V, Conclusions:

- **Benefits of UV Stable SMC:**
  - EPA Fuel Economy and weight reduction
  - Mechanical properties necessary to structural applications
  - Favorable cosmetic appearance
  - Durability to retain appearance and properties under severe conditions
  - Improvement in cost, quality, and environmental concerns
  - Reduction in number of steps to completed product

- **Limitations:**
  - Complex molding geometries may present challenges
  - Need for texturing in molded application
  - Consistency in compounding and molding is critical
THANK YOU!