Recycling of Whole PET Carpet to Manufacture a Polymer Modified Aggregate for Hot Mix Asphalt

Charles A. Wilson, Ph.D.
Six Sigma Blackbelt
Polymer Modifications
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Overview of Presentation

- High Level Summary of Latest Recycling Process
- Development of Older Technology – How this All Started
  - Synthetic Lightweight Aggregate Technology (SLA)
  - Materials
  - Process
- Development of Latest Technology – Why Carpet can be Used
  - Polymer Modified Aggregate (PMAG) Technology
  - Materials
  - Process
  - Testing to be Completed
- Application: Hot Mix Asphalt (HMA)
  - Testing
  - Results
- SWOT Analysis
- Patents
Background on Newest Recycling Process

- Process Uses Entire Carpet
  - Face Fiber
  - Primary Backing and Secondary Backing
  - Latex and CaCO3
- Process Can Use Mixed Carpet Blends
  - PET, Nylon 6, Nylon 6/6, PP Face Fibers
  - PP and PVC Backing
  - Commercial Carpet
- Product: Sustainable Aggregate for Hot Mix Asphalt
- Benefit: Product Enhances Present Infrastructure
- Market: Large Carpet Capacity

How Do We Get There?
Synthetic Lightweight Aggregate (SLA) Technology (already developed)
Discussion of Aggregate Types

Normal Weight Aggregate (NWA) – Density ~ 2.50 – 2.80 g/cm³

Expanded Shale Lightweight Aggregate (ELA) – Density ~ 0.75 g/cm³

Synthetic Lightweight Aggregate – Density ~ 1.50 g/cm³
Materials Used in Synthetic Lightweight Aggregate

- **Binding Polymers – 20%**
  - Post Consumer Waste Plastics
- **Particulate Matter – 80%**
  - High Carbon Coal Fly Ash
  - Where it Comes From
- **Bonding - Discussion**
  - Polymers are Not Miscible
  - No Compatibilizers Used

<table>
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<tr>
<th>Polymer</th>
<th>% of Batch</th>
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<tr>
<td>PET (#1)</td>
<td>16.3</td>
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<tr>
<td>HDPE (#2)</td>
<td>30.1</td>
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<td>PS (#6)</td>
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<td>ABS</td>
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<td>HIPS</td>
<td>8.5</td>
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Takeaway: (a) Binding Polymers are Not Miscible  
(b) Very High Fly Ash Loading
SLA Manufacturing Process

Very Simple Twin Screw Extrusion Process
Milled Synthetic Lightweight Aggregate (SLA)

A: 80% Fly Ash/20% Mixed Plastic
B: 50% Fly Ash/50% Mixed Plastic
Unmilled Synthetic Lightweight Aggregate (SLA)

Takeaway: Unmilled SLA has Increased Surface Area
Transfer of Technology from Synthetic Lightweight Aggregate (SLA) to Polymer Modified Aggregate (PMAG)
Similarities Between the Technologies

- **SLA Particulate Matter**
  - **Fly Ash**
    - Shape - Angular
    - SG = 2.1 – 3.0
    - Size ~ 0.5 - 300 microns
    - Loading = 70 – 80%
  - **Post Consumer Plastics**
    - PET
    - HDPE
    - LDPE
    - PP
    - PS
    - ABS

- **PMAG Particulate Matter**
  - **CaCO3 in Carpet**
    - Shape - Round
    - SG = 1.9 – 2.4
    - Size ~ 30 – 75 microns
    - Loading = 45 - 55% +
  - **Mixed Waste Plastics**
    - Nylon 6
    - Nylon 6/6
    - PP
    - PET
    - PVC
    - Commercial
PMAG Manufacturing Process – Shear Carpet

Takeaway:
(a) Increases CaCO3 Content in Carpet
(b) Fibers Used in Asphalt Matrix as Reinforcement
New Technology Developed to Avoid Capital Equipment Costs, Energy and Time
Takeaway:
PMAG Technology Identical to SLA Technology
How is the Synthetic Lightweight Aggregate (SLA) Used: Application and Test Results
SLA Application – Hot Mix Asphalt (HMA)

- Partial Replacement of NWA with SLA in HMA
  - 0 (control), 5, 10, 15, and 20% SLA in HMA Mixes

- Made Asphalt Cement to Test (paving material)

Tests Included

- Resilient Modulus
  - (stiffness of bound pavement)
- Indirect Tensile Strength
  - (load is perpendicular to tensile failure)
- Rutting Test with Asphalt Pavement Analyzer
  - Discuss Apparatus
Resilient Modulus Test Results

Resilient Modulus vs. Percentage SLA in Blend

200% Increase in Resilient Modulus

Percentage of SLA in Aggregate Blend
Indirect Tensile Modulus Test Results

Tensile Strength vs. Percentage of SLA in Blend

210% Increase in Indirect Tensile Strength

Percentage of SLA in Aggregate Blend
Road Rutting
Rutting Test Results

Rut Depth vs. Percentage of SLA in Blend

- 80% Decrease in Rutting Depth

Percentage of SLA in Aggregate Blend:

- 0% SLA
- 5% SLA
- 10% SLA
- 15% SLA
- 20% SLA
Polymer Modified Aggregate Testing

- Same Initial Testing Protocol
  - Resilient Modulus
  - Indirect Tensile Modulus
  - Rutting Test
  - PMAG Test Results AS GOOD AS SLA Test Results

- Additional Testing
  - Freeze-Thaw Testing
    - (pothole analysis)

- Asphalt Pavement Analyzer
Business Impact - SWOT Analysis

**Strengths**
- Goes under the sea using a tube!
- Fifth Busiest Rail Transit in USA
- Adapts to new Tech: Clipper Cards
- Wifi and Cellphone Coverage
- Has Own Police Force
- Operators are chipper!
- Students ride free

**Weaknesses**
- Gets stuck in the transbay tube.
- Fifth Busiest Rail Transit in USA
- The Seats

**Opportunities**
- New Train Cars
- New Seats
- Complete Line to San Jose

**Threats**
- BART train cars are very expensive to maintain
- Funding hard to secure from taxpayers
- Employee Strike
- Misc Protest

**Internal factors**

**External factors**

**Positive**

**Negative**
Strengths - Advantages Over Others

- Process Can Use Whole Carpet
  - Reduces Capital Costs
- Process Uses ALL Carpet Types at Same Time
  - No Sorting of Carpet
  - Savings of Time and Money
- Innovative Method of Processing Whole Carpet
  - Reduces Capital Equipment Costs
  - Significant Cost Savings to Manufacture
  - Reduces Time to Manufacture
- Patent Pending Technology
- Process Not Limited to Producing Just Aggregate
Weaknesses - Disadvantages Over Others

- Not YET a Proven Material in HMA Market
- Change is Not Always Popular
  - “This is the Way We’ve Always Done It”
- PMAG More Expensive than NWA
- Sheared Carpet - 50% by Weight CaCO3
  - Is Particulate Concentration High Enough???
  - More CaCO3 - Additional Cost and Handling
- Adhesive - Commercial Carpet
  - Is Adhesive Attached to Carpet
  - How Will Extruder Deal with Adhesive
  - Any Toxicity Associated with Offgassing of Adhesive
- Need Government Interest Personnel on Team
  - Carpet Companies and Organizations
Opportunities – Exploit Elements to Advantage

- Recycling of Polyester Carpeting
- Green Infrastructure - Sustainable Technology
  - Diverts Carpet from Landfills
- Huge Market for Carpet Reclamation
  - Excellent Opportunity to Partner with Existing CARE Collectors
  - Assists Them in Collecting MORE Carpet
  - Decrease Disposal Costs
- Can Utilize Carpet Carcasses from Other Reclamation Companies
- Investment Capital from Variety of Resources
  - Carpet Industry
  - Asphalt Industry
  - Government - EPA/DEP/DOT – Local, State and Federal Level
  - Private Funding
- Increase Longevity of Infrastructure
  - Decrease Time Between Paving
  - Potential to Reduce of Potholes
Threats – Elements That Could Cause Trouble

- Asphalt Companies
  - May not Like Business Model
  - May not be Able to Pave as Often
  - Typically Have Long Term Contracts with Municipalities
- Working with Government Agencies Takes Time
  - Proving Out Technology Could take Time
  - Getting Technology Used in Field Could Take Time
  - Contracts in Place with Vendors May Have to Expire
- Contend with Special Interest Groups and Lobbyists
  - Need Key Personnel to Overcome Threat
- Commercial Carpet
  - Must Deal with Adhesives
Conclusions

- Straightforward Process to Recycle Carpet
- Process Can Utilize Whole Carpet
- Process Can Utilize Mixed Blends of Carpet
- Market for Recycled Product is Extremely Large
- Asphalt Pavement Test Results are Very Promising
- Additional Testing is Needed
- Several Processing Techniques are Advantageous
  - Extreme Savings in Time and Money
- Next Step: Economic Analysis for New Process
- Other Applications
  - Process Can be Used in Concrete and Cement
  - Material can be Profile Extruded
Developmental Partners

- Mr. James N. Sakorafos, Managing Partner, Polymer Modifications
  - Plastics Engineer, Sales and Marketing
- Dr. Robert Malloy, University of Massachusetts at Lowell
  - Plastics Engineering Department Chair
- Dr. Christopher Swan, Tufts University
  - Professor, Civil and Environmental Engineering
- Dr. Mohsen Kashi, AECOM, Inc.
  - Geotechnical Engineer
- Dr. Rajib Mallick, Worcester Polytechnic Institute
  - Professor, Civil and Environmental Engineering
  - Pavement Engineering, Recycling, Sustainable Engineering
- Mr. William Welisevich, Independent Environmental Consultant
- Mr. Fred Hooper, inTerra Innovation, Inc., Vice President
  - Civil Engineer Specializing in Asphalt and Concrete Products
- Mr. Terry Minnick, Molding Business Solutions, President
  - Economic Analysis, Synthetic Lightweight Aggregate Production Process
Questions

Polymer Modifications
Charles A. Wilson, Ph.D., Six Sigma Blackbelt
29 Brookline Street
Needham, MA 02492
617.512.9050
charlesadamwilson@verizon.net