Foundry Sand for Engineered Fills & Road Bases

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Foundries are crucial to transportation systems

- Foundries produce critical parts
  - Automotive
  - Construction
  - Aerospace
  - Rail
  - Defense
- DOD and DOE have industry partnerships

What is Foundry Sand?

- Sustainable & recycled material choice
- Local source of high quality fine aggregate
- Superior or comparable performance
- May provide cost savings

- FHWA Priority Material
- Part of US EPA’s Industrial Material Recycling Program
  - http://www.epa.gov/wastes/conserve/imr/foundry/

What is Foundry Sand?

- Engineered sand
- Byproduct of metal casting process
- Uniform grain size per source
- Most amended with bentonite
- High structural integrity
**Engineering Properties**

- Physical properties of foundry sand and natural sand

  - Foundry Sand, 45X Mag
  - Natural Ohio Fine Sand, 45X Mag

**Two types, different “fits”**

- **“Green sands”**
  - Bentonite clay bonds
  - 80% of volume
  - Large scale external molds
  - Intensively studied
  - Best “fit” where clay is an advantage

- **“Resin sands”**
  - Chemical resin bonds
  - 20% of volume
  - Used for cores and some sand molds
  - Fewer fines
  - Best “fit” where fine aggregate is required

**Engineering Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>ASTM Standard</th>
<th>FG1</th>
<th>FG2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density</td>
<td>C29</td>
<td>60-70 pcf</td>
<td>80-90 pcf</td>
</tr>
<tr>
<td>Moisture content</td>
<td>D2216</td>
<td>3-5%</td>
<td>0.5-2%</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>D854</td>
<td>2.5-2.7</td>
<td>2.6-2.8</td>
</tr>
<tr>
<td>Dry density</td>
<td>D698 Standard Proctor</td>
<td>110-115 pcf</td>
<td>100-110 pcf</td>
</tr>
<tr>
<td>Optimum moisture content</td>
<td>D69</td>
<td>8-12%</td>
<td>8-10%</td>
</tr>
<tr>
<td>Permeability coefficient</td>
<td>D2434</td>
<td>$10^{-7}$ – $10^{-5}$ cm/s</td>
<td>$10^{-7}$ – $10^{-6}$ cm/s</td>
</tr>
</tbody>
</table>

*Table 1. Typical physical properties of foundry sand*

**Constructability**
Conventional Equipment

Engineered Uses for Foundry Sand

- Embankment and structural fill
- Retaining wall backfill
- Roadway structural systems (Working Platform/Subbase)
- Blended granular bases
- Flowable fill
- Asphalt mix
- Concrete mix
- Manufactured soils/bioswales

Structural Fills & Embankments

Ohio Turnpike Project 779901

- Embankment required 54,000 tons of granular backfill
- Third lane extension
- Reinforced Using a Pre-Cast Concrete Modular System
- Contractor: The Great Lakes Construction Co.
Ohio Turnpike Project 439901

- Embankment required 58,000 tons of material
- Reinforced pavement supporting embankment
- Used MSE Retention system
- Contractor: Trumbull Corp./National Engineering

Wisconsin Hwy. 10 Embankment

IR 271 Slide Repair

- 10,000 tons of Spent Foundry Sand
- Excellent Drainage
- Excellent Compaction
- Layered Composite

FS in Granular Backfill

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soundness</td>
<td>15% max loss</td>
<td>3 %</td>
</tr>
<tr>
<td>Liquid limit</td>
<td>25% max</td>
<td>N/A</td>
</tr>
<tr>
<td>Plastic</td>
<td>6% max</td>
<td>Non Plastic</td>
</tr>
<tr>
<td>Proctor</td>
<td>&gt;=120 pcf</td>
<td>122 pcf</td>
</tr>
<tr>
<td>Friction angle</td>
<td>&gt;=34 degrees</td>
<td>35 degrees</td>
</tr>
<tr>
<td>Resistivity</td>
<td>&gt;=300 ohm-cm</td>
<td>5,600 ohm-cm</td>
</tr>
<tr>
<td>pH</td>
<td>5-10</td>
<td>9.2</td>
</tr>
<tr>
<td>Sulfates</td>
<td>&lt;200 ppm</td>
<td>87.6 ppm</td>
</tr>
<tr>
<td>Chloride levels</td>
<td>&lt;100 ppm</td>
<td>35 ppm</td>
</tr>
</tbody>
</table>

Source: Kurtz Bros., Inc. – typical ferrous sand used in Ohio Turnpike projects
Road Bases

Flexible pavement structure

- Flexible Pavement
- Base
- Subbase
- Subgrade

Cheap

Rigid pavement structure

- Rigid Pavement
- Base or Subbase
- Subgrade

State Highway Project

City Street Project

"K" Street

County Road Project

County "HH"
Performance Advantages in Sub Base or Embankment

- Not Susceptible to Freeze/Thaw
- Excellent compaction values
- Easy to use, handling not an issue
- Extremely uniform material, in contrast to conventional granular materials
- Relatively abundant and low cost
- Not moisture sensitive

Blended Granular Bases

- Foundry sand is being used in a variety of blended bases, inc.
  - Cement treated aggregate
  - Blends with Recycled Concrete Aggregate

Blended Aggregate Base Study – Cuyahoga Heights, Ohio

- Test Area
- Recycled Crushed Concrete Blended with Foundry Sand Compared to Standard ODOT Crushed Limestone

RCA AND FS PROPERTIES

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>DESCRIPTION</th>
<th>CBR</th>
<th>P200</th>
<th>MAX DRY DENSITY, PCF ASTM D698</th>
<th>OPTIMUM MOISTURE CONTENT, %</th>
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<tbody>
<tr>
<td>8521</td>
<td>Subgrade fill: Cinder, gravel, brick, &amp; slag</td>
<td>2</td>
<td>23</td>
<td>101</td>
<td>18</td>
</tr>
<tr>
<td>8454</td>
<td>Recycled Concrete</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>8428</td>
<td>Foundry Sand</td>
<td>18</td>
<td>9.5</td>
<td>114</td>
<td>15</td>
</tr>
<tr>
<td>8525</td>
<td>304 RCA/FS Blend</td>
<td>34</td>
<td>7.9</td>
<td>119</td>
<td>13</td>
</tr>
<tr>
<td>8522</td>
<td>304 Crushed Limestone</td>
<td>55</td>
<td>11</td>
<td>141</td>
<td>6</td>
</tr>
</tbody>
</table>
**Flowable Fill (CLSM)**

**Typical Mix Design**

- As recommended in ACI 229R:

<table>
<thead>
<tr>
<th>Component</th>
<th>Typical Mix Design (lb/yd$^3$)</th>
<th>Range (lb/yd$^3$)</th>
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<tbody>
<tr>
<td>Fine Agg/RFS</td>
<td>2850</td>
<td>1850 - 2910</td>
</tr>
<tr>
<td>Cement</td>
<td>100</td>
<td>50 - 200</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>250</td>
<td>0 - 300</td>
</tr>
<tr>
<td>Water</td>
<td>500</td>
<td>325 - 580</td>
</tr>
</tbody>
</table>
Advantages in CLSM

- Reduced cost with better properties
  - Less bleed water than concrete sand or other materials
  - Less consolidation/settlement
  - Excellent workability – no segregation

Foundry Sand Role in CLSM

- Replace virgin fine aggregate in flowable fill with foundry sand
- Reduce the need for adding fines (fly ash)
- Additional water may be required when flowable fills contain foundry sand for hydration of bentonite
- Reduces need for more expensive cementitious fly ash
- EPA’s CPG requires use of RFS and/or Fly Ash in Federally-financed projects

Hot Mix Asphalt

- Gradation
- Particle Cleanliness
- Soundness
- Absorption & Stripping

Experience in HMA

- Commercial applications successful
- FHWA has done research
  - Meets Superpave guidelines
- PennDOT fine aggregate spec
- National Asphalt Pavement Association (NAPA) has endorsed use
- Guidelines under development
  - Will recommend 7-10 % mixture
  - Some mixes use up to 30%
**Asphalt Paving**

*Foundry Sand Market in NW Indiana*

- Hummer test track – South Bend
- ~1500 tons of core sand in the asphalt mix.

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**Traction Control Material**

- Traction with added vehicle weight over drive wheels
- Traction if your stuck
- Mixing with road salt

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**Concrete**

- Non-conforming with specifications for concrete sand
  - Lower strength for same cement content due to finer material
  - Air void system is consistent with industry standards
  - Good workability
  - Can be combined with other materials that are recycled
Manufactured Soils

- 50 million TPY used in blending soils for horticulture
- Demand for high quality topsoil in urban areas
- Foundry sand blends have excellent properties

Iron Foundry Slags

- Similar in chemistry & uses to blast furnace slags
  - Air Cooled
  - Granulated
- Road bases
- Bituminous aggregates
- Road abrasives

For More Information:

- Documented field projects
  - WisDOT, InDOT, TxDOT, PennDOT, Ohio Turnpike, & others
  - Univ. of Texas, Purdue, Penn State, Univ. of Wisconsin, et. al.
- FHWA “Foundry Sand Facts for Civil Engineers”
- For more information:
  - http://www.foundryrecycling.org/