Use of Lightweight Aggregate Fill in Highway Projects for Settlement Control and Construction Speed

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**Structural Lightweight Aggregate**

ESCS LWA is a manufactured aggregate
- Raw material is shale, clay or slate
- Expanded in a rotary kiln at 1900-2200° F

- Gas bubbles formed in softened material are trapped when cooled
Relative Density of Lightweight vs. Normal Weight Aggregate

Relative density for rotary kiln expanded lightweight aggregates
  ◦ Range from 1.3 to 1.6
Relative density for normal weight aggregates
  ◦ Range from 2.6 to 3.0

Twice the volume for same mass

Half the mass for the same volume
Aggregate Gradations

- After crushing and screening, lightweight aggregate (LWA) fractions are blended for
  - Uniformity of specific gravity
  - Optimal gradation

- LWA conforms to AASHTO M 195 gradations & other properties
  - Coarse sizes shown
  - Several finer gradations of fine aggregate (sand) available
Physical Properties of LWA

Vitrified ceramic material
  – Hardness equivalent to quartz
Pores with limited connectivity reduce density
  – Results in increased absorption
  – But does not act like a sponge
  – Porosity vs. Permeability
## General Engineering Properties of ESCS 3/4" to No. 4 Aggregate Grading*

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<td>Magnesium Sulfate</td>
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<td>&lt;6 %</td>
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<td>Abrasion Resistance</td>
<td>Los Angeles Abrasion</td>
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<td>Chloride Content of Soils</td>
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<td>Sieve Analysis</td>
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<td>Stability (Phi Angle, φ)</td>
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<td>ASTM D 3080 Comment 3</td>
<td>Comment No. 3</td>
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<td>30° - 38° (fine sand - sand &amp; gravel)</td>
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<td>Consolidated Drained</td>
<td>Corps of Engineers EM 1110-2-1906 Appendix X Comment 3</td>
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<td>Loose</td>
<td>ASTM C 29</td>
<td>Dry &lt;50 lb/ft³ Saturated &lt;65 lb/ft³</td>
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<td>89 -105 lb/ft³</td>
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<td>pH Meter</td>
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</tbody>
</table>

*From “Lightweight Expanded Slate Coarse Aggregate for Geotechnical Applications”*
ESCS Geotechnical Projects

- Picardy Avenue Interchange – 2004-05
- 150,000 + CY
Keystone walls
Case History:

Baton Rouge, Louisiana

- Material: Gravelite® Lightweight Aggregate
- Project: I-10 Picardy Interchange
- Project Completion: 2006
- Application: Embankment fill / retaining wall backfill
- Quantity: 210,000 cu yd
Rapid Embankment Construction of US 17 Bypass Interchange Over Soft Compressible Soils Using Lightweight Aggregate Myrtle Beach, SC
Myrtle Beach, SC
Regional Experience

Fantasy Harbour
2 Miles Away!
US 17/SC 707 (Backgate)
Fantasy Harbour
Geotechnical Experience

- 10’ – 42’ Embankment Ht.
- Settlement 9” to 67”
- Liquefaction – Loose Sands
- Embankment Slope Instability
  ◦ (Static/Seismic)

- Ground Improvement!!!
- 2 Year Embankment Construction Contract
- 2-3 Year Bridge Construction Contract
- 4 1/2 to 5 Years total construction time
US 17/ SC707 Interchange (Backgate)

South Bridge Approach

North Bridge Approach
Geotechnical Challenges

- 30’ to 60’ - Soft to Firm Clay
- Pockets of Loose Sands in upper 10’
- Intermediate Medium Sands (253+00 to 256+00)
- Loose Sands above Dense Sands (Liquefiable)
- Pee Dee Formation
Bridge Abutment Settlement
(Normal Weight Fill \approx 120 \text{ pcf})

78\text{"} of settlement!!
Geotechnical Design Approach

- Lightweight Aggregate Borrow – Reduce Magnitude of Settlement
- Prefabricated Vertical Drain (PVD) / Granular Surcharges – Increase Rate of Settlement and Facilitate Rapid Construction
- Deep Soil Mixing – Improve Seismic Slope Stability and Bridge Abutment Foundation Performance
- Mechanically Stabilized Earth (MSE) Walls
  - 2-Stage and 3-Stage MSE Wall Construction
  - Vertical Slip Joints
PVD Installation

3 Million LF
MSE Walls

Permanent MSE Walls
- Two-Stage Construction
- Three-Stage Construction (w/Drainage Structures)

Temporary MSE Walls
(Welded Wire Mesh Facing)

30,500 SF
51,500 SF
Deep Soil Mixing Columns (Overlap – Block Pattern)

- Seismic Slope Stabilization – Shear Key 35,600 CY
- Improved Performance of Bridge Abutment Foundations
Project Construction Stages (North Abutment 252+01)

Bridge Approach Embankment
Stage 4

Ramp D
Stage 3

Ramp B
Stage 2
11TH ST. BRIDGE REPLACEMENT DESIGN-BUILD PROJECT

Location: Washington, D.C.
Owner: District DOT
Designers: URS, HNTB Corp.
Geotechnical Engineer: JMT
Contractor: Skanska/Facchina JV
Winner of the Road and Bridge 2012 Bridge Project of the Year
Lightweight aggregate fill used to:

• Speed the construction
• Reduce settlement under the roadway
• Protect historic structures
Project area contained storm water drainage outfall structures constructed in the 1850s.

- Up to 20 feet of new fill over historic structures.
- LWA fill used over the structures to minimize load.
- Normal weight fill was used in areas not above the structures.
Comparison of Vertical Stress

\[ \sigma_v = 50 \times 20 = \textbf{1,000 lbs/sq.ft.} \]

\[ \sigma_v = 120 \times 20 = \textbf{2,400 lbs/sq.ft.} \]
Project: Corridor X

Project Completion:
- Phase I – 2012;
- Phase II - April, 2013

Application: Fill over concrete box culvert

Quantity: 16,500 CY
LYNX Light Rail Station

Location: Charlotte, NC
Owner: City of Charlotte
Structural Engineer: King Guinn and Associates
Geotechnical Engineer: F&R
Contractor: Crowder Construction Company
• 3-story parking structure
• Adjacent to elementary school
• 3-story backfill required to maintain embankment level with schoolyard
Location: Woodbridge, VA
Owner: Virginia Department of Transportation
Designer: Parsons Binckerhoff
Geotechnical Engineer: Burgess and Niple
Contractor: Lane Construction of Chantilly, VA
• Abutments scoured by 2011 storms
• Cracking and subsequent failure of one abutment
• Bridge was closed in January 2012.
• New bridge abutments are founded on drilled shafts.
• LWA backfill behind abutments to decrease the lateral earth pressure on abutment walls and lateral loads on the drilled shafts.
• New bridge opened August 2012
GREENSBORO WESTERN LOOP FROM NORTH OF I-85 NEAR GROOMETOWN TO SR-1541 (WENDOVER AVE).

OWNER: NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
WALL DESIGNER: FOSTER GEOTECHNICAL
CONTRACTOR: ARCHER WESTERN CONTRACTORS
New SME retaining wall
Compressible soils
Limited area for over excavation.
Secured Pentagon Entrance

LOCATION: Washington, District of Columbia
Contractor: Facchina Construction
Designer: Dewberry Fairfax, Virginia
Geotechnical Engineer: Mactec Richmond, Virginia
• Relocation of a major highway
• Improvements to existing road and site access network
• Increased traffic volumes and enhance security.
• Underlying compressible clay soils, up to 15 feet thick.
• Total consolidation using normal weight fill ~15”
• Consolidation time using normal weight fill soils (110 pcf) estimated to be >180 days.
NC Highway 133
Roadway Repair

Designer: NC DOT Geotechnical Unit
Contractor: APAC Wilmington, NC
Removal of ~300 linear feet of roadway on Hwy 133 on each side of Allen Creek Bridge.
Asphalt removed was >18” thick in isolated areas of the roadway prior to the repair.
LWA fill in with a geotextile fabric to remediate the area.
Compacted moist density shall be determined by a modification of ASTM D 698 (AASHTO T 99) “Standard Test Methods For Laboratory Compaction Characteristics For Soil Using Standard Effort.”
ESCSI Recommended Compaction Procedure for LW Coarse Aggregate

Modification:

- The aggregate shall be placed in three layers in a standard 1/2 cubic foot bucket.
- Each layer compacted by 25 blows of a 5.5 pound hammer dropped from a distance of 12 inches.
- The aggregate is compacted only once at the received moisture content.

This procedure is referred to as the One Point Proctor (OPP).
One Point Proctor Test
(Modified ASTM D 698)

- LWA sample tested only once at the as received moisture content
Field Density Control

Open graded coarse aggregate is often thought of as self-compacting.

Not so!

All open graded coarse aggregates, lightweight included, require some level of compaction to give the maximum stability and minimize settlement of the aggregate.
None of these methods work well for **coarse** LWA
- Not necessary – just dump and compact like 57 or 67 stone
The method most often used for density control of lightweight aggregate is a combination of prescriptive compaction requirements and the modified ASTM D 698 test.
Typical prescriptive construction recommendations include:

- Place material in approximately uniform horizontal layers
- Max. thickness of layers = 12 inches loose thickness when using a vibratory roller.
- Avoid operation of construction equipment other than compaction equipment on exposed lightweight aggregate.
- Vibratory roller static weight ≤12 tons
- Min. and max. passes specified
Prescriptive Requirements Cont.

• In areas where portable vibratory plate compactors must be, it is recommended that the maximum lift thickness be 6 inches and a minimum of 2 passes be made across the area.

• In this case, a pass is considered to be vibration of the area covered by the vibratory plate compactor for at least 10 seconds before moving to an adjacent location.
Resistivity and pH

- Field resistivity testing is recommended (ASTM G57)
  - Lab test requires addition of water until resistivity of the water is being tested.

- pH test should be run on aggregate gradation used. If test method is for pH of soil or water, do not grind aggregate to make it soil.
For more information

www.ESCSI.org
Questions?

1 lb. Soil
1 lb. Gravel
1 lb. Limestone
1 lb. Sand