Structural Lightweight Concrete for Accelerated Bridge Construction

AASHTO T-4 Meeting
June 28, 2005

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Carolina Stalite Company

EXPANDED SHALE, CLAY AND SLATE INSTITUTE

ROTARY KILN PRODUCED STRUCTURAL LIGHTWEIGHT AGGREGATE
Structural Lightweight Aggregate

Manufactured aggregate

- Expanded shale, clay or slate
- Manufactured in a rotary kiln
Structural Lightweight Aggregate

Quality control

• Manufacturing
• Storage
• Shipping
20 plants in the US
See [www.escsi.org](http://www.escsi.org) for locations
Specific Gravity of Lightweight vs. Normal Weight Aggregate

Specific gravity for rotary kiln expanded lightweight aggregates
• Range from 1.3 to 1.6

Specific gravity for normal weight aggregates
• Range from 2.6 to 3.0

1 lb. of each type of aggregate
Unit Weight of Lightweight vs. Normal Weight Concrete

Lightweight concrete
  • 103 to 125 lbs per cubic foot

Normal weight concrete
  • 140 to 150 lbs per cubic foot

Specified density concrete
  • Between the above ranges
  • Combination of lightweight and normal weight aggregates
Benefits of Using Lightweight Concrete

Main benefits

- Reduced dead load of structure
- Improved durability
- Reduced handling and transportation costs for precast components
  - Discussed later in presentation with applications and projects
Benefits of Using Lightweight Concrete

Reduced dead load

- A typical reduction of 25-35% in dead load compared to normal weight concrete

- Improves efficiency of designs
  - Increased spans
  - Wider girder spacings
  - Increased deck width on same superstructure
  - Reduced foundations
  - Reduced reinforcement and prestressing
  - Reduced structure mass for seismic designs
  - Reduced transportation costs for precast
Benefits of Using Lightweight Concrete

Compressive strength

• Structural lightweight concrete is specified as having a minimum compressive strength of 2,500 psi

• Depending on the type of aggregates specified, structural lightweight concretes can achieve compressive strengths up to 12,000 psi
Benefits of Using Lightweight Concrete

Improved bond between cement paste and lightweight aggregates

- Cellular structure and irregular surface of aggregate (mechanical bond)
- Chemistry of the aggregates and cement (pozzolanic bond)
- Transition zone
- Improves durability by reducing cracking
Benefits of Using Lightweight Concrete

Elastic compatibility

- Modulus of elasticity of lightweight aggregates are closer to the modulus of the cement paste
  - Reduces microcracking, autogenous shrinkage, and shrinkage cracking
  - Reduces stress concentrations that form around stronger normal weight aggregate

- Improves durability by reducing cracking
Benefits of Using Lightweight Concrete

Internal curing

• Absorbed moisture within the lightweight aggregate is released over time into the matrix providing enhanced curing

• Especially helpful for high performance concrete that is nearly impermeable to externally applied curing moisture

• Improves tolerance of concrete to improper curing

• May increase strength of concrete
Benefits of Using Lightweight Concrete

Wear and safety characteristics for bridge decks

• Uniform wear
• Non-polishing aggregate
• High skid resistance
• Excellent freeze thaw performance even when lightweight aggregate is exposed
Boulevard Bridge, Richmond, VA

After 34 yrs service
- Wear was minimal
- Wear was uniform
- No deterioration
- No corrosion

- Slabs from bridge are still available for evaluation
Structural Lightweight Concrete: Applications and Projects
Applications of Lightweight Concrete

Bridge Construction
- Decks
- Superstructures
- Other components

Marine Structures

Multi-story Buildings
- Mid-Rise/High-Rise Construction

Tilt-Up Concrete Construction
Lightweight Concrete in Bridges

References

• "Criteria for Designing Lightweight Concrete Bridges" FHWA/RD-85/045
• "Building Bridges and Marine Structures" ESCSI
• "Back-Up Statistics to Building Bridges and Marine Structures" ESCSI
• "Bridge Rehabilitation with Structural Lightweight Concrete – Whitehurst Freeway, Washington, DC" ESCSI Reprint
Lightweight Concrete in Bridges

FHWA Report (1985)

- Estimated "... that more than 400 bridges have used lightweight concrete in US."
- Earliest recorded use of structural lightweight concrete in bridges in 1927
- San Francisco-Oakland Bay Bridge (1936)
  - Original upper deck is lightweight concrete
  - Reconstructed lower deck is lightweight concrete (early 1960s)
- Use appeared to peak in mid 1950s
Lightweight Concrete in Bridges

Napa River Br.
Napa, CA
Ltwt CIP PT Box
1977

Coronado Br.
San Diego, CA
Ltwt PS Girders
1969

Neuse River Br.
New Bern, NC
Ltwt CIP Deck
1999
Bridge Applications for Lightweight Concrete

- Rehabilitation projects
- Improved handling
- Cost considerations
- Geotechnical projects
Whitehurst Freeway, Washington, DC

Major artery in Washington, DC

- Upgrade from H20 to HS20
- Increase bridge width
- Normal weight deck with topping was replaced with lightweight concrete deck
- Only minor modifications to the steel framing
James River Bridge, Richmond, VA

I-95 through downtown Richmond

• Replace deck while maintaining traffic

• Prefabricated full-span units with lightweight concrete deck
Emergency deck replacement

- 3 options considered
- Selected system used metal grating filled with lightweight concrete
- Deck was replaced using 7.5 ft x 30 ft prefabricated panels
Coleman Bridge, Yorktown, VA

Original structure completed in 1952
  • 26 ft wide with 2 lanes

Replacement completed in 1996
  • 74 ft wide with 4 lanes and shoulders

Three deck options were considered
  • Orthotropic deck
  • Filled grid deck with an overlay
  • Lightweight concrete deck

Lightweight deck selected based on good experience in VA and cost
Coleman Bridge, Yorktown, VA

Lightweight concrete deck reduced weight of new structure

- The pier caps only had to be widened
- Reduced steel in new trusses

All truss spans were replaced in single two-week closure

- Entire spans were prefabricated and barged to the site
- Detour was more than 70 miles
Woodrow Wilson Bridge, Washington, DC

Original structure completed in 1962
• 2 – 38 ft roadways with 89 ft overall width

Replacement completed in 1983
• 2 – 44 ft roadways with > 93 ft overall width
• Improvements made without strengthening the steel structure

Lightweight concrete used for deck panels
• Reduced weight
• Excellent record of durability on bridge projects in the Mid-Atlantic region
Benefit of Lightweight Concrete for Handling

Recent research for GDOT at Georgia Tech on high performance lightweight concrete

Analytical study
- Designing a 150 ft bulb tee girder
- Limiting weight of girder + truck to 150 kips

Physical testing
- Design $f_{c'} = 10$ ksi with unit weight = 120 pcf
- Measured other properties
- Compared to AASHTO Specs
Benefit of Lightweight Concrete for Handling

Results of analytical study at Georgia Tech

Gross Vehicle Weight (GVW) vs. Girder Length

- Type IV (N)
- Type IV (L)
- Type V (N)
- Type V (L)
- BT-54 (N)
- BT-54 (L)
- BT-54M (N)
- BT-54M (L)
- BT-63 (N)
- BT-63 (L)
- BT-63M (N)
- BT-63M (L)
- BT-72 (N)
- BT-72 (L)
- BT-72M (N)
- BT-72M (L)

(GVW (kips) vs. Girder Length (ft) (fc' = 8, 10 and 12 ksi))
Benefit of Lightweight Concrete for Handling

Results of analytical study at Univ. of TX at Austin

- Assumed unit weights of concrete
  - 150 pcf for normal weight concrete
  - 118 pcf for lightweight concrete

4" thick PS concrete SIP deck forms

25% increase in panels per load

FHWA/TX-03/1852-2, p. 55
Benefit of Lightweight Concrete for Handling

Example using Edison Bridges, Fort Myers, FL

Precast columns
- Max wt = 89 kips at 150 pcf
- Max wt = 74 kips at 125 pcf

17% reduction

Precast caps
- Max wt = 155 kips at 150 pcf
- Max wt = 129 kips at 125 pcf
Benefit of Lightweight Concrete for Handling

PS plant was manufacturing 60 ft voided slabs

• Wt of 60 ft slab = 40,800 lbs at 150 pcf

Begins manufacturing 70 ft voided slabs

• Wt of 70 ft slab = 47,400 lbs at 150 pcf

• Crane in plant cannot handle 70 ft slabs

Reduce weight with blended coarse aggregate

• Wt of 70 ft slab at 129 pcf = wt of 60 ft slab at 150 pcf
Benefit of Lightweight Concrete for Handling

<table>
<thead>
<tr>
<th>Analysis of Shipping Costs of Low-Density Products</th>
<th>Project Example 1</th>
<th>Project Example 2</th>
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<tbody>
<tr>
<td><strong>Shipping Cost / Truck Load</strong></td>
<td>$1,100</td>
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<td><strong>Number of Loads Required</strong></td>
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<td>Normal Weight</td>
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<td>Less Premium Cost of LWC</td>
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<td>Increased Gross Margin</td>
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Courtesy of Big River Industries, Inc. Specified Density (ESCSI), p. 10
Costs of Lightweight Concrete

Survey of users (mostly PS plants) conducted as part of project at University of TX at Austin

Premium cost for lightweight concrete

- Range from $6 to $30 per CY
- Average of about $18.50 per CY
- Report published in January 2002
**Geotechnical Applications**

**Providence, RI**

Retaining wall behind the Rhode Island State House at the Providence River

- Approx. 3,500 CY of lightweight aggregate fill were used behind the wall
- Project weight was reduced so dramatically that the probability of deep seated bulkhead failure was virtually eliminated
Geotechnical Applications

Pentagon Secured Entrance

MSE wall with lightweight aggregate fill

- Reduced amt. of settlement
- Shortened time of settlement
For more information, please call, or visit www.escsi.org
## Benefit of Lightweight Concrete for Handling

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**Incr. Margin / LWC Premium**

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*Courtesy of Big River Industries, Inc.*

Specified Density (ESCSI), p. 10