



March 19, 2012

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Subject: **Final Report of ASTM C 330-09 *Standard Specification for Lightweight Aggregates for Structural Concrete* on Livlite Intermediate Lightweight Aggregate**
TEC Services Project No.: 10-0825
TEC Services Sample ID: 11-675

Dear Mr. Pelicone:

Testing, Engineering & Consulting Services, Inc. (TEC Services) is a AASHTO R18 and International Accreditation Services (IAS) (TL-458) accredited laboratory in compliance with ANS/ISO/IEC Standard 17025:2005 and a Army Corps of Engineering approved laboratory. TEC Services is pleased to present this report of our testing on the Livlite Intermediate lightweight aggregate submitted to our laboratory on December 21, 2011. The results of this testing pertain only to the samples tested. The aggregate was tested in accordance to ASTM C330-09 *Standard Specification for Lightweight Aggregates for Structural Concrete* as authorized by the service agreement (TEC-PRO-10-0825) dated August 2010.

This specification covers lightweight aggregates intended for use in structural concrete in which prime considerations are reducing the density while maintaining the compressive strength of the concrete. The maximum and minimum requirements for this specification are presented in Section 4 *Chemical Composition* and Section 5 *Physical Properties* of ASTM C330 and are reported in Table 1. Based on the results to date, the Livlite Intermediate lightweight aggregate submitted to our laboratory meets and/or exceeds the requirements of ASTM C330.

Table 1: Summary of Test Results

| Section 4 - Chemical Composition | Test Results | ASTM C330 Requirements |
|---|--------------------------|-------------------------------|
| Organic Impurities (Color change) | 1 | 3 (max) |
| Staining (Stain index) | 0 | 60 (max) |
| Loss on Ignition | 0.75 | 5% (max) |
| Section 5 – Physical Properties | | |
| Clay Lumps and Friable Particles (Dry mass) | 0.20% | 2% (max) |
| Bulk Density (Loose) | 30.8 lbs/ft ³ | 55 lbs/ft ³ (max) |
| Density Factor (Specific Gravity) | 1.14 | ---- |
| Compressive Strength (Based off of Equilibrium Density) | 4,440 psi | 2,870 psi (min) |
| Splitting Tensile (Based off of Equilibrium Density) | 375 psi | 305 psi (min) |
| Drying Shrinkage | -0.032 | -0.070 % (max) |
| Popouts | 0 | 0 |
| Grading | See Section 5.1.2 Below | |
| Resistance to Freezing and Thawing | 97% | ---- |

Concrete mixtures containing the intermediate lightweight aggregate were batched in order to make test specimens for compressive strength, splitting tensile, drying shrinkage and resistance to freezing and thawing. The material sources and amount of material used in the concrete mix are reported in Table 2. Fresh properties are reported in Table 3.

Concrete Mix Proportions

Table 2: Mix Proportions

| Material | Source | Amount (pcy) |
|-----------------------|--------------------------|-------------------------|
| Cement | Vulcan, Newberry | 564 |
| Fine Aggregate | Shorter Natural Sand | 1,247 |
| Coarse Aggregate | Vulcan Norcross #57 | 550 |
| Lightweight Aggregate | Livlite Intermediate | 500 |
| Air Entrainment | Vinsol Resin | 2.15 oz/yd ³ |
| Water Reducer | Grace, Zyla 620 | 15.8 oz/yd ³ |
| Water | Lawrenceville City Water | 290 |
| Total | | 3,151 |

Table 3: Fresh Properties

| | |
|------------------------------------|-------|
| Slump (inches) | 3.00 |
| Unit Weight (lbs/ft ³) | 115.9 |
| Air Content (%) | 6.5 |
| Temperature (°F) | 73 |

Test Results

Section 4.1.1 Organic Impurities

Requirement – Lightweight aggregate subjected to the test for organic impurities shall not produce darker color than standard.

Result – The intermediate lightweight aggregate did not show any color change.

Section 4.1.2 Staining

Requirement – Lightweight aggregate shall have a stain index of less than sixty.

Result – The intermediate lightweight aggregate showed no stain, which indicates an index of zero.

Section 4.1.3 Loss on Ignition

Requirement – Lightweight aggregate shall have a loss of ignition not more than five percent.

Result – The Intermediate lightweight aggregate had a loss on ignition of 0.75 percent.

Section 5.1.1 Clay Lumps and Friable Particles

Requirement – The amount of clay lumps and friable particles shall not exceed two percent by dry mass.

Results – The intermediate lightweight aggregate had 0.20 percent clay lumps and friable aggregate.

Section 5.1.2 Grading

The grading shall be by mutual agreement between interested parties. The Grading and the suggested ranges are reported in Table 4.

Table 4: Grading and Suggested Range

| Sieve Size | % Passing | % Range Suggested |
|------------|-----------|-------------------|
| ½ in | 100 | 100 |
| ¾ in | 100 | 80 - 100 |
| #4 | 30.6 | 5 - 40 |
| #8 | 7.0 | 0 - 20 |
| #16 | 2.5 | 0 - 10 |
| #30 | 0.9 | |
| #50 | 0.5 | |
| #100 | 0.4 | |
| #200 | 0.2 | 0 - 10 |
| Pan | 0 | |

Section 5.1.4 Bulk Density (Loose)

Requirement – The maximum bulk density (loose) for coarse aggregate is 55 lbs/ft³.

Result – The intermediate lightweight aggregate had an average bulk density (loose) of 30.8 lbs/ft³.

Section 5.1.6 Density Factor

The density factor was tested in accordance with ACI 211.2 *Standard Practice for Selecting Proportions for Structural Lightweight Concrete*. The sample was dried to a constant mass, soaked for 24 hours, and allowed to drain for 10 minutes before testing. The aggregate had an absorption of 18.8%, and the specific gravity was 1.14.

The calculated equilibrium density of the concrete was determined in order to determine the specification requirements for the compressive strength and split tensile. The results of the calculated equilibrium density are reported in Table 5.

Table 5: Equilibrium Density of the Compressive Strength Specimens

| Specimen ID | Equilibrium Density (lbs/ft ³) |
|----------------|--|
| 11-675-A | 108.6 |
| 11-675-B | 108.7 |
| 11-675-C | 107.9 |
| Average | 108.4 |

Section 5.2.1 Compressive Strength and Splitting Tensile Strength

Compressive Strength

Requirement – For a concrete with an equilibrium density of 108.4 lbs/ft³, the minimum compressive strength is 2,870 psi; this was calculated by interpolation from the values presented in section 5.2.1 and are reported in Table 6. The specimens tested were 4” x 8” cylinders and the results are reported in Table 7.

Table 6: Compressive Strength Requirements

| Equilibrium Density (lbs/ft³) | Compressive Strength Requirements (psi) |
|---|--|
| 110 | 3,000 |
| 105 | 2,500 |

Table 7: Compressive Strength Results

| Sample ID | Compressive Strength (psi) |
|------------------|---------------------------------------|
| 11-675-(A) | 4,590 |
| 11-675-(B) | 4,300 |
| 11-675-(C) | 4,250 |
| 11-675-(D) | 4,600 |
| Average | 4,440 |

Splitting Tensile

Requirement – For a concrete with an equilibrium density of 108.4 lbs/ft³, the minimum splitting tensile strength is 305 psi. The specimens tested were 6” x 12” cylinders and the results are reported in Table 8.

Table 8: Splitting Tensile Strength Result

| Sample ID | Splitting Tensile Strength (psi) |
|------------------|---|
| 11-675-1 | 440 |
| 11-675-2 | 270 |
| 11-675-3 | 460 |
| 11-675-4 | 390 |
| 11-675-5 | 360 |
| 11-675-6 | 430 |
| 11-675-7 | 400 |
| 11-675-8 | 250 |
| Average | 375 |

Section 5.2.3 Drying Shrinkage

Three length change beams (3" x 3" x 11¼") were moist cured for seven days. Upon the completion of the moist curing an initial reading was obtained, which was used as the base length for the drying shrinkage calculations. The samples were then placed in a curing cabinet maintained at 100 ± 2°F with a relative humidity of 32 ± 2%.

Requirement – Due Date 2/23/2012

Table 9: Drying Shrinkage at 28 Days

| Sample ID | Length Change at 28 Days (%) |
|----------------|------------------------------|
| 11-675 (1) | -0.031 |
| 11-675 (2) | -0.034 |
| 11-675 (3) | -0.032 |
| Average | -0.032 |

Section 5.2.4 Popouts

Requirement – There shall be no popouts observed after test concrete made with the tested lightweight aggregate is subjected to an autoclave in accordance with ASTM C151-09 *Standard Test Method for Autoclave Expansion of Hydraulic Cement*.

Result – No popouts were observed.

Section 5.2.5 Resistance to Freezing and Thawing

Requirement – Satisfactory performance for intended use.

Results – Relative Dynamic Modulus = 97%

We appreciate the opportunity to provide our services to you on this project. Should you have any questions or comments regarding this report, please feel free to contact us at your convenience

Sincerely,

Testing, Engineering & Consulting Services, Inc.



Steven Maloof
Project Manager



Shawn P. McCormick
Laboratory Manager