TEC Services
Testing • Engineering • Consulting

June 12, 2017

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Subject: **Final Report of ASTM C330**
Carolina Stalite ⅜ Inch Coarse Lightweight Aggregate
TEC Services Project No: 04-0514
TEC Services Sample ID: 17-095

Dear Mr. Wall:

Testing, Engineering and Consulting Services, Inc. (TEC Services) is an AASHTO R18, ANS/ISO/IEC 17025:2005, and Army Corps of Engineers accredited laboratory. TEC Services is pleased to present this final report of our testing on the ⅜-inch lightweight aggregate submitted to our laboratory on January 30, 2017. The results of this testing pertain only to the samples tested. The aggregate was tested in accordance with ASTM C330-14 *Standard Specification for Lightweight Aggregates for Structural Concrete* as authorized by the service agreement (TEC-PRO-04-0514) dated March 29, 2005.

This specification covers lightweight aggregates intended for use in structural concrete in which the 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, the ⅜-inch 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)	20	60 (max)
Loss on Ignition	0.74	5% (max)
Section 5 – Physical Properties		
Clay Lumps and Friable Particles (Dry mass)	0.1 %	2% (max)
Bulk Density (Loose)	47 lb/ft^3	55 lb/ft^3 (max)
Relative Density (Specific Gravity – Wetted Surface Dry)	1.516	----
72-Hour Absorption	5.9 %	----
Compressive Strength (Requirement based off of Calculated Equilibrium Density)	4,470	2,890 psi (min)
Splitting Tensile (Requirement based off of Calculated Equilibrium Density)	410	308 psi (min)
Drying Shrinkage	-0.028	-0.070 % (max)
Popouts	No Popouts	No Popouts
Grading	See Section 5.1.2 Below	
Resistance to Freezing and Thawing - Average Relative Dynamic Modulus (%)	100	

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 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 lightweight aggregate showed light stain, which indicates an index of 20.

Section 4.1.3 Loss on Ignition

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

Result – The lightweight aggregate had a loss on ignition of 0.74 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. The lightweight aggregate had 0.1 percent clay lumps and friable aggregate.

Section 5.1.2 Grading

The grading shall conform to the requirements in Table 1 of ASTM C330. The Grading and the required grading are reported in Table 2.

Table 2: Grading & Required Grading

Sieve Size	% Passing	Required % passing (⅜" to #4)
½ in (12.5mm)	100	100%
$^{3}/_{8}$ in (9.5mm)	96.6	80-100%
#4 (4.75mm)	11.7	5-40%
#8 (2.36mm)	4.7	0-20%
#16 (75µm)	4.0	0-10%
#200 (75µm)	2.0	0-10%

Section 5.1.4 Bulk Density (Loose)

Requirement – The maximum bulk density (loose) for coarse aggregate is 55 lbs/ft^3.

Result – The lightweight aggregate had an average bulk density (loose) of 47 lb/ft^3.

Section 5.1.6 Specific Gravity & Absorption

The density factor was tested in accordance with ASTM C128 - 12 *Standard Test Method for Density, Relative Density (Specific Gravity) & Absorption of Coarse Aggregate*. The sample was dried to a constant mass and soaked for 72 hours. The specific gravity and absorption is reported in Table 3.

Table 3: Specific Gravity & Absorption

Absorption after 72 hour Soak (percent)	Relative Density (Specific Gravity) (OD)	Relative Density (Specific Gravity) (SSD)	Apparent Relative Density (Apparent Specific Gravity)	Density Oven Dry (lb/ft^2)	Density SSD (lb/ft^2)	Apparent Density (lb/ft^2)
5.9	1.429	1.516	1.559	89.6	94.3	97.1

Concrete mixtures containing the 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 4. Fresh properties are reported in Table 5.

Table 4: Mix Proportions

Material	Source	Amount (pcy)
Portland Type I/II Cement	Lehigh, Leeds	564
Fine Aggregate	Lambert, Natural Sand	1,342
⅜-inch Lightweight Aggregate	Carolina Stalite	900
Air Entrainment	Vinsol Resin	1.8 oz/yd³
Water Reducer	Type F – High Range	7.9 oz/yd³
Water	Lawrenceville City Water	290
	Total	3,096

Table 5: Fresh Properties

Slump (inches)	2.50
Unit Weight (lb/ft^3)	115.1
Air Content (%)	6.00
Concrete Temperature (°F)	72

The oven-dry density of the concrete mixture was calculated by the mixture quantities, aggregate moisture content, and the volume of the concrete batch. The calculated equilibrium density of 108.9 lb/ft³ was calculated by adding 3 lb/ft³ to the calculated oven-dry density. The calculated equilibrium density is used to determine the specification requirements for the compressive and split tensile strengths.

Section 5.2.1 Compressive Strength and Splitting Tensile Strength

Compressive Strength

Requirement – For a concrete with combinations of normal weight and lightweight aggregates and a calculated equilibrium density of 108.9 lb/ft^3, the minimum compressive strength is 2,890 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 & Splitting Tensile Strength Requirements

Calculated Equilibrium Density (lbs/ft^3)	Splitting Tensile Strength Requirements (psi)	Compressive Strength Requirements (psi)
110	310	3,000
105	300	2,500

Table 7: Compressive Strength Results

Sample ID	Compressive Strength (psi)
17-095-A	4,300
17-095-B	4,560
17-095-C	4,450
17-095-D	4,580
Average	**4,470**

Splitting Tensile

Requirement – For a concrete with combinations of normal weight and lightweight aggregates and a calculated equilibrium density of 108.9 lb/ft^3, the minimum splitting tensile strength is 308 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)
17-095-1	435
17-095-2	310
17-095-3	485
17-095-4	395
17-095-5	470
17-095-6	415
17-095-7	440
17-095-8	340
Average	**410**

Section 5.2.3 Drying Shrinkage

Three length change beams (4" x 4" x 11¼") were moist cured for seven days. Upon the completion of the 7 day 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% for 28 days. The drying shrinkage of the concrete specimens shall not exceed 0.07% at 28days.

Table 9: Drying Shrinkage at 28 Days

Sample ID	Length Change at 28 Days (%)
17-095 (1)	-0.028
17-095 (2)	-0.027
17-095 (3)	-0.028
Average	**-0.028**

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.

Resistance to Freezing and Thawing

The freeze-thaw samples were tested in accordance with ASTM C666-03 (2008) *Resistance of Concrete to Rapid Freezing and Thawing – Procedure A (freezing and thawing in water)* with the curing modifications listed in ASTM C330. Test results are reported in Table 10.

Table 10– Freeze-Thaw Testing – Cast Concrete Samples (3 beams)

Total Cycles Completed	Fundamental Transverse Frequency, khz			Relative Dynamic Modulus (%)			Weight Change (grams)			Length Change (inches)		
	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3
0	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
22	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
45	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
70	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
95	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
116	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
137	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
159	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
179	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
205	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
232	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
268	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
300	2.012	2.012	2.012	100	100	100	0	0	0	0	0	0
Average Relative Dynamic Modulus				**100**			**0**			**0**		

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 Principal