TEC Services
Testing • Engineering • Consulting

November 8, 2019

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Subject: **Interim Report - ASTM C 330-17 *Standard Specification for Lightweight Aggregates for Structural Concrete* on ½-Inch Coarse Aggregate**
TEC Services Project No: 12-0505
TEC Laboratory No: 19-1178

Dear Mr. Boyle:

Testing, Engineering and Consulting Services, Inc. (TEC Services) is an AASTHO R18, ANS/ISO/IEC 17025:2005 and Army Corp of Engineers accredited laboratory. TEC Services is pleased to present this report of our testing on the lightweight aggregate submitted to our laboratory August of 2019. It was communicated to TEC Services that the material source is Glass Mountain Pumice, Siskiyou County, CA. The aggregate was tested in accordance to ASTM C330-17 *Standard Specification for Lightweight Aggregates for Structural Concrete*. Our services were performed in accordance with the terms and conditions of our Service Agreement TEC-PRO-05-0505. The test results presented only pertain to the samples tested.

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 5 *Chemical Composition* and Section 6 *Physical Properties* of ASTM C330 and are reported in Table 1. Based on the results to date, the pumice 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	1.342	5% (max)
Section 5 – Physical Properties		
Clay Lumps and Friable Particles (Dry mass)	0.3%	2% (max)
Bulk Density (Loose)	40 lb/ft^3	55 lbs/ft^3 (max)
Density Factor (Specific Gravity, SSD)	1.286	----
72-Hour Absorption	23.1%	----
Compressive Strength (Requirement based off of Calculated Equilibrium Density)	3,610 psi	2,640 psi (min)
Splitting Tensile (Requirement based off of Calculated Equilibrium Density)	365 psi	305 psi (min)
Drying Shrinkage	-0.034	-0.070 % (max)
Popouts	0	0
Grading	See Section 5.1.2 Below	
Resistance to Freezing and Thawing (Average Relative Dynamic Modulus- %)	Testing Ongoing	----

Test Results

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.

Iron Staining

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

Result – The lightweight aggregate showed no color change, which indicates an index of 0.

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 1.342 percent.

Clay Lumps and Friable Particles

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

Results – The lightweight aggregate had 0.3 percent clay lumps and friable aggregate.

Grading

The Grading and the required grading for 12.5 mm to 4.75mm is reported in Table 2.

Table 2: Grading and Suggested Range for 12.5 mm to 4.75 mm

Sieve Size	% Passing	Required Grading (1/2")
¾ in	100	100
½ in	100	90 - 100
$^{3}/_{8}$ in	79.8	40 - 80
#4	19.1	0 - 20
#8	9.7	0 - 10
Pan	0	---

Bulk Density (Loose)

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

Result – The lightweight aggregate had an average bulk density (loose) of 40 lb/ft^3.

Relative Density

The relative density (specific gravity) was tested in accordance with ASTM C127 - 15 *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

Specific Gravity (SSD)	Specific Gravity (OD)	72-hour Absorption (%)
1.286	1.044	23.1

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.

Concrete Mix Proportions

Table 4: Mix Proportions

Material	Source	Amount (pcy)
Cement	Lehigh, Leeds	564
Fine Aggregate – Natural Sand	Lambert, Wiregrass	1,285
Coarse Aggregate - #57 Stone	Vulcan, Lithonia	351
Lightweight Aggregate	Pumice	636
Air Entrainment	Grace, Daravair M	2.2 oz/yd³
Water Reducer	Sika, Viscocrete 2100	1.75 oz/yd³
Water	Lawrenceville City Water	290
	Total	3,126

Table 5: Fresh Properties

Slump (inches)	3.25
Unit Weight (lb/ft^3)	115.1
Air Content (%)	6.0
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 106.4 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 strength and split tensile.

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 106.4 lb/ft^3, the minimum compressive strength is 2,640 psi. This was calculated by interpolation from the values presented in section 6.2.1 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

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

Table 7: Compressive Strength Results

Sample ID	Compressive Strength (psi)
19-1178 -A	3,490
19-1178 -B	3,580
19-1178 -C	3,550
19-1178 -D	3,820
Average	**3,610**

Splitting Tensile

Requirement – For a concrete with combinations of normal weight and lightweight aggregates and a calculated equilibrium density of 106.4 lb/ft^3, 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)
19-1178 -1	280
19-1178 -2	380
19-1178 -3	405
19-1178 -4	345
19-1178 -5	375
19-1178 -6	365
19-1178 -7	365
19-1178 -8	385
Average	**365**

Drying Shrinkage

Three length change beams (4" x 4" 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% for 28 days.

Requirement – The drying shrinkage of the concrete specimens shall not exceed 0.07% at 28days.
Results are reported in Table 9.

Table 9: Drying Shrinkage at 28 Days

Sample ID	Length Change at 28 Days (%)
19-1178 (1)	-0.033
19-1178 (2)	-0.037
19-1178 (3)	-0.032
Average	**-0.034**

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 C151-18 *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 C666-15 *Resistance of Concrete to Rapid Freezing and Thawing – Procedure A (freezing and thawing in water)* with the curing modifications listed in ASTM C330.

Results – Testing is currently ongoing

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
Average Relative Dynamic Modulus												

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