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Wiss, Janney, Elstner Associates, Inc.
330 Pfingsten Road
Northbrook, Illinois 60062
847.272.7400 tel | 847.291.5189 fax
www.wje.com

October 13, 2010

Mr. Michael Phillips
Custom StoneWorks, LLC
2132 Pisgah Church Road
Kernersville, NC 27284

Re: Laboratory Evaluation of Pre-Cast Stone Veneer
ICC Evaluation Criteria - AC 51 Acceptance Criteria for Precast Stone Veneer
WJE No. 2010.1318

Dear Mr. Phillips:

Per your request, Wiss, Janney, Elstner Associates, Inc. (WJE) has performed testing on Custom StoneWorks precast veneer units. The purpose of testing the veneer product was to meet the testing requirements of the International Code Council-Evaluation Service (ICC-ES) Acceptance Criteria AC 51, *Acceptance Criteria for Precast Stone Veneer*, effective date March 1, 2008. All testing was performed in WJE's laboratory in Northbrook, Illinois (TL 165). WJE's laboratory in Northbrook, Illinois meets the requirements of the IAS Accreditation Criteria for Testing Laboratories (AC89) and has demonstrated compliance with ANS/ISO/IEC Standard 17025:2005, *General Criteria for the Competence of Testing and Calibration Laboratories*. WJE is accredited to perform testing in accordance with ICC-ES AC51. This report is being presented to Custom StoneWorks as part of the necessary submittal to meet the requirements of AC51.

TEST PROCEDURES AND REQUIREMENTS

The applicable test procedures are described in AC51 and are presented in Table 1. The acceptance criteria generally include maximum or minimum test requirements, as well as maximum variation limits for individual test results.

Table 1: AC51 Test Procedures and Acceptance Criteria

Test Property	Test Method	AC51 Requirement
Equilibrium Density	ASTM C567	Section 3.1.1: No requirement.
Product Density	AC51, Section 4.1	Section 3.1.2: The in-place weight must not exceed 15 pounds per square foot of wall.
Mix Compressive Strength	ASTM C39	Section 3.1.3.1: Minimum 1800 psi average, with a maximum variation of 10 percent from average.
Mix Tensile Strength	ASTM C190	Section 3.1.3.2: Maximum variation of 10 percent from average.
Mix Flexural Strength	ASTM C348	Section 3.1.3.4: Maximum variation of 10 percent from average.
Product Bond Strength	ASTM C482	Section 3.1.3.4: Minimum of 50 psi, with a maximum variation of 20 percent from the average or the lowest bond strength has to be greater than 50 psi.
Absorption	AC51	Section 3.1.4: Dependent on the density of the concrete, Table 2 of AC51.
Product Freeze Thaw Durability	ASTM C67	The samples must not break or disintegrate, and the sample loss must be less than 3.0 percent.

SAMPLING

On April 9, 2010, Mr. Todd Nelson of WJE visited the Custom StoneWorks manufacturing facility in Kernersville, North Carolina to observe production and fabrication of the veneer units; randomly sample production veneer units for testing; and randomly sample the concrete used to produce the veneer units. The facility uses a 4 cubic foot drum mixer to batch the concrete for the veneer units. All materials are loaded manually into the mixer.

The concrete mixture proportions for the sampled concrete are presented in Table 2. The plant uses crushed, expanded shale as the only aggregate source.

Table 2: Concrete Mixture Proportions

Mix Constituent	Quantity (lb/yd^3)
Cement - Roanoke	535
Coarse Aggregate - Big River	1583
Water	251
Buff Dye	12
Krete HQ	20 oz/cwt
Water : Cement	0.47

For fabrication of the physical test specimens (compressive, flexural, and tensile strength), a composite concrete sample was collected from the batched concrete. A total of five concrete samples each were cast for the compressive, tensile, and flexural strength testing. The compressive samples were 4-in. diameter by 8-in. long cylinders. The tensile samples were dog bones with a nominal throat dimension of 1.0 in. and a length of 5-in. The flexural strength samples were 1.6-in. by 1.6-in. by 6-in. prisms. .

A total of thirty veneer units were randomly sampled from the units manufactured from the batch of concrete that was sampled for the physical tests. The veneer units were sampled for density, shear bond strength, absorption, and freeze-thaw durability testing.

After 14 days of moist cure, the 30 sampled veneer units and 15 cast samples were shipped to WJE.

LABORATORY TESTING AND RESULTS

Equilibrium Density Testing

Ten of the veneer units were randomly selected for density testing and were identified as C1 through C10, accordingly. The equilibrium density was determined by measurement in accordance with Section 8.2 of ASTM C567, *Standard Test Method for Determining Density of Structural Lightweight Concrete.* The units were submerged in water at 73.5 ± 3.5 °F for 24 hours. The mass of the units was then determined while suspended in water. The units were removed from the water, and the saturated surface dry weight was measured. The units were then placed in a controlled humidity environment (50 ± 5 % relative humidity and 73.5 ± 3 °F) until the mass of the specimen changed no more than 0.5 % (gain or loss) in successive determinations of mass 28 days apart. For these units, this occurred at 56 days. The equilibrium density is calculated by dividing the equilibrium mass by the difference between the SSD and suspended mass. The results of the density testing are presented in Table 3. Based on the C567 testing, the average equilibrium density of the selected veneer units was 75.9 pcf.

Table 3. Equilibrium Density - ASTM C567

Sample ID	Weight at SSD (g)	Submerged Weight (g)	Equilibrium Weight (g)	Equilibrium Density (lb/ft^3)
C1	469.2	128.2	416.4	76.0
C2	298.9	75.2	265.7	73.9
C3	631.2	169.6	560.7	75.6
C4	405.9	112.4	355.8	75.5
C5	268.8	77.7	238.8	77.8
C6	310.1	89.0	276.6	77.9
C7	336.5	98.1	301.0	78.6
C8	495.0	123.8	439.6	73.7
C9	229.3	64.1	203.7	76.7
C10	219.2	56.3	192.5	73.6
			Average	**75.9**

Compressive Strength Testing

Five 4-in by 8-in cylinders were tested in accordance with ASTM C39, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*. The specimens were moist cured for 28 days and sulfur capped in accordance with ASTM C617, *Standard Practice for Capping Cylindrical Concrete Specimens*, prior to testing.

The average 28-day compressive strength for the five samples was measured to be 4,020 psi, which exceeds the 1800 psi minimum strength value requirement of AC51. In addition, the maximum measured variation from the test average was 130 psi for Sample 4 (3.2 percent of 4,020 psi); which is less than the 10 percent maximum limit requirement of AC51. A summary of the compressive strength test results is included in Table 4.

Table 4. ASTM C39 Compressive Strength of Concrete Cylinders

Sample ID	Length (in)	Diameter (in)		Avg. Dia. (in)	Area (in^2)	Max Load (lbs)	Compressive Strength (psi)	Variation from Average (%)
		D1	D2					
1	8.135	4.035	4.002	4.019	12.68	50,260	3,960	1.5%
2	8.178	4.012	4.019	4.016	12.66	52,350	4,130	2.7%
3	8.223	4.000	4.020	4.010	12.63	51,180	4,050	0.7%
4	8.136	4.036	4.016	4.026	12.73	49,510	3,890	3.2%
5	8.217	4.033	4.000	4.017	12.67	51,540	4,070	1.2%
						Average	**4,020**	-

Tensile Strength Testing

Five briquette samples, with a nominal throat dimension of 1.0-in., were moist cured for 28 days and tested for tensile strength in accordance with ASTM C190, *Standard Test Method for Tensile Strength of Hydraulic-Cement Mortars*. The average tensile strength was measured to be 280 psi. The maximum measured variation of test results versus the test average was 8.9 percent for Sample 2 (variation of 25 psi), which meets the AC51 requirement of a maximum of 10 percent. A summary of the tensile test results is included in Table 5.

Table 5. ASTM C190 Tensile Strength of Hydraulic Cement Mortars

Sample ID	Age at Test, days	Width of Briquette at Waist, in	Depth of Briquette at Waist, in	Maximum Load, lbf	Tensile Strength (psi)	Variation from Average (%)
6	28	1.049	1.047	329	300	7.1%
7	28	1.016	1.068	277	255	8.9%
8	28	1.119	1.031	309	270	3.6%
9	28	1.019	1.052	306	285	1.8%
10	28	1.020	1.042	318	300	7.1%
				Average	**280**	-

Flexural Strength Testing

Five concrete samples were moist cured for 28 days and tested for flexural strength in accordance with ASTM C348, *Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars.* The samples measured nominally 1.6-in. by 1.6-in. with a test span length of 5.5 inches. The samples were loaded with the finished face (top face) parallel to the loading. The average flexural strength of the cast samples was 495 psi. The test results of the five samples are presented in Table 6. Sample 11 varied from the average by more than 10 percent (12.1 percent). As described in ASTM C348 Section 11.1, if a test result differs by more than 10 percent from the average, the sample shall not be considered in determining the average. After discarding Sample 11, the average was calculated to be 510 psi with a maximum sample variation of 2.9 percent for Sample 13 (Table 7).

Table 6. ASTM C348 Flexural Testing

Sample ID	Width (in)	D1	Max Load (lbs)	Modulus of Rupture (psi)	Variation from Average (%)
11	1.597	1.596	241	435	11.9%
12	1.614	1.635	282	510	3.2%
13	1.585	1.579	291	525	6.3%
14	1.583	1.600	276	500	1.2%
15	1.600	1.570	276	500	1.2%
			Average	**495**	-

Table 7. ASTM C348 Flexural Testing (after removing Sample 11)

Sample ID	Width (in)	D1	Max Load (lbs)	Modulus of Rupture (psi)	Variation from Average (%)
12	1.614	1.635	282	510	0.0%
13	1.585	1.579	291	525	2.9%
14	1.583	1.600	276	500	2.0%
15	1.600	1.570	276	500	2.0%
			Average	**510**	-

Shear Bond Strength Testing

Six of the veneer units were randomly selected and tested by WJE for shear bond testing in accordance with ASTM C482, *Standard Test Method for Bond Strength of Ceramic Tile to Portland Cement Paste.* The units were cut to a maximum dimension width and height of 4-in with a thickness of ½-inch. The mortar bed and backing material for the veneer units were prepared with a Type S mortar in accordance with ASTM C482 and AC51, Section 4.7. The mortar bed was cast into a wooden form with interior dimensions of 4 ½-in. by 6-in with a thickness of 2-in. After the mortar bed had cured for approximately 1 ½ hours, the backing material was applied to each of the six veneer units at a thickness of ⅜-in. using a flat-trowel. The units were then placed in the mortar bed with the top ¼-in. of the unit projecting over the form edge, and the units were firmly tapped ensuring contact with the mortar bed.

The samples were moist cured for 24 hours, removed from the mold, and continued to moist cure for a total of seven days in accordance with Section 9.8 of ASTM C482. After moist curing, the samples were tested for bond strength in a fixture similar to Fig. 2 in ASTM C482. The samples were loaded until failure, and the maximum load, failure type, and bonded area were recorded. The bond strength is calculated by dividing the maximum load by the bonded area.

The average bond strength was measured at 145.1 psi, which exceeds the 50 psi requirement of AC51. The maximum measured variation was 29.0 percent for Sample C12 (42.1 psi variation), which exceeds the maximum allowable variation of 20 percent. However, no single measurement is less than 50 psi, so the shear bond strength meets the requirements of Section 3.1.3.4 of AC51. A summary of the bond testing results is included in Table 8.

Table 8. Shear Bond Test Results

ID	Width	Height	Area (in^2)	Load (lb)	Bond Strength (psi)	Variance (%)	Location of Failure
C11	4.00	2.50	10.0	1729	172.9	19.1%	50 between backing and mortar, 50 % mortar bed
C12	4.00	2.50	10.0	1030	103.0	-29.0%	Mortar bed
C13	4.00	3.75	15.0	2327	155.1	6.9%	Between the backing and mortar bed
C14	4.00	3.75	15.0	2474	164.9	13.6%	Between the backing and mortar bed
C15	3.75	3.79	14.1	2239	157.7	8.7%	60% between backing and mortar, 40 % mortar bed
C16	4.00	3.79	15.1	1772	117.0	-19.4%	85 % between backing and mortar, 15 % mortar bed
				Average	**145.1**	-	

Absorption Testing

Ten veneer units were selected randomly for the moisture absorption testing, which was performed using the procedure described within AC51, Section 4.6. The ten full sized units were cleaned with a wire brush to remove any loose particles and then oven dried at approximately 212°F for 24 hours. The oven dried mass is determined after cooling the samples for 15 minutes at room temperature. The samples were then submerged in water for 48 hours at a temperature of approximately 68°F. A suspended mass of each veneer unit was measured while the samples were submerged. The SSD weight is determined by wiping

the veneer surfaces dry and immediately weighing the samples. The absorption is calculated by subtracting the oven dried mass from the SSD mass and dividing by the dry mass. The oven dried density is calculated by dividing the oven dried mass by the difference between the SSD mass and the suspended mass.

The average oven-dry density and absorption of the samples were determined to be 71.1 pcf and 20.4 percent, respectively. In accordance with AC51 Table 2, for a density less than 85 pcf and greater than 65 pcf, the maximum absorption is to be 22 percent. The samples tested meet this requirement. A summary of the density and absorption test results is included in Table 9.

Table 9. AC51 Absorption Test Results

Sample ID	Weight of Dried Sample (g)	Weight at SSD (g)	Submerged Weight (g)	Oven-Dry Density (pcf)	Absorption (%)
C1	391.9	469.2	128.2	71.5	19.7%
C2	247.3	298.9	75.2	68.8	20.9%
C3	524.3	631.2	169.6	70.7	20.4%
C4	338.9	405.9	112.4	71.9	19.8%
C5	222.7	268.8	77.7	72.5	20.7%
C6	257.6	310.1	89.0	72.5	20.4%
C7	280.4	336.5	98.1	73.2	20.0%
C8	410.6	495.0	123.8	68.8	20.6%
C9	190.9	229.3	64.1	71.9	20.1%
C10	180.9	219.2	56.3	69.1	21.2%
			Average	**71.1**	**20.4 %**

Product Density

To calculate the product wall density, the calculated "average saturated density" of the units is multiplied by the maximum average thickness of the units. Per section 4.1 of AC51, the saturated weight is calculated by increasing the average equilibrium density (Table 3) by the average absorption value for the units (Table 9). The calculated "average saturated density" for the units following this procedure was 91.4 pcf. A maximum average product thickness of 1 ½ inches (0.125 feet) multiplied by the "average saturated density" is approximately 11.4 psf, which is less than the AC51 maximum requirement of 15 psf.

Freeze-Thaw Testing

Five full size veneer units were selected and tested in accordance with ASTM C67, *Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile*. At an age of 28 days, the veneer units were dried to a constant weight, and the mass was measured. The samples were then exposed to 50 cycles of freezing and thawing per ASTM C67. A freeze-thaw cycle consisted of submerging the samples for 4 hours followed by freezing of the samples for 20 hours face down in ½-in. of water. The final sample weight of the units, after drying to a constant mass, was determined. The mass loss of each unit was determined by subtracting the final weight from the initial weight and dividing by the initial weight. The results are presented in Table 10.

For each of the veneer units tested, the mass increased very slightly from the initial dry weight to the final dry weight. Based on our experience with testing of precast veneer units per ASTM C67, a slight increase in mass is common when no deterioration of the samples is visually apparent. It is possible that the mass increase is due to the continued hydration of the units. Regardless, the tested units meet the requirements of AC51, Section 3.1.5, which requires a mass loss of less than 3.0 percent.

Table 10: Freeze-Thaw Testing Results

Sample ID	Initial Dry Weight (g)	Final Dry Weight (g)	Percent Change in Mass (%)	Comments
C17	426.6	430.5	+ 0.91%	No signs of deterioration
C18	303.8	305.9	+ 0.69%	No signs of deterioration
C19	377.2	379.3	+ 0.56%	No signs of deterioration
C20	355.5	358.7	+ 0.90%	No signs of deterioration
C21	620.9	627.4	+ 1.05%	No signs of deterioration

It has been our pleasure assisting you on the testing of your product to meet the requirements of AC51. If you have any questions or comments regarding this report, please feel free to call.

Sincerely,

WISS, JANNEY, ELSTNER ASSOCIATES, INC.

Todd Nelson, P.E.
Senior Associate