EEI

EVANS ENGINEERING, INC.
CONSULTING ENGINEERS

Civil Engineering
Land Development
Hydrology
Permitting
Structural Engineering
Building Structural Design
Transportation
Surveying

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June 21, 2021

Brundy Pursley
Piazza Stone, LLC
3817 Martinez Blvd
Augusta, Georgia 30802

Re: Piazza Stone – Exterior Wall Panel Design using Hydraulic Cement

Upon your request, Evans Engineering, Inc. (EEI) conducted an analytic structural review of the hydraulic concrete ingredients and mix designs related to the proposed precast panel product. During our investigation we reviewed the data and performance results from the various ASTM tests.

Testing Agency and Reports:

FDOT IAS ACCREDITED Testing Laboratory

UNIVERSITY OF MIAMI
STRUCTURES and MATERIALS
LABORATORY
www.um-sml.com

- **Report number R-5.10_02-03-21B_PS; April 27, 2021**
  ASTM C39 Compressive Strength of Cylindrical Hydraulic Cement Mortar
- **Report number R-5.10 02-03-21A PS; April 27, 2021**
  ASTM C348 Flexure Strength of Hydraulic-Cement Mortar

Analytical References:

- PCA Design and Control of Concrete Mixtures 14th Edition; Chapter 15.
- ACI – Structural Design Guide to the ACI Building Code -1998- Chapter 16 Structural Plain Concrete
- ACI 318-19 Building Code Requirements for Structural Concrete- Chapter 14

Based on the ASTM results; Our review of the admixtures; and associated mix proportions, we were able to determine the viable strength and service strength of the concrete. EEI used the tested Modulus of Rupture and Compressive strengths. Indications of this modulus of rupture occurred by the formation of cracking in the unreinforced concrete test specimen. Our EEI letter dated April 24, 2020, is also considered in this analysis. This letter discusses the temperature and shrinkage characteristic associated with this type of cement mortar. We believe temperature and shrinkage should be considered along with the imposed wind and seismic forces. All this information is important to establish a credible performance strength for the wall panel concept to resist the Wind and Seismic loading.

Conclusion

Based on our analysis of the panel concept we believe there is a possibility that a viable unreinforced panel could be used as a function of an exterior, non-bearing wall component. The panel concept involves a maximum 8'-0 wide panel with unlimited height related to the design. The height in this case, would be limited by the means and methods of the contractor in handling the product or by the schemes related to the specific project. Our iterations of the design found that concrete stiffeners could be used on 1'-4" to 2'-8" spacing to support a 5/8" thin shell concrete face. The stiffeners would span the 8'-0" width. SK-001 attached indicates the final scheme. Therefore, we see the following results related to allowable out of plane wind loading.

- Stiffeners at 2'-8" on center
    - 53 PSF (Strength) 31 PSF (ASD – Service)
- Stiffeners at 1'-4" on center
    - 85 PSF (Strength) 51 PSF (ASD – Service)

Note that the values above are established as a function of plain, unreinforced concrete where the Modulus of Rupture alone controls the flexure. It is imperative these values are not exceeded since any visible cracking or development thereof will render the panel ineffective for its use. Panel deflection in the spans must be maintained less than 3/16 inches in 8'-0" panel width. The 5/8" face shell is more than adequate to span the 2'-8" since it will be cast integral with the stiffener and continuous supported along the stiffeners.

A plain unreinforced shell of 5/8" also has the ability to span the 2'-8" as a single vertical panel element between groups of punch type windows. This would involve all four sides to return with 3" thick edges. In that manner the edges are stiffened allowing the 53 PSF wind loading to be resisted. Any widths greater than this would need internal stiffeners with limitations of 1'-4" or 2'-8" spacings as seen in the previous 8'-0" wide panels.

Fabrication should consider a periodic cylinder test to ensure the compressive strength of the concrete is consistent and the standard beam test to ensure the Modulus of Rupture is attained. These procedures should be implemented for each batch of mix design when fabricating the panels. Since this is controlled proprietary mix design it should yield compatible results. Testing procedures should be implemented within a Quality control standard operating procedure manual.

It should be noted that any cracking that develops will compromise the integrity of the panel performance. Although Hydraulic Concrete tends to more elastic, it is still subject to cracking. By notation of the ACI, it is stated as follows.

*"….Even with the best floor designs and proper construction,
it is unrealistic to expect crack-free and curl-free floors…." – ACI 302.1R-96*

In that matter, serious caution is advised for a fine-tuned quality control program.
One way to ensure the panel integrity is provide minimum reinforcing to ensure ductility and flexural viability. If cracking develops in the reinforced section, it will maintain its integrity without the possibility of explosive failure. This should be offered as an option or mandate in the manuals.

Our conclusion is derived from published engineering manuals, EEI correspondence, and ASTM test reports. EEI is not responsible for the Testing that was performed by the University of Miami.

We encourage Piazza Stone to render the services of an agency to test the wall panel concepts. This will establish credible as-built configurations beyond this analysis and its localized testing. Once a full performance mock-up testing scheme is complete, the information may be published in the manuals for use.

Evans Engineering, Inc. appreciates the opportunity of working with Piazza Stoneworks, LLC in this matter.

If you should have any questions or require further assistance, please contact us.

Respectfully,

EVANS ENGINEERING, INC.

Daniel S Swartz

Daniel S. Swartz
Structural Project Engineer

ATTACHMENTS:

- SK-001 and Structural Analysis
- Test Reports as indicated under “Testing References” in this cover letter.

Holly R. Evans, P.E.

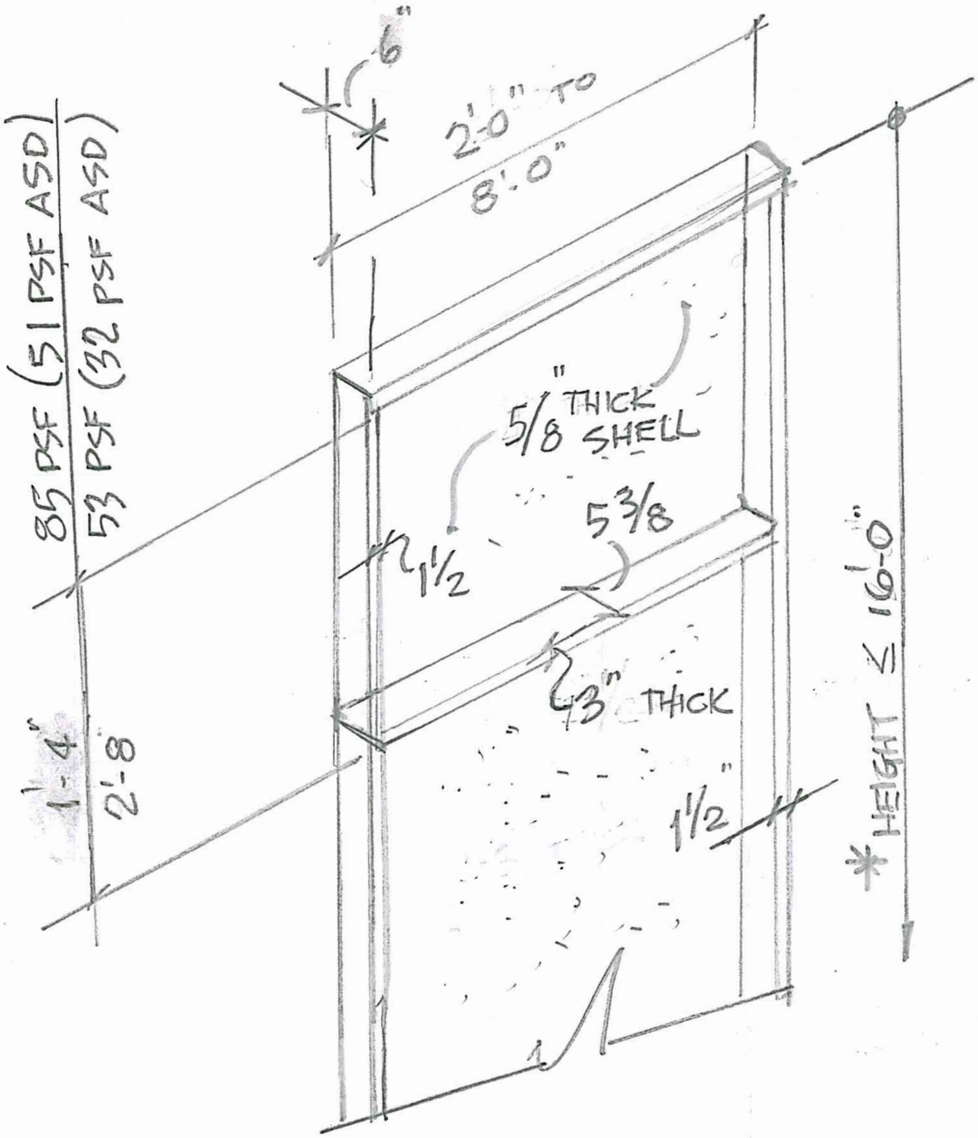
SEAL:

COMMONWEALTH OF PENNSYLVANIA
HOLLY R. EVANS
No. PE037923E

June 21, 2021

EVANS ENGINEERING, INC.

JOB PIAZZA STONE, LLC
SHEET NO. SK OF 001
SUBJECT HYDRAULIC CEMENT UNREINFORCED PANEL
BY DSS DATE 6/16/2021
CHK'D ______ DATE ______



* HEIGHT IS UNRESTRICTED AS LONG PTLB RAILS AND CLIPS FOR ATTACHMENT ARE SPACED AS REQUIRED TO RESIST LATERAL SEISMIC AND WIND LOADS. GRAVITY LOADING AT FLOORS AND FOUNDATIONS.

HEIGHT IS ALSO RELATED TO MEAN & METHODS OF FABRICATION, SHIPPING & ERECTION.

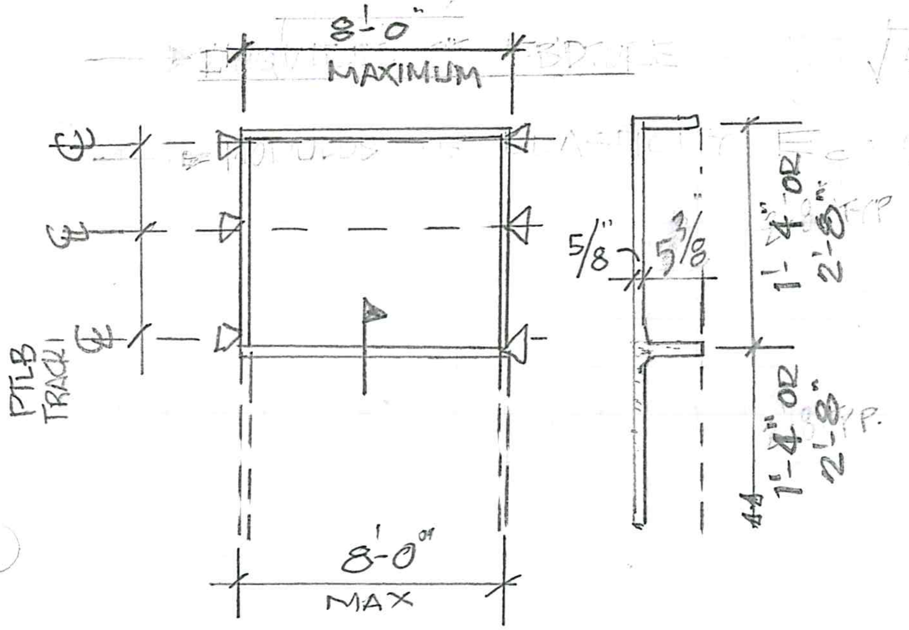
JOB PIAZZA STONE, LLC
SHEET NO. ______ OF ______
SUBJECT HYDRAULIC CEMENT UNREINFORCED PANEL
BY DSS DATE 6/16/2021
CHK'D ______ DATE ______

FLEXURAL TESTING FOR BEAM STRENGTH

- ASTM C348 FLEXURAL STRENGTH OF HYDRAULIC MORTARS.
- REPORT NUMBER R-5.10_02-03-21A_PS; APRIL 27, 2021
- UNIVERSITY OF MIAMI - STRUCTURES AND MATERIALS LABORATORY
- S_R - IN THE REPORT REPRESENTS AN ULTIMATE MODULUS OF RUPTURE. CRACKS APPEARED AT THIS LOADING

- 7 DAY STRENGTH = 991 psi ← SHOP
- 28 DAY STRENGTH = 1171 psi ← SHIPPING & PERFORMANCE

→ UNREINFORCED SECTION WAS TESTED. $f'_c = 5000$ psi (AVG.)



$$M_N = \frac{wl^2}{8}$$

$$M_R = \phi M_N$$

$$M_R = \frac{f_r I}{c}; \quad \frac{I}{c} = S_{STIFFNER}$$

SEE NEXT

JOB PIAZZA STONE, LLC SHEET NO.____ OF ____

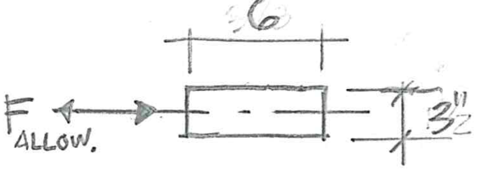
SUBJECT HYDRAULIC CEMENT BY DSS DATE 6/16/2021

UNREINFORCED PANEL CHK'D ____ DATE ____

ANALYSIS CONTINUED.

ASSUME STIFFNESS OF PROJECTION IS 6" WITH SHELL.

THUS, $S_{STIFFNER} = 3''(6'')^2/6 = 18\ in^3$



STRENGTH DESIGN

$M_R = \underline{f_r(S)} \times 0.65 = 197\ psi\ (18\ in^3)(0.65)$ 13,701 #-IN (1142 #-FT)

@ PERFORMANCE

ASSUME $\ell = 8\text{-}0''$

- $W_{STRENGTH} = \frac{M8}{\ell^2} = \frac{1142(8)}{8^2} = 143\ plf$
- STIFFENER @ 2'-8"

$q_{STRENGTH} = 143\ plf/2.67 = \underline{\underline{53.47}}$

USD = 53.47 psf SAY 53 psf. WIND LOAD.
ASD = 53 psf × 0.6 = 31.8 psf

- REDUCING THE STIFFENER TO 1'-8"

$q_{STRENGTH} = 143\ plf/1.67' = 85.6\ psf$

USD = 85 psf.
ASD = 85 psf × 0.6 = 51 psf.

EVANS ENGINEERING, INC.

JOB PIAZZA STONE, LLC SHEET NO. SK OF 001
SUBJECT HYDRAULIC CEMENT BY DSS DATE 6/16/2021
UNREINFORCED PANEL CHK'D ____ DATE ____

CHECK BEAM SHEAR

$$V_U = 0.65\left(\frac{4}{3}\right)\sqrt{5000}\ 6" \times 3" = \underline{1103^{\#}}\ \text{MAX}$$

$$V_{MAX} = \frac{143\ \overset{\text{STRENGTH.}}{\text{plf} \times 8}}{2} = 572^{\#} < 1103^{\#}\ \text{OK}$$

CHECK DEFLECTION

SINCE THIS IS AN UNREINFORCED SECTION A CRACK CANNOT FORM.

ASD LOADING OF 51 psf. WILL BE USED

$$W = 51 \times 1.67' = \underline{85\ \text{plf}}$$

$$I_g = \frac{3(6)^3}{12} = \underline{54\ \text{in}^4}$$

$$M_A = 703 \times 54\,\text{in}^4 = 37962^{\#\text{-IN}}\ (3163^{\#\text{-FT}})$$

$$M_c = \frac{f_r I}{c} = 632(54\,\text{in}^4) = 34{,}128^{\#\text{-IN}}\ (2844^{\#\text{-FT}})$$

(AVOID CRACK)

$$I_e = \left\{\left(\frac{M_{CR}}{M_a}\right)^3 I_g + \left[1 - \left(\frac{M_{CR}}{M_A}\right)^3\right] I_g\right\}$$

$$I_e = \left\{\underbrace{\left(\frac{2844}{3163}\right)^3 54}_{39.25} + \underbrace{\left[1 - 0.73\right]54}_{14.28}\right\} = \underline{53.83\ \text{in}^4}$$

- SMALLER REDUCED SECTION ∴ DEFLECTIONS MUST NOT EXCEED THE FOLLOWING

$$\underline{\Delta} = \frac{5 M l^2}{48 E_c I_e} = \frac{5(37962)(96)^2}{48(4{,}030{,}000)(54\,\text{in}^4)} = \underline{0.167\ \text{in.}}$$

- LIMIT DEFLECTION TO 3/16" OVER THIS 8'-0" SPAN