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

Re: Piazza Stone – Precast Architectural Stone Cornice / Entablature Elements
Structural Review of Shrinkage and Expansion Characteristics

Upon your request, Evans Engineering, Inc. (EEI) conducted an extensive forensic, structural review of the ingredients and mix designs of your precast cement stone product. During our investigation we reviewed the performance results from the various ASTM tests performed on this product. Based on the ASTM results; our review of the admixtures; and associated mix proportions, we were able to ascertain that normal chemical reactions and heat of hydration will occur during the bonding and curing process. Since the curing occurs in a controlled shop environment under ambient temperatures, normal shrinkage should occur. Additionally, the concrete mix includes Carbonate ingredients with water reducing agents. Therefore the thin shell shrinkage should be approximately .0063 inch of unit length. Nevertheless as the EPS bonded shell thickness undergoes compression across the face, bonding stresses will compress the EPS. If the cladding element is too long the piece will exhibit a curve or warp along its length. Therefore we would recommend unit lengths not exceed 10'-0". This will avoid the potential delamination or warping of the singular element.

When the pieces are in service, temperature expansion or volumetric changes pertaining to moisture penetration need to be considered. We are of the opinion the thin shell, 5/8" thick, concrete face will not undergo appreciable changes in length or volume. This is because the current cement mix is most typical related to a Type III – High Early Strength. The concrete in its 7 Day condition is volumetrically stable and exhibits strengths above 8000 PSI. Furthermore this system is well protected against moisture penetration and freeze/thaw as indicated in your ASTM testing. Based on this information and Portland Cement Association (PCA) literature, we have concluded the average Coefficient of Thermal Expansion (CTE) is in the range of 3.8×10^{-6} in/in $-^{0}$F. This (CTE) is primarily based upon the limestone characteristics present in the concrete. Temperature changes of 100 ^{0}F will result in length change of approximately 1/16 inch in 10'-0" of length. Once again due to the restraint of the thin concrete shell on the EPS backing we recommend the unit lengths be limited to 10'-0". This length will limit the potential of unsightly tensile cracking or delamination of the EPS bonding. The height of the cornice piece has minute changes due to the facial profiles that are broken up into varying planes and protrusions. This alternating facial effect stiffens the piece in its short height.

The flat work elements that vary in thickness ½" to ¾" are less stable since the thin shell is not restrained by the EPS backing. Although temperature and shrinkage will affect an element of given length and width, it is more important to consider the cladding element connections and the restraint of the pieces on the Main Wind Force Resisting System (MWFRS) or building infrastructure. Height and widths of these segments are more importantly related to their shipping and erection tolerances.

In both cases concerning Entablature / Cornice profiles or flatwork, we recommend the attachment of these pieces be spaced no greater than 2'-0" intervals in height and width. These actions will avoid deformity such as creep, warping, curling and limit cracking that will occur over time in the serviceable state. Other more stringent design and performance requirements may be dictated by specific project specifications. Cladding system and connection criteria will need to be engineered in accordance to Code Wind and Seismic requirements as well as consider movements in the MWFRS such as drift, deflection, or creep. Furthermore, considerations must be made for proper joint widths. We recommend the flexible joints be no less than 3/8" inches for element pieces up to 10'-0" and 1/4 inch minimum for elements lengths of 6'-0 and less.

In most cases the individual cladding lengths and heights should be positively restrained perpendicular to their face. Lateral and vertical restraint parallel to the face should be located at one defined edge with vertical and horizontal slip or flexibility at all other tie-back (perpendicular to face) connectors. In a combined support application, the flatwork and cornices use structural adhesives for attachment to the building. We recommend the use of flexible structural adhesive dollops at a maximum 2'-0", horizontal and vertical, interval for this application. Positive gravity load bearing of the cladding element can be achieved by light-gage clips with screw, lag or expansion anchor application.

While reviewing the Product Manual, we viewed numerous examples of construction techniques and practices that meet or exceed the performance standards as previously stated. The cladding elements manufactured by Piazza Stoneworks range in size from 2'-0" to 5'-0" in length. In these cases the thermal expansion is so small that any flexibility in the connections or structural adhesives will absorb the small volumetric changes of this cladding without causing long term fatigue in the connections.

The aforementioned information is derived from published engineering manuals, ASTM test reports, and Company manuals. We encourage Piazza Stone to render the services of testing agency to determine an actual Coefficient of Thermal Expansion. A more finite determination of the Coefficient of Thermal Expansion (CTE) can be made using the test procedures of AASHTO-TP 60 or latest version AASHTO T336-09

References

- PCA Design and Control of Concrete Mixtures 14th Edition; Chapter 15.
- Piazza Stoneworks Information Manual 2012. ASTM tests reports as indicated and included in this literature.

  TEST DATA

  Testing that is performed by an independent laboratory.
  ASTM C 1364-03, *Standard Specification for Architectural Cast Stone*.
  Compressive Strength (ASTM C 1194-03) 8339 psi
  Rapid Freeze/Thaw Resistance (ASTM C 666/C 666M-03) 0.17% loss
  Water Absorption - Cold (ASTM C 1195-03) 5.0%
  Water Absorption - Boiling (ASTM C 1195-03) 5.0%
  Water Permeability (ASTM C 1167-03) 0.0% penetration
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  Compressive Strength (ASTM C 109)
  1 Day = 3485 psi
  7 Day = 6655 psi
  14 Day = 6815 psi
  28 Day = 7360 psi
  Tensile Strength (ASTM C 190)
  7 Day = 600 psi
  14 Day = 720 psi
  Flexural Strength (ASTM C 348)
  7 Day = 1550 psi
  14 Day = 1750 psi
  Flame Spread / Developed Smoke (ASTM E 84-10b) Passed (No Flame / No Smoke)
  EPS Adhesion (14 Day Cure) Dry = 18.20 psi / EPS Failure = 100%
  EPS Adhesion (13 Day Dry, 1 Day Wet) Wet = 15.15 psi / EPS Failure = 95%
  Cylinder Water Absorption (ANSI 118.7) 7 Day = 1.55% wt. gain
  28 Day = 1.36% wt. gain

  Note: All above testing administered to product with a water demand of 14%
- Mix Design (Classified- On record at Piazza Stone, L

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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
Structural Project Engineer

Holly R. Evans, P.E.

April 24, 2020