

CHAPTER SIX

GUIDE SPECIFICATION FOR ARCHITECTURAL PRECAST CONCRETE

THIS DOCUMENT

This document provides a basis for specifying in-plant fabrication including product design not shown on contract documents, and field erection of architectural precast concrete. It does not include structural precast concrete, coatings, or sealing the joints between units.

DRAWINGS AND SPECIFICATIONS

Drawings:

The Architect's or Engineer's drawings should show panel locations and necessary sections and dimensions to define the size and shape of the architectural precast concrete units, indicate location and size of reveals, bullnoses and joints (both functional and aesthetic) and illustrate details between panels and adjacent materials. When more than one type of panel material or finish is used, indicate the extent and location of each type on the drawings. The location and details of applied and embedded items should be shown on the drawings. Plans should clearly differentiate between architectural and structural precast concrete if both are on the same project. Illustrate the details of corners of the structure and interfacing with other materials. Identify the requirements for design and design loads, and indicate load support points and space allowed for connections. The Engineer of Record needs to be aware of the magnitude and direction of all anticipated loads to be transferred to the building structural framing and their point of application. These loads should be addressed in the bid documents. It is especially critical that the Engineer of Record provide stiffeners and bracing that are required to transfer precast loads to the structural frame.

Specifications:

Describe the type and quality of the materials incorporated into the units, the design strength of the concrete, the mix and finishes and the tolerances for fabrication and erection. In the event of a performance specification appropriate data should be included for the precaster to assess the scope and quality of the precast units to be fabricated.

Specifiers should consider permitting variations in production, structural design, materials, connection and erection techniques to accommodate varying plant practices. Specifying the results desired without specifically defining manufacturing procedures will ensure the best competitive bidding. Required submittals should also include range-bracketing samples for color and texture.

The specification section should include connection components embedded in the precast concrete, related loose connection hardware, and any special devices for lifting or erection, if required, as responsibilities of the precaster. Items to be specified in other sections include building frame support provisions required to support units, including portions of connectors attached to the structure, joint sealing and final cleaning and protection.

Coordination:

The responsibility for supply of precast concrete support items to be placed on or in the structure in order to receive the architectural precast concrete units depends on the type of structure and varies with local practice. Clearly specify responsibility for supply and installation of hardware. If not supplied by the precast concrete fabricator, list supplier and requirements in related trade sections.

The type and quantity of hardware items required to be cast into precast concrete units for other trades should be clearly specified. Specialty items should be required to be detailed, and supplied to precaster in a timely manner by the trade requiring them. Verify that materials specified in the section on flashing are galvanically compatible with reglets or counterflashing receivers. Check that concrete coatings, adhesives and sealants specified in other sections are compatible with each other and with the form release agents or surfaces to which they are applied.

Items mentioned in the Guide Specification as supply and/or installation by others should be mentioned in the specifications covering the specific trades. Such items may include:

- Cost of additional inspection by an independent testing laboratory, if required.
- Hardware for interfacing with other trades (window, door, flashing and roofing items).
- Placing of precast hardware cast into or attached to the structure, including tolerances for such placing.
- Joint treatment for joints between precast concrete and other materials.
- Access to building and floors.
- Power and water supply.
- Cleaning.
- Water repellent coatings.
- Plant-installed facing materials such as natural stone and clay products.

Guide Specification Development:

These Guide Specifications have been developed jointly by PCI, Gensler and the American Institute of Architects (AIA), Master Systems publishers of MASTERSPEC®.

PERFORMANCE SPECIFICATIONS

Performance specifications may be employed with good results as long as the architect identifies the purpose to be served and includes appropriate safeguards such as pre-qualification of precasters, pre-bid approval of materials and surface finishes, careful review of shop drawings, and architect's approval of initial production units.

Prescriptive specifications often contain inflexible to stringent requirements which can adversely affect a projects budget and delivery schedule. A common use of prescriptive specifying is with pre-engineered cladding systems. Typically an owner will engage a design firm to engineer a cladding system in order to

shorten the time period necessary to design and develop project shop drawing. The most common form of a precast specification is by performance. The principal advantage of performance specifications is that it allows precaster to combine economy and optimum quality, utilizing established tooling and production techniques not envisioned by the Architect or specifier.

Performance specifications may create additional work for the architect at the design stage, because the end result must be clearly defined and several different proposals must be assessed. The accepted proposals will eventually become the standards for manufacturing. However, this additional work in the early stages is generally offset by time saved later in detailing in the architect's office.

Performance specifications should define the scope (statement of needs) and quality of the precast concrete at an early stage. In performance specifications, the manufacturer is responsible for selecting means and methods to achieve a satisfactory result.

Properly prepared performance specifications should conform to the following criteria:

1. They should clearly state all limiting factors such as minimum or maximum thickness, depth, weight, tolerances, and any other limiting dimensions. Acceptable limits for requirements not detailed should be clearly provided. These limits may cover insulation (thermal and acoustical), interaction with other materials, services and appearance.
2. They should be written so that the scope is clearly defined. Items not included under the scope of the precast work must be identified and cross referenced in the Project Documents.
3. The architect should request samples, design and detail submissions from prospective bidders and make pre-bid approval of such submissions a prerequisite for bidding.
4. To the degree that such requests for pre-bid approvals form a part of the specifications, the architect should adhere to the following:
 - a. Sufficient time must be allowed for the precaster to submit samples or information for approval by the architect. Approval should be conveyed to the manufacturer in writing with sufficient time to allow completion of estimate and submittal of bid.
 - b. All proprietary pre-bid submittals should be treated in confidence and the individual producer's original solutions or techniques protected both before and after bidding

Guide Specification

This Guide Specification is intended to be used as a basis for the development of an office master specification or in the preparation of specifications for a particular project. In either case this Guide Specification must be edited to fit the conditions of use. Particular attention should be given to the deletion of inapplicable provisions or inclusion of appropriate requirements. Coordinate the specifications with the information shown on the contract drawings to avoid duplication or conflicts.

Shaded portions are Notes to the Specification Writer.

SECTION 03450 ARCHITECTURAL PRECAST CONCRETE

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions. Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This section includes the performance criteria, materials, production, and erection of architectural precast concrete for the entire project. The work performed under this section includes all labor, material, equipment, related services, and supervision required for the manufacture and erection of the architectural precast concrete work shown on the contract drawings.

Adjust list below to suit Project. Delete paragraph below if not listing type of units.

- B. This Section includes the following:
 - 1. Architectural precast concrete cladding and load bearing units.
 - 2. Insulated, architectural precast concrete units.
 - 3. Brick-faced, architectural precast concrete units.
 - 4. Stone-faced, architectural precast concrete units.

- C. Related Sections include the following:

List below only products and construction that the reader might expect to find in this Section but are specified elsewhere. Other sections of the specifications not referenced below, shall also apply to the extent required for proper performance of this work.

1. Division 3 Section “Cast-in-Place Concrete” for placing connection anchors in concrete.
2. Division 3 Section “Glass-Fiber-Reinforced Concrete.”
3. Division 4 Section “Dimension Stone Cladding” for furnishing stone facings and anchorages.
4. Division 4 Section “Cast Stone” for wet or dry cast stone facings, trim, and accessories.
5. Division 4 Section “Unit Masonry Assemblies” for full-thickness brick facing, mortar, and anchorages.
6. Division 5 Section “Structural Steel” for connection attachment to structural-steel framing.
7. Division 7 Section “Water Repellents” for water-repellent finish treatments.
8. Division 7 Section “Sheet Metal Flashing and Trim” for flashing receivers and reglets.
9. Division 7 Section “Joint Sealants” for elastomeric joint sealants and sealant backings.
10. Division 8 Section “Aluminum Windows” for windows set into architectural precast concrete units and tiebacks for window washing equipment.

1.3 DEFINITIONS

Retain paragraph below if a design reference sample has been pre-approved and is available for review.

- A. Design Reference Sample: Sample of approved architectural precast concrete color, finish and texture, pre-approved by Architect.

1.4 PERFORMANCE REQUIREMENTS

Retain this Article if delegating design responsibility for architectural precast concrete units to fabricator. AIA Document A201 requires Owner or Architect to specify performance and design criteria.

- A. Structural Performance: Provide architectural precast concrete units and connections capable of withstanding design loads within limits and under conditions indicated.

Retain paragraph above if placing design loads on Drawings; retain paragraph and applicable subparagraphs below if including design loads here. Revise requirements below to suit Project, and add other performance and design criteria if applicable.

ASHRAE/IES Standard 90.1 requires that thermal performance be established using the isothermal planes analysis method. This standard is now incorporated by reference in model energy code. Calculations must include the effects of any thermal bridges that penetrate the insulation, including concrete or metal connections. Thermal bridges significantly compromise the thermal performance of insulated concrete sandwich wall panels. Envelope performance must account for varying insulation locations when not on the same side of an envelope construction. Standard 90.1 requires that in addition to analysis of penetrations through insulation, analysis of thermal bridges created by the construction proper is considered. For example, walls may be designed with insulation at the top of the wall. Others are designed with insulation located outside the wall for the first twelve feet and inside the wall for the remaining height up to the roof system. These designs create a thermal bridge (the wall) at the point where the two systems cross or the top insulation ends without physical intersection with an adjacent insulation system. The specifier should identify the acceptable R-value for the panels.

- B. Thermal Performance: The insulated concrete sandwich panels must be constructed to maintain the effective acceptable material R- **<Insert R-value required>** of the panels with less than one (1) percent reduction due to penetrations and connection detailing. The reduction in thermal performance must be calculated using the Isothermal planes method of R-value calculation.
- C. Moisture Performance: The insulated concrete sandwich panels must be adequately designed and constructed to prevent the growth of mold and mildew and the formation of frost or ice on any panel surface and must maintain inner-wall condensation potential below **<Insert allowable moisture >** oz./day/sq.ft. based on summer design extremes. Provide calculations complying with the ASHRAE Handbook of Fundamentals – Theory of Water Vapor Migration and confirming the requirements for effective moisture condensation prevention.

Full-thickness concrete and metallic connectors can have serious detrimental effects on the performance of sandwich panels. If a panel manufacturer opts to use full-thickness concrete or metallic connections, consideration must be given to the effects those connections have on the panels and surrounding materials in the project. These negative effects can include concrete panel cracking and bowing induced by the constraint of the outer (thinner) wythe movement relative to the structural wythe. Also, full-thickness concrete sections will allow condensation to form at the breaks in the insulation system, resulting in heating and cooling loss, moisture migration, inconsistent face appearance, coating failures on painted panels, and growth of mold and mildew.

- D. Structural Performance: Provide architectural precast concrete units and connections capable of withstanding the following design loads within limits and under conditions indicated:

As a minimum dead loads include panel weight and the weight(s) of the materials that bear on them.

- 1. Dead Loads: **<Insert applicable dead loads.>**
- 2. Live Loads: **<Insert applicable live loads.>**
- 3. Wind Loads: **<Insert applicable wind loads or wind-loading criteria, positive and negative for various parts of the building as required by applicable building code or ASCE 7, including basic wind speed, importance factor, exposure category, and pressure coefficient.>**
- 4. Seismic Loads: **<Insert applicable seismic design data including seismic performance category, importance factor, use group, seismic design category, seismic zone, site classification, site coefficient and drift criteria.>**
- 5. Project Specific Loads: **<Insert applicable loads.>**

Show locations here or on Drawings if different movement is anticipated for different building elements. If preferred, change deflection limits below to ratios such as L/300 for floors and L/200 for roofs.

- 6. Design framing system and connections to maintain clearances at openings, to allow for fabrication and construction tolerances, to accommodate live load deflection, shrinkage and creep of primary building structure, and other building movements as follows: a. Upward and downward movement of **[1/2 inch (13 mm)] [3/4 inch (19 mm)] [1 inch (25 mm)]**.

Temperature value in first subparagraph below is suitable for most of the U.S. based on assumed design temperature of 70 deg. F (21 Deg. C). Revise to suit local conditions. Temperature data is available from National Oceanic and Atmospheric Administration at www.ncdc.noaa.gov.

7. Thermal Movements: Provide for in-plane thermal movements resulting from annual ambient temperature changes of 80 deg F (27 deg C) <Insert temperature>. Use other values, greater or smaller, whenever justified by climatic conditions at the project site. If the insulated concrete sandwich wall panels are to include full-thickness concrete sections or metallic connectors between the concrete wythes (surfaces) indicate how wall panel thermal bowing and concrete cracking will be mitigated.

Delete paragraph below if fire resistance rating is not required. Fire ratings depend on occupancy and building construction type, and are generally a building code requirement. When required, fire-rated products should be clearly identified on the design drawings.

8. Fire Resistance Rating: Select material and minimum thicknesses to provide <one hour> <two hour> fire rating.

Delete paragraph below if window washing system is not required.

9. Window Washing System: Design panels for window washing system indicated to resist forces transmitted from window washing equipment pull-out and horizontal shear. All design criteria for window washing system, including material and equipment, furnished by Owner.

Retain paragraph below if stone faced precast concrete are used on project.

10. Stone to Precast Anchorages: Provide anchors, as determined through Owner's or stone supplier testing, in numbers, types and locations as required to satisfy the performance criteria specified, but not less than the following.
 - a. Minimum Anchorage Requirement: Not less than 2 anchors per stone unit of less than 2 sq. ft. (0.19 sq. m) in area and 4 anchors per unit of less than 12 sq. ft. (1.1 sq. m) in area and for units larger than 12 sq. ft. (1.1 sq. m) in area, provide anchors spaced not more than 24 inches (600 mm) o.c. both horizontally and vertically, all located a minimum of 6 inches (150 mm) from stone edge.

Delete paragraph below if units are not used in parking structure to resist impact load.

11. Vehicular Impact Loads: Design spandrel beams acting as vehicular barrier for passenger cars to resist a single load of 6,000 lbs (26.7 kN) service load and 10,000 lbs (44.5 kN) ultimate load applied horizontally in any direction to the spandrel beam, with anchorages or attachments capable of transferring this load to the structure. For design of these beams, assume the load to act at a height of 18 inches (460 mm) above the floor or ramp surface on an area not to exceed 1 sq. ft. (305 mm²).

1.5 SUBMITTALS

- A. Product Data: For each type of product indicated. Retain quality control records and certificates of compliance for 5 years or period of warranty, whichever is greater.
- B. Design Mixes: For each concrete mix along with compressive strength and water-absorption tests.

- C. Thermal Performance: Provide calculations complying with ASHRAE/IES Standard 90.1 and confirming the effective thermal resistance for the concrete sandwich wall system.
- i. Sandwich panel system is designed and configured to eliminate “thermal bridging” resulting from penetrations of insulation layer by highly conductive or non-insulating materials.
 - ii. Sandwich wall connecting system shall not reduce the thermal resistance of the wall assembly by more than 2% when R-value is calculated using the series parallel path method of calculation according to ASHRAE Fundamentals Handbook.
- D. Moisture Performance: Provide calculations complying with the ASHRAE Handbook of Fundamentals – Theory of Water Vapor Migration and confirming the requirements for effective moisture condensation prevention.
- E. Thermal bowing and crack mitigation: Provide calculations and details that indicate how panel wall bowing and concrete cracking will be mitigated if the concrete sandwich wall panels are to include full-thickness concrete sections or metallic connectors between the concrete wythes (surfaces).
- F. Shop (Erection) Drawings: Detail fabrication and installation of architectural precast concrete units. Indicate member locations, plans, elevations, dimensions, shapes and cross sections. Indicate aesthetic intent including joints, reveals, and extent and location of each surface finish. Indicate details at building corners.
1. Indicate separate face and backup mix locations, and thicknesses.
 2. Indicate welded connections by AWS standard symbols. Detail loose and cast-in hardware, and connections.
 3. Indicate locations, tolerances and details of anchorage devices to be embedded in or attached to structure or other construction.
 4. Indicate locations, extent and treatment of dry joints if two-stage casting is proposed.
 5. Indicate plans, and/or elevations showing unit location, and sequence of erection for special conditions.
 6. Indicate location of each architectural precast concrete unit by same identification mark placed on panel.
 7. Indicate relationship of architectural precast concrete units to adjacent materials.
 8. Indicate locations and details of brick units and joint treatment.
 9. Indicate locations and details of stone facings, stone anchors, and joint widths.
 10. Design Modifications:
 - a. If design modifications are necessary to meet the performance requirements and field conditions, submit design calculations and drawings. Do not adversely affect the appearance, durability or strength of units when modifying details or materials and maintain the general design concept.

Retain subparagraph below if “Performance Requirements” Article is retained. Delete or modify if Architect assumes or is required by law to assume design responsibility.

11. Comprehensive engineering design [**signed and sealed**] [**certified**] by the qualified professional engineer responsible for its preparation registered in the state in which the project is located. Show governing panel types, connections, and types of reinforcement, including special reinforcement. Coordinate the location, type, magnitude and direction of all imposed loadings from the precast system to the building structural frame with the Engineer of Record.

Retain paragraph below if finishes, colors, and textures are preselected, specified, or scheduled.

- D. Samples: Design reference samples for initial verification of design intent, approximately 12 by 12 by 2 inches (300 by 300 by 50 mm), representative of finishes, color, and textures of exposed surfaces of architectural precast concrete units.
1. When back face of precast concrete unit is to be exposed, show samples of the workmanship, color, and texture of the backup concrete as well as the facing.
- E. Samples for each brick unit required, showing the full range of color and texture expected. Supply sketch of each corner or special shape with dimensions. Supply sample showing color and texture of joint treatment.

Retain first paragraph below if procedures for welder certification are retained in "Quality Assurance" Article.

- F. Welding Certificates: Copies of certificates for welding procedure specifications (WPS) and personnel.

Manufacturer should have a minimum of 2 years of production experience in architectural precast concrete work comparable to that shown and specified, in not less than three projects of similar scope with the Owner or Architect determining the suitability of the experience.

- G. Qualification Data: For firms and persons specified in "Quality Assurance" Article to demonstrate their capabilities and experience. Include list of completed projects with project names and addresses, names and addresses of architects and owners, and other information specified.

Delete test reports below if not required.

- H. Material Test Reports: From a qualified testing agency indicating and interpreting test results of the following for compliance with requirements indicated:

Retain paragraph above or below.

- I. Material Certificates: Signed by manufacturers certifying that each of the following items complies with requirements.

Retain list below with either paragraph above. Edit to suit Project.

1. Concrete materials.
2. Reinforcing materials and prestressing tendons.
3. Admixtures.

4. Bearing pads.
5. Structural-steel shapes and hollow structural sections.
6. Insulation
7. Insulated sandwich panel accessories (Wythe Connectors)
8. Brick units.
9. Stone anchors.

17.6 QUALITY ASSURANCE

A. Erector Qualifications:

Erector should have a minimum of 2 years of experience in architectural precast concrete work comparable to that shown and specified in not less than three projects of similar scope with the owner or Architect determining the suitability of the experience. The inclusion of erection in the precast concrete contract should be governed by local practices. See PCI's website www.pci.org for current PCI-Qualified Erectors.

1. A precast concrete erector Qualified by the Precast/Prestressed Concrete Institute (PCI) prior to beginning work at the projectsite. Submit a current Certificate of Compliance furnished by PCI designating qualification in [**Category A (Architectural Systems) for non-load-bearing members**] [**Category S2 (Complex Structural Systems) for load-bearing members**].

Retain paragraph below if PCI-Qualified Erector is not available for Project.

2. An erector with a minimum of 2 years of experience who has completed architectural precast concrete work similar in material, design, and extent to that indicated for this Project and whose work has resulted in construction with a record of successful in-service performance and who meets the following requirements:
 - a. Retains a PCI Certified Field Auditor, at erector's expense, to conduct a field audit of a project in the same category as this Project prior to start of erection. Submits Erectors Post Audit Declaration.
 - b. The basis of the audit is the "PCI Erector's Manual - Standards and Guidelines for the Erection of Precast Concrete Products" MNL 127.

B. Fabricator Qualifications: A firm that complies with the following requirements and is experienced in producing architectural precast concrete units similar to those indicated for this Project and with a record of successful in-service performance.

1. Assumes responsibility for engineering architectural precast concrete units to comply with performance requirements. This responsibility includes preparation of Shop Drawings and comprehensive engineering analysis by a qualified professional engineer.

Delete subparagraph above and below if Contractor is not required to engage the services of a qualified professional engineer and if submission of a comprehensive engineering analysis is not retained in "Submittals" Article.

2. Professional Engineer Qualifications: A professional engineer who is legally qualified to practice in jurisdiction where Project is located and who is experienced in providing engineering services of the kind indicated. Engineering services are defined as those performed for installations of architectural precast concrete that are similar to those indicated for this Project in material, design, and extent.
3. Participates in PCI's Plant Certification program at the time of bidding and is designated a PCI-certified plant for Group A, Category A1- Architectural Cladding and Load Bearing Units.
4. Has sufficient production capacity to produce required units without delaying the Work.

Delete subparagraph below if fabricators are not required to be registered with and approved by authorities having jurisdiction. List approved fabricators in Part 2 if required.

5. Is registered with and approved by authorities having jurisdiction.

Retain first paragraph below if PCI Certification Program provides quality assurance testing, and additional quality assurance testing is required. Testing agency is normally engaged by Owner.

C. Insulation Manufacturer's Qualifications:

1. Provide shop drawings and detailing for concrete wall insulation system.
2. Attend pre-construction meetings and initial wall panel insulation placement to instruct in the proper installation of the wall panel system.
3. Provide quality assurance instruction and equipment for evaluation of connector installation.
4. Provide traceable and verifiable quality assurance by a recognized third party testing agency.
 - i. Listing requirements vary with product; however, all require that the manufacturers established testing and evaluation procedures must be repeatable and open to third party review and verification. Wythe connectors should be evaluated for the following:
 - a. Dimensional accuracy
 - b. Material hardness per ASTM D 785-89
 - c. Material flexural capacity per ASTM D 790-86

Also as part of the listing process, connector samples should be subjected to shear, pullout, and fire tests. Shear and pullout tests were both monotonic and cyclic. These tests are conducted to verify that the connectors are capable of maintaining their capacity in extreme seismic and fire events.

- D. Testing Agency Qualifications: An independent testing agency, **[acceptable to authorities having jurisdiction]** qualified according to ASTM C 1077 and ASTM E 329 to conduct the testing indicated, as documented according to ASTM E 548.
- E. Design Standards: Comply with ACI 318 (ACI 318M) and the design recommendations of PCI MNL 120, "PCI Design Handbook – Precast and Prestressed Concrete," applicable to types of architectural precast concrete units indicated.
- F. Quality-Control Standard: For manufacturing procedures and testing requirements, quality-control recommendations, and dimensional tolerances for types of units required, comply with PCI MNL

117, “Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products.”

Delete paragraph below if no welding is required. Retain “Welding Certificates” Paragraph in “Submittals” Article if paragraph below is retained. AWS states that welding qualifications remain in effect indefinitely unless welding personnel have not welded for more than six months or there is a specific reason to question their ability.

- G. Welding: Qualify procedures and personnel according to AWS D1.1, “Structural Welding Code – Steel”; and AWS D1.4, “Structural Welding Code – Reinforcing Steel.”

Retain paragraph below if fire-rated units or assemblies are required. Select either PCI MNL 124 or ACI 216.1/TMS 0216.1 or retain both if acceptable to authorities having jurisdiction.

- H. Calculated Fire-Test-Response Characteristics: Where indicated, provide architectural precast concrete units whose fire resistance has been calculated according to [PCI MNL 124, “Design for Fire Resistance of Precast Prestressed Concrete,”] [ACI 216.1/TMS 0216.1, “Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies,”] and is acceptable to authorities having jurisdiction.

PCI recommends review of preproduction sample panels or first production unit. Revise size and number of sample panels to suit Project.

- I. Sample Panels: After sample approval and before fabricating architectural precast concrete units, produce a minimum of two sample panels approximately 16 square feet in size for review by Architect. Incorporate full scale details of architectural features, finishes, textures, and transitions in the sample panels.

1. Locate panels where indicated or, if not indicated, as directed by Architect.
2. Damage part of an exposed-face surface for each finish, color, and texture, and demonstrate adequacy of repair techniques proposed for repair of surface blemishes.
3. After acceptance of repair technique, maintain one sample panel at the manufacturer’s plant and one at the project site in an undisturbed condition as a standard for judging the completed Work.
4. Demolish and remove sample panels when directed.

PCI recommends production of finish and texture range samples when color and texture uniformity concerns could be an issue, the Architect or precaster has not had previous experience with the specified mix and finish, or a large project has multiple approving authorities.

- J. Range Samples: After sample panel approval and before production fabrication of architectural precast concrete units, produce a minimum of ~~three~~ **five** samples, approximately 16 square feet in size, representing anticipated range of color and texture on project’s units. Following range sample acceptance by the Architect, maintain samples at the manufacturer’s plant as color and texture acceptability reference.

Delete paragraph and subparagraphs below if sample panels above will suffice and the added

expense of mockups is not required. If retaining, indicate location, size, and other details of mockups on Drawings or by inserts. Revise wording if only one mockup is required.

- J. Mockups: After sample approval but before production fabrication of architectural precast concrete units, construct full sized mockups to verify selections made under sample Submittals and to demonstrate aesthetic effects and qualities of materials and execution. Mockup to be representative of the finished work in all respects including glass, aluminum framing, sealants and architectural precast concrete complete with all anchors, connections, flashings, and joint fillers as accepted on the final shop drawings. Build mockups to comply with the following requirements, using materials indicated for the completed work:

Revise or delete subparagraphs below to suit Project.

1. Build mockups in the location and of the size indicated or, if not indicated, as directed by Architect.
2. Notify Architect in advance of dates and times when mockups will be constructed.
3. Obtain Architect's approval of mockups before starting fabrication.
4. In presence of Architect, damage part of an exposed face for each finish, color, and texture, and demonstrate materials and techniques proposed for repairs to match adjacent undamaged surfaces.
5. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
6. Demolish and remove mockups when directed.

Retain subparagraph below if mockups are erected as part of building rather than separately and the intention is to make an exception to the default requirement in Division 1 Section, "Quality Requirements" for demolishing and removing mockups.

7. Approved mockups may become part of the completed Work if undamaged at the time of Substantial Completion.

Delete paragraph below if mockup above is to be used for Testing Mockup.

- K. Testing Mockup: Provide a single full sized mockup for testing by others to the extent shown or indicated to simulate the precast and window wall assembly. Refer to Division 8 WINDOW AND CURTAIN WALLS for requirements applicable to testing architectural precast concrete systems in conjunction with windows and window wall.

Delete below if Work of this Section is not extensive or complex enough to justify a pre-installation conference. If retaining, coordinate with Division 1.

- L. Pre-installation Conference: Conduct conference at Project site to comply with requirements in Division 1 Section "Project Management and Coordination."

1.7 PRODUCT DELIVERY, STORAGE AND HANDLING

- A. Store units with adequate dunnage and bracing and protect units to prevent contact with soil, staining, and to prevent cracking, distortion, warping or other physical damage.
- B. Store units, unless otherwise specified, with non-staining, resilient supports.
- C. Place stored units so identification marks are clearly visible, and product can be inspected.
- D. Deliver all architectural precast concrete units to the project site in such quantities and at such times to assure compliance with the agreed project schedule and proper setting sequence so as to limit unloading units temporarily on the ground.
- E. Handle and transport units in a position consistent with their shape and design in order to avoid excessive stresses which would cause cracking or damage.
- F. Lift and support units only at designated points shown on the Shop Drawings.
- G. Place non-staining resilient spacers of even thickness between each unit.
- H. Support units during shipment on non-staining shock absorbing material.

1.8 SEQUENCING

Coordination and responsibility for supply of items to be placed on or in the structure to allow placement of precast concrete units depends on type of structure and varies with local practice. Clearly specify responsibility for supply and installation of hardware. If not supplied by precast concrete fabricator, supplier should be listed and requirements included in related trade sections. When the building frame is structural steel, erection hardware welded to the steel frame should be supplied and installed as part of the structural steel. Ensure that type and quantity of hardware items to be cast into precast concrete units for use of other trades are specified or detailed in contract drawings and furnished to fabricator, with instructions, in a timely manner in order not to delay the Work.

- A. Furnish loose connection hardware and anchorage items to be embedded in or attached to other construction without delaying the Work. Provide setting diagrams, templates, instructions, and directions, as required, for installation.

PART 2 – PRODUCTS

2.1 FABRICATORS

Delete this Article unless naming fabricators. See PCI's magazine "Ascent" or its Web site www.pci.org for current PCI-certified plant listings.

- A. Available Fabricators: Subject to compliance with requirements, fabricators offering products that may be incorporated into the Work include, but are not limited to, the following:

Retain above for nonproprietary or below for semiproprietary specification. If above is retained, include procedure for approval of other fabricators in Instructions to Bidders. Refer to Division 1 Section "Product Requirements."

- B. Fabricators: Subject to compliance with requirements, provide products by one of the following:
1. <Insert fabricators' names and product designations for acceptable manufacturers.>

2.2 MOLD MATERIALS

- A. Molds: Rigid, dimensionally stable, nonabsorptive material, warp and buckle free, that will provide continuous and true precast concrete surfaces within fabrication tolerances indicated; non-reactive with concrete and suitable for producing required finishes.
1. Mold-Release Agent: Commercially produced liquid-release agent that will not bond with, stain or adversely affect precast concrete surfaces and will not impair subsequent surface or joint treatments of precast concrete.

Delete below if form liners are not used. Form liners may be used to achieve a special off-the-form finish or to act as a template for thin or half brick facings. Revise to add description if particular form liner is selected.

- B. Form Liners: Units of face design, texture, arrangement, and configuration **[indicated] [to match precast concrete design reference sample]**. Provide solid backing and form supports to ensure that form liners remain in place during concrete placement. Use with manufacturer's recommended liquid-release agent that will not bond with, stain, or adversely affect precast concrete surfaces and will not impair subsequent surface or joint treatments of precast concrete.

Delete below if not using retarder to help obtain exposed aggregate finish.

- C. Surface Retarder: Chemical set retarders capable of temporarily delaying hardening of newly placed concrete mix to depth of reveal specified.

2.3 REINFORCING MATERIALS

Select only one of the paragraphs and subparagraphs below to suit steel reinforcement requirements. If retaining "Performance Requirements" Article, consider reviewing selections with fabricators.

- A. Reinforcing Bars: ASTM A 615/A 615M, Grade 60 (Grade 420), deformed.

Retain paragraph below for reinforcement that is welded or if added ductility is sought.

- B. Low-Alloy-Steel Reinforcing Bars: ASTM A 706/A 706M, deformed.

The presence of chromate film on the surface of the galvanized coating is usually visible as a light yellow tint on the surface. ASTM B 201 describes a test method for determining the presence of chromate coatings. Use galvanizing where corrosive environment or severe exposure conditions justify extra cost.

- C. Galvanized Reinforcing Bars: ASTM A 767/A 767M, Class II zinc coated, hot-dip galvanized and chromate wash treated after fabrication and bending, as follows:

Select type of reinforcement to be galvanized from subparagraph below.

1. Steel Reinforcement: [ASTM A 615/A 615M, Grade 60 (Grade 420)] [ASTM A 706/A 706M], deformed.

Use epoxy coating where corrosive environment or severe exposure conditions justify extra cost. ASTM A775 is a bendable coating while ASTM A934 is a non-bendable coating.

- D. Epoxy-Coated Reinforcing Bars: ASTM A 775/A 775M or ASTM A 934/A 934M, as follows:

Select type of reinforcement to be epoxy coated from subparagraph below.

1. Steel Reinforcement: [ASTM A 615/A 615M, Grade 60 (Grade 420)] [ASTM A 706/A 706M], deformed.

- E. Steel Bar Mats: ASTM A 184/A 184M, assembled with clips, as follows:

Select type of reinforcement for mat fabrication from subparagraph below.

1. Steel Reinforcement: [ASTM A 615/A 615M, Grade 60 (Grade 420)] [ASTM A 706/A 706M], deformed bars.

Select only one of the paragraphs and subparagraphs below to suit steel reinforcement requirements. If retaining “Performance Requirements” Article, consider reviewing selections with fabricators.

- F. Plain-Steel Welded Wire Reinforcement: ASTM A 185, fabricated from [**as-drawn**] [**galvanized and chromate wash treated**] steel wire into flat sheets.
- G. Deformed-Steel Welded Wire Reinforcement: ASTM A 497, flat sheet.
- H. Epoxy-Coated-Steel Welded Wire Reinforcement: ASTM A 884/A 884M Class A coated, [**plain**] [**deformed**], flat sheet, [**Type 1 bendable coating**] [**Type 2 non-bendable coating**].
- I. Supports: Suspend reinforcement from back of mold or use bolsters, chairs, spacers, and other devices for spacing, supporting, and fastening reinforcing bars and welded wire reinforcement in place according to PCI MNL 117.

2.4 PRESTRESSING TENDONS

Retain this Article if precast concrete units will be prestressed, either pre-tensioned or post-tensioned. ASTM A 416/A 416M establishes low-relaxation strand as the standard

- A. Prestressing Strand: ASTM A 416/A 416M, Grade 270 (Grade 1860), uncoated, 7-wire, low-relaxation strand.

- B. Un-bonded Post-Tension Strand: ASTM A416/A416M with corrosion inhibitor conforming to ASTM D1743, Grade 270 (Grade 1860), 7-wire, low-relaxation strand with polypropylene conduit sheath.

2.5 CONCRETE MATERIALS

Delete materials below not required. Revise to suit Project.

- A. Portland cement: ASTM C150, Type I or III.

Select Portland cement color from options in subparagraph below. Mixing with white cement will improve color uniformity of gray cement. White cement has greater color consistency than gray cement and should be used for pastel colors. For darker colors, the variations of gray cement have less effect on the final color hue.

1. For surfaces exposed to view in finished structure, use **[gray] [and] [white]**, same type, brand, and mill source throughout the precast concrete production.
2. Standard gray Portland cement may be used for non-exposed backup concrete.

- B. Supplementary Cementitious Materials.

Select mineral or cementitious admixtures from four paragraphs below. Where appearance is an important factor, it is recommended that fly ash, silica fume and ground slag not be permitted.

1. Fly Ash Admixture: ASTM C 618, Class C or F with maximum loss on ignition of 3 percent.
2. Metakaolin Admixture: ASTM C 618, Class N.
3. Silica Fume Admixture: ASTM C 1240 with optional chemical and physical requirement.
4. Ground Granulated Blast-Furnace Slag: ASTM C989, Grade 100 or 120.

ASTM C 33 limits deleterious substances in coarse aggregate depending on climate severity and in-service location of concrete. Class 5S is the most restrictive designation for architectural concrete exposed to severe weathering. PCI MNL 117 establishes stricter limits on deleterious substances for fine and coarse aggregates.

- B. Normal-Weight Aggregates: Except as modified by PCI MNL 117, ASTM C 33, with coarse aggregates complying with Class 5S. Provide and stockpile fine and coarse aggregates for each type of exposed finish from a single source (pit or quarry) for entire project.

Revise subparagraph below and add descriptions of selected coarse- and fine-face mix aggregate colors, sizes, and sources if required.

1. Face-Mix Coarse Aggregates: Selected, hard, and durable; free of material that reacts with cement or causes staining; to match selected finish sample.

Retain one option from first subparagraph below or insert gradation and maximum aggregate size if

known. Fine and coarse aggregates are not always from same source.

- a. Gradation: [**Uniformly graded**] [**Gap graded**] [**To match design reference sample**].
2. Face-Mix Fine Aggregates: Selected, natural or manufactured sand of the same material as coarse aggregate, unless otherwise approved by Architect.

Delete paragraph below when architectural requirements dictate that face-mix be used throughout.

C. Backup Concrete Aggregates: ASTM C33 or C330.

Lightweight aggregates in a face-mix are not recommended in cold or humid climates (if exposed to the weather) unless their performance has been verified by tests or records of previous satisfactory usage in similar environments. If normal-weight aggregates are used in face-mix, lightweight aggregates in backup are not recommended due to bowing potential.

D. Lightweight Aggregates: Except as modified by PCI MNL 117, ASTM C 330 with absorption less than 11 percent.

Delete first paragraph below if coloring admixture is not required. Add color selection if known.

- E. Coloring Admixture: ASTM C 979, synthetic or natural mineral-oxide pigments or colored water-reducing admixtures, temperature stable and non-fading.
- F. Water: Potable; free from deleterious material that may affect color stability, setting, or strength of concrete and complying with chemical limits of PCI MNL 117.

Delete paragraph below if air entrainment is not required. Air entrainment should be required to increase resistance to freezing and thawing where environmental conditions dictate.

G. Air Entraining Admixture: ASTM C 260, certified by manufacturer to be compatible with other required admixtures.

Add types of chemical admixtures, if known, or limit types if required. Water-reducing admixtures, Types A, E, and D, or a high-range water reducer, Type F, predominate.

- H. Water-Reducing Admixture: ASTM C 494/C494M, Type A.
- I. Retarding Admixture: ASTM C 494/C494M, Type B.
- J. Water-Reducing and Retarding Admixture: ASTM C 494/C494M, Type D.
- K. High-Range, Water-Reducing Admixture: ASTM C 494/C494M, Type F.
- L. High-Range, Water-Reducing and Retarding Admixture: ASTM C 494/C494M, Type G.
- M. Plasticizing Admixture for Flowable Concrete: ASTM C 1017/C1017M.

- N. Admixtures containing calcium chloride or more than 0.15 percent chloride ions or other salts by weight of admixture are not permitted.

2.6 STEEL CONNECTION MATERIALS

Edit this Article to suit Project. Add other materials as required.

- A. Carbon-Steel Shapes and Plates: ASTM A 36/A 36M except silicon (Si) content in the range of 0 to 0.03% or 0.15 to 0.25% for materials to be galvanized. Steel with chemistry conforming to the formula $Si + 2.5P \leq 0.09$ is also acceptable.
- B. Carbon-Steel Headed Studs: ASTM A 108, Grades 1018 through 1020, cold finished and bearing the minimum mechanical properties for studs as indicated under MNL 117, Table 3.2.3.; AWS D1.1, Type A or B, with arc shields.
- C. Carbon-Steel Plate: ASTM A 283/A 283M.
- D. Malleable Iron Castings: ASTM A 47/A 47M. Grade 32510 or 35028.
- E. Carbon-Steel Castings: ASTM A 27/A 27M, Grade U-60-30 (Grade 415-205).
- F. High-Strength, Low-Alloy Structural Steel: ASTM A 572/A 572M except silicon (Si) content in the range of 0 to 0.03% or 0.15 to 0.25% for materials to be galvanized. Steel with chemistry conforming to the formula $Si + 2.5P \leq 0.09$ is also acceptable.
- G. Carbon-Steel Structural Tubing: ASTM A 500, Grade B.
- H. Wrought Carbon-Steel Bars: ASTM A 675/A 675M, Grade 65 (Grade 450).
- I. Deformed-Steel Wire or Bar Anchors: ASTM A 496 or ASTM A 706/A 706M.

ASTM A 307 defines the term “studs” to include stud stock and threaded rods.

- J. Carbon-Steel Bolts and Studs: ASTM A 307, Grade A (ASTM F 568M, Property Class 4.6) carbon-steel, hex-head bolts and studs; carbon-steel nuts (ASTM A563/A563M, Grade A); and flat, unhardened steel washers (ASTM F844).

High-strength bolts are used for friction-type connections between steel members and are not recommended between steel and concrete since concrete creep and crushing of concrete during bolt tightening reduce effectiveness.

- K. High-Strength Bolts and Nuts: ASTM A 325/A 325M or ASTM A490/A490M, Type 1, heavy hex steel structural bolts, heavy hex carbon-steel nuts, (ASTM A563/A563M) and hardened carbon-steel washers (ASTM F436/F436M).

Retain paragraph and subparagraph below if galvanized finish is required. Revise locations of galvanized items if required. Field welding should generally not be permitted on galvanized

elements, unless the galvanizing is removed or acceptable welding procedures are submitted. Hot-dip galvanized finish provides greater corrosion resistance than electrodeposited zinc coating. Electrodeposition is usually limited to threaded fasteners.

L. Finish: For exterior steel items and items indicated for galvanizing, apply zinc coating by **[hot-dip process according to ASTM A 123/A 123M, after fabrication, or ASTM A 153/A 153M, as applicable] [electrodeposition according to ASTM B 633, SC 3, Type 1 and 2]**.

1. Galvanizing Repair Paint: High-zinc-dust-content paint with dry film containing not less than 94 percent zinc dust by weight, and complying with DOD-P-21035A or SSPC-Paint 20.

Retain paragraph below if paint finish is required. Revise locations of priming, if required. MPI 79 (FS TT-P-664) in first option below provides some corrosion protection while SSPC-Paint 25, without top coating, provides minimal corrosion protection.

M. Shop-Primed Finish: Prepare surfaces of non-galvanized steel items, except those surfaces to be embedded in concrete, according to requirements in SSPC-SP 1 followed by SSPC-SP 3 and shop-apply **[lead- and chromate-free, rust –inhibitive primer, complying with performance requirements in MPI 79] [SSPC-Paint 25]** according to SSPC-PA 1.

N. Welding Electrodes: Comply with AWS standards.

2.7 STAINLESS-STEEL CONNECTION MATERIALS

Delete this Article if not required. Use when resistance to staining merits extra cost in parking structures and other high moisture or corrosive areas.

A. Stainless-Steel Plate: ASTM A 666, Type 304, of grade suitable for application.

B. Stainless-Steel Bolts and Studs: ASTM F 593, alloy 304 or 316, hex-head bolts and studs; stainless-steel nuts; and flat, stainless steel washers. Lubricate threaded parts of stainless steel bolts with an anti-seize thread lubricant during assembly.

C. Stainless-Steel Headed Studs: ASTM A 276 and bearing the minimum mechanical properties for studs as indicated under MNL 117, Table 3.2.3.

2.8 BEARING PADS AND OTHER ACCESSORIES

Delete this Article if not applicable. Choice of bearing pad can usually be left to fabricator; coordinate selection with structural engineer if required.

A. Provide bearing pads for architectural precast concrete units as follows:

1. Elastomeric Pads: AASHTO M 251, plain, vulcanized, 100 percent polychloroprene (neoprene) elastomer, molded to size or cut from a molded sheet, 50 to 70 Shore A durometer according to ASTM D2240, minimum tensile strength 2250 psi (15.5 MPa) per ASTM D 412.
2. Random-Oriented, Fiber-Reinforced Elastomeric Pads: Preformed, randomly oriented synthetic fibers set in elastomer. Surface hardness of 70 to 90 Shore A durometer according to ASTM D2240. Capable of supporting a compressive stress of 3000 psi (20.7 MPa) with no

cracking, splitting or delaminating in the internal portions of the pad. Test one specimen for each 200 pads used in the project.

3. Cotton-Duck-Fabric-Reinforced Elastomeric Pads: Preformed, horizontally layered cotton-duck fabric bonded to an elastomer. Surface hardness of 80 to 100 Shore A durometer according to ASTM D2240. Conforming to Division II, Section 18.10.2 of AASHTO LRFD Bridge Design Specifications, or Military Specification, MIL-C-882D.
4. Frictionless Pads: Tetrafluoroethylene (teflon), glass-fiber reinforced, bonded to stainless or mild-steel plates, of type required for in-service stress.
5. High-Density Plastic: Multimonomer, nonleaching, plastic strip.

Select material from options in paragraph below or add another material to suit Project. Coordinate with counterflashing materials and details.

- B. Reglets: [**PVC extrusions.**] [**Stainless steel, Type 302**] [**Copper**] [**Reglets and flashing are specified in Division 7 Section “Sheet Metal Flashing and Trim.”**] felt or fiber filled or cover face opening of slots.
- C. Accessories: Provide clips, hangers, plastic or steel shims, and other accessories required to install architectural precast concrete units.

2.9 GROUT MATERIALS

Add other proprietary grout systems to suit Project. Show locations of each grout here or on Drawings if more than one type is retained.

- A. Sand-Cement Grout: Portland Cement, ASTM C 150, Type I, and clean, natural sand, ASTM C 144, or ASTM C 404. Mix at ratio of 1 part cement to 2-1/2 parts sand, by volume, with minimum water required for placement and hydration.

Retain paragraph below if nonshrink grout is required or if cement-grout shrinkage could cause structural deficiency. For critical installations, require manufacturer to provide field supervision.

- B. Nonmetallic, Nonshrink Grout: Premixed, nonmetallic, noncorrosive, nonstaining grout containing selected silica sands, portland cement, shrinkage-compensating agents, plasticizing and water-reducing agents, complying with ASTM C 1107, Grade A for drypack and Grades B and C for flowable grout and of a consistency suitable for application within a 30-minute working time.
- C. Epoxy-resin grout: Two-component mineral-filled epoxy-resin: ASTM C881 of type, grade, and class to suit requirements.

2.10 THIN AND HALF BRICK UNITS AND ACCESSORIES

Retain this Article if specifying thin veneer brick-faced precast concrete panels. Type TBX brick units feature the tightest dimensional tolerances but may be too dimensionally variable to fit securely within form liner templates. Pre-select brick and name prior to bid or establish set cost allowance. If full-size brick units are required, use Division 4 Section “Unit Masonry Assemblies.”

- A. Thin or Half Brick Units: ASTM C216, Type FBX or ASTM C 1088, Grade Exterior, Type TBX, **[not less than ½ inch (13 mm)] [¾ inch (19 mm)] [1 inch (25 mm)]** thick with a tolerance of plus or minus 1/16 inch (1.59 mm) and as follows:
1. Face Size: Standard, 2-1/4 inches (57 mm) high by 8 inches (203 mm) long.
 2. Face Size: Modular, 2-1/4 inches (57 mm) high by 7-1/2 to 7-5/8 inches (190 to 194 mm) long.
 3. Face Size: Engineer Modular, 2-3/4 to 2-13/16 inches (70 to 71 mm) high by 7-1/2 to 7-5/8 inches (190 to 194 mm) long.
 4. Face Size: Closure Modular, 3-1/2 to 3-5/8 inches (89 to 92 mm) high by 7-1/2 to 7-5/8 inches (190 to 194 mm) long.
 5. Face Size: Utility, 3-1/2 to 3-5/8 inches (89 to 92 mm) high by 11-1/2 to 11-5/8 inches (292 to 295 mm) long.
 6. **[Where shown to “match existing,”]** provide face brick matching color, texture, and face size of existing adjacent brickwork.
 - a. **<Insert information on existing brick if known.>**

Select from subparagraphs above face sizes with equivalent metric dimensions or from subparagraphs below for products manufactured to metric face sizes. If retaining below, verify availability of sizes.

7. Face Size: Metric modular, 57 mm high by 190 mm long.
8. Face Size: Metric engineer, 70 mm high by 190 mm long.
9. Face Size: Metric closure, 90 mm high by 190 mm long.
10. Face Size: Metric utility, 90 mm high by 290 mm long.

Show details on Drawings of special conditions and shapes if required.

11. Special Shapes: Include corners, edge corners, and end edge corners.

Thin brick units with higher rates of absorption than values in first subparagraph below should be wetted before placing concrete to improve bond. Before retaining paragraph, verify that thin brick selected complies with requirements.

12. Initial Rate of Absorption: Less than 30g/30 sq. in. (30g/194 sq. cm.) per minute when tested per ASTM C 67.
13. Efflorescence: Provide brick that has been tested according to ASTM C 67 and is rated “not effloresced.”

Delete subparagraph below if surface-colored brick is not used.

14. Surface Coloring: Brick with surface coloring, other than flashed or sand-finished brick, shall withstand 50 cycles of freezing and thawing per ASTM C 67 with no observable difference in the applied finish when viewed from 10 feet (3 m).

Options in subparagraph below are examples of descriptive requirements for appearance where a proprietary specification cannot be used. If approving a color range for brick, view 100 square feet of loose bricks or a completed building. Edit to suit Project or delete if brick is specified by product name.

15. Face Color and Texture: **[Match Architect's samples] [Medium brown, wire cut] [Full-range red, sand molded] [Gray, velour].**

Retain first subparagraph below, deleting inapplicable descriptions if required.

16. Back Surface Texture: Scored, combed, wire roughened, ribbed, keybacked or dovetailed.

17. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:

Retain subparagraph above for nonproprietary or subparagraph below for semiproprietary Specification. Refer to Division 1 Section "Materials and Equipment."

18. Products: Subject to compliance with requirements, provide one of the following:

a. <Insert manufacturers' names and product designations for acceptable face brick.>

Refer to American National Standards Institute (ANSI) A 137.1 for the commonly available sizes and shapes, physical properties, the basis for acceptance and methods of testing.

B. Glazed and Unglazed Ceramic Tile Units: ANSI A 137.1 **[not less than 3/8 inch (10 mm)]**

1. Body of glazed tile shall have a water absorption of less than 3 percent using ASTM C373.
2. Manufacturer shall warrant materials as frost-resistant.
3. Glazed units shall conform to ASTM C126.

C. Architectural Terra Cotta Units: Comply with requirements of Architectural Terra Cotta manufacturers' standards for the application indicated.

Retain paragraph below if mortar setting brick unit joints before placing precast concrete mix.

D. Setting Mortar: Portland cement, ASTM C 150, Type I, and clean, natural sand, ASTM C 144. Mix at ratio of 1 part cement to 4 parts sand, by volume, with minimum water required for placement.

Delete paragraph and subparagraphs below if not filling thin brick unit joints with pointing grout after precast concrete panel production.

E. Latex-Portland Cement Pointing Grout: ANSI A118.6 and as follows:

Select one or both types of grout from first two subparagraphs below.

1. Dry-grout mixture, factory prepared, of portland cement, graded aggregate, and dry, redispersible, ethylene-vinyl-acetate additive for mixing with water; uniformly colored.
2. Commercial portland cement grout, factory prepared, with liquid styrene-butadiene rubber or acrylic-resin latex additive; uniformly colored.
3. Colors: **[As indicated by manufacturer's designations] [Match Architect's samples] [As selected by Architect from manufacturer's full range].**

F. Setting Systems

Retain paragraphs below if thin brick, ceramic tile, or full brick will be laid after casting of panel.

1. Thin brick and Ceramic Tile Units: [**Dry-Set Mortar: ANSI A118.1**] [**Latex-Portland Cement Mortar: ANSI A 118.4**]
2. Full Brick Units: Install <**Galvanized**> <**Type 304 stainless steel**> dovetail slots in precast: not less than 0.5 mm thick, felt or fiber filled or cover face opening of slots. Attach brick units with wire anchors, ASTM A82 or B227, Grade 30HS not less than 3/16 inch (W2.8) in diameter and hooked on one end and looped through a 7/8 in. (25 mm) wide, 12-gage (2.68 mm) steel sheet bent over the wire with dovetail on opposite end.

2.11 STONE MATERIALS AND ACCESSORIES

Retain this Article if stone facing is required. Material, fabrication, and finish requirements are usually specified in Division 4 Section "Dimension Stone Cladding." Replace first paragraph below with stone requirements, if preferred.

- A. Stone facing for architectural precast concrete is specified in Division 4 Section "Dimension Stone Cladding."
 1. Tolerance of length and width of +0, -1/8 inch (+0, -3mm).

Anchors are generally supplied by stone fabricator or, in some cases, by precaster. Specify supplier. Anchors may be toe-in, toe-out, or dowels.

- B. Anchors: Stainless steel, ASTM A 666, Type 304, of temper and diameter required to support loads without exceeding allowable design stresses.

Grommets will usually be required if filling dowel holes with rigid epoxy.

1. Fit each anchor leg with 60 durometer neoprene grommet collar of width at least twice the diameter and of length at least five times the diameter of the anchor.

- C. Sealant Filler: ASTM C 920, low-modulus, multicomponent, nonsag urethane sealant complying with requirements in Division 7 Section "Joint Sealants" and that is nonstaining to stone substrate.

Dowel hole filling is used to prevent water intrusion into stone and future discoloration at anchor locations. Retain paragraph above for a flexible filler or paragraph below for a rigid filler.

- D. Epoxy Filler: ASTM C 881, 100 percent solids, sand -filled non-shrinking, non -staining of type, class, and grade to suit application.
- E. Bond Breaker:
 1. Preformed, compressible, resilient, nonstaining, nonwaxing, closed-cell polyethylene foam pad, nonabsorbent to liquid and gas, 1/8 inch (3.2 mm) thick.
 2. Polyethylene sheet, 6 to 10 mil thick.

2.12 INSULATED PANEL ACCESSORIES

Retain this Article if integrally, insulated, architectural precast concrete panels are required. State desired minimum aged R-value or insulation thickness required, or both. Select insulation material from one of the three following paragraphs; if using more than one type identify location. As identified above, the precaster must provide calculations to the architect to verify the performance of the sandwich wall panels. The specifier should identify the “acceptable” R-value for the panels. See *1.5 Submittals, C. Thermal Performance*” above.

- A. Expanded-Polystyrene Board Insulation: Rigid, cellular polystyrene thermal insulation complying with ASTM C578 formed by expansion of polystyrene base resin; **<square edges> <ship-lap edges>**; with aged R-value of **<state value>**; board stock density **<state density>** and thickness of **<state thickness>**.

Expanded polystyrene insulation is subject to variances in density and product quality. The product is generally cut from a billet. Depending upon where the specific sheets originate in a billet, the density of the board may vary from 1.0 to 2.5 pounds per cubic foot. Additionally, moisture can be trapped in large voids between polystyrene beads, contributing to higher thermal conductivity.

- B. Extruded-Polystyrene Board Insulation: Rigid cellular polystyrene thermal insulation complying with ASTM C578 formed from polystyrene base by an extrusion process; **<square edges> <ship-lap edges>**; with aged R-value of **<state value>**, board stock density **<state density>** and thickness of **<state thickness>**.
- C. Polyisocyanurate Board Insulation: Rigid, cellular polyisocyanurate thermal insulation; complying with ASTM C 1289; square edged; with aged R-value of **<state value>** and thickness of **<state thickness>**.

Extruded polystyrene insulation has a higher R-value and is more vapor and water-resistant than other rigid insulation products such as expanded polystyrene (bead-board) insulation. Un-faced polyisocyanurate and polyurethane insulation (ASTM C591) are not acceptable replacements for extruded polystyrene in general applications. Polyisocyanurate insulation (ASTM C1289) with aluminum/poly facer is moisture resistant and offers high thermal performance.

Select wythe connectors from paragraph below. It is imperative that the connectors expand and contract similarly with the concrete during temperature changes to significantly reduce the likelihood of concrete cracking or spalling.

The fiber-composite connectors are the only elements penetrating or crossing the insulation in the panels. They perform as insulators. The low conductivity of the connectors is vital to retaining 99.3% of the insulation’s R-value. Thermal testing has been performed at Construction Technology Laboratories and at the Oak Ridge National Laboratory, United States Department of Energy, to determine the effectiveness of the fiber-composite connectors in the elimination of loss of R-value in a sandwich wall construction.

- C. Wythe Connectors: **<Glass-fiber and vinyl-ester polymer connectors>**, manufactured to connect wythes of precast concrete panels.
1. Provide corrosion and alkali resistant fiber composite connectors having the following physical properties:

- i. Structural component of connector comprising long glass fiber composite pultrusion with 76% (by weight) glass fibers in a thermoset vinyl-ester resin matrix.
- ii. Connector shall have been shown, by testing laboratory certified by ICBO ES, to provide static pullout capacities exceeding 1600 lbs, static shear capacities exceeding 500 lbs, and post-dynamic tension and shear capacities exceeding 80 percent of their static capacities, when tested in accordance with ICBO ES AC01.
- iii. Connector shall have been shown, by testing laboratory certified by ICBO ES, to resist 300 lb tension loads for over 90 minutes when embedded in 3 inches of concrete and subjected to a furnace exposure per Section 7.8 of ASTM E1512.
- iv. Upon request, connector supplier shall provide documentation of alkali resistance of connector and long-term shear capacity of connector.
 - v. Coefficient of thermal expansion: 5×10^{-6} in/in/°F, nominal.
 - vi. Thermal Conductivity: 2.1 Btu/ (°F•ft²•h) per inch of length.
- vii. Proven accelerated aging testing. Provide reports showing compliance with accelerated aging equivalent to up to 100 years of service in concrete.

2.13 CONCRETE MIXES

- A. Prepare design mixes to match Architect's sample for each type of concrete required.

Revise subparagraph below if fly ash, blast furnace slag, or silica fume are not permitted. Revise percentage to suit Project.

1. Limit use of fly ash and granulated blast-furnace slag to 20 percent replacement of portland cement by weight; metakaolin and silica fume to 10 percent of portland cement by weight.

- B. Design mixes may be prepared by a qualified independent testing agency or by qualified precast plant personnel at architectural precast concrete fabricator's option.
- C. Limit water-soluble chloride ions to the maximum percentage by weight of cement permitted by ACI 318 (ACI 318M) or PCI MNL 117 when tested in accordance with ASTM C1218/C1218M.

Architectural precast concrete units may be manufactured with a separate "architectural" face mix and a "structural" backup mix. Face and backup mixes should have similar shrinkage and expansion coefficients. Similar water-cementitious materials ratios and cement-aggregate ratios are recommended to limit bowing or warping.

- D. Normal-Weight Concrete Face and Backup Mixes: Proportion mixes by either laboratory trial batch or field test data methods according to ACI 211.1, with materials to be used on project, to provide normal-weight concrete with the following properties:

Retain subparagraph below or revise to suit Project. Higher-strength mixes may be available; verify with fabricators.

1. Compressive Strength (28 Days): 5000 psi (34.5 MPa).

A water-cementitious materials ratio of 0.40 to 0.45 is usual for architectural precast concrete. Lower ratios may be possible with use of high-range water reducers. Revise ratio as required.

2. Maximum Water-Cementitious Materials Ratio: 0.45.

Water absorption indicates susceptibility to weather staining. The limit in paragraph below, corresponding to 6 percent by weight, is suitable for average exposures. Different parts of a single panel cannot be produced with different absorptions. Verify that fabricator can produce units with lower water absorption because special consolidation techniques to increase concrete density are required.

E. Water Absorption: 6 percent by weight or 14 percent by volume, tested according to PCI MNL 117.

Lightweight backup mixes must be compatible with normal-weight face mixes to minimize bowing or warping. Retain lightweight concrete backup mixes if required or as an option if satisfactory durability and in-service performance are verified by fabricator.

F. Lightweight Concrete Backup Mixes: Proportion mixes by either laboratory trial batch or field test data methods according to ACI 211.2, with materials to be used on Project, to provide lightweight concrete with the following properties:

Retain subparagraph below or revise to suit Project. Higher-strength mixes may be available; verify with fabricators.

1. Compressive Strength (28 Days): 5000 psi (34.5 MPa).

Increase or decrease unit weight as required. Coordinate with lightweight-aggregate supplier and architectural precast concrete fabricator. Lightweight concretes with lightweight and normal-weight aggregate in mix will usually be heavier than unit weight below.

2. Unit Weight: Calculated equilibrium unit weight of 115 lb/cu.ft. (1842 kg/cu.m), plus or minus 3 lb/cu.ft. (48 kg/cu.m), according to ASTM C 567.

G. Add air-entraining admixture at manufacturer's prescribed rate to result in concrete at point of placement having an air content complying with PCI MNL 117.

H. When included in design mixes, add other admixtures to concrete mixes according to manufacturer's written instructions.

2.14 MOLD FABRICATION

A. Molds: Accurately construct molds, mortar tight, of sufficient strength to withstand pressures due to concrete-placement and vibration operations and temperature changes and for prestressing and detensioning operations. Coat contact surfaces of molds with release agent before reinforcement is placed. Avoid contamination of reinforcement and prestressing tendons by release agent.

Delete form liners unless needed to produce exposed surface finish.

1. Place form liners accurately to provide finished surface texture indicated. Provide solid backing and supports to maintain stability of liners during placing of concrete. Coat form liner with form-release agent.
- B. Maintain molds to provide completed architectural precast concrete units of shapes, lines, and dimensions indicated, within fabrication tolerances specified.
 1. Form joints are not permitted on faces exposed to view in the finished work.

Select one option from below; show details on Drawings or revise description to add dimensions. Sharp edges or corners of precast concrete units are vulnerable to chipping.

2. Edge and Corner Treatment: Uniformly [**chamfered**] [**radiused**].

2.15 THIN AND HALF BRICK FACINGS

Retain this Article if using thin or half brick facings on architectural precast concrete units.

- A. Place form liner templates accurately to provide grid for brick facings. Provide solid backing and supports to maintain stability of liners while placing bricks and during placing of concrete.
- B. Securely place brick units face down into form liner pockets and place precast concrete backing mix.
- C. Clean faces and joints of brick facing.

2.16 STONE FACINGS

Retain this Article if stone facing is required. Refer to Division 4 Section “Dimensional Stone Cladding” for precast veneer.

- A. Accurately position stone facings to comply with requirements. Install spring clips, anchors, supports, and other attachments indicated or necessary to secure stone in place. Set stone facings accurately, in locations indicated on Shop Drawings. Orient stone veining in direction indicated on Shop Drawings. Keep reinforcement a minimum of ¾ inch (19 mm) from the back surface of stone. Use continuous spacers to obtain uniform joints of widths indicated and with edges and faces aligned according to established relationships and indicated tolerances. Ensure no passage of precast matrix to stone surface.
- B. See Division 7 Section “Joint Sealants” for furnishing and installing sealant backings and sealant into stone-to-stone joints and stone-to-concrete joints. Apply a continuous sealant bead along both sides and top of precast panels at the stone/precast interface using the bond breaker as a joint filler back-up. Do not seal panel bottom edge.

Retain one of two subparagraphs below if sealing dowel holes. Use sealant if a flexible filler is required; use epoxy if a rigid filler is required.

1. Fill anchor holes with low modulus polyurethane sealant filler and install anchors.
2. Fill anchor holes with epoxy filler and install anchors with ½ inch (13 mm) long 60 durometer elastomeric sleeve at the back surface of the stone.

PCI recommends preventing bond between stone facing and precast concrete to minimize bowing, cracking, and staining of stone. Retain one of two subparagraphs below.

3. Install 6 to 10 mil polyethylene sheet to prevent bond between back of stone facing and concrete substrate.
4. Install 1/8 inch (3 mm) polyethylene-foam bond breaker to prevent bond between back of stone facing and concrete substrate. Maintain minimum projection requirements of stone anchors into concrete substrate.

PCI recommends anchor spacing be determined prior to bidding. Retain below if precaster is to test stone anchors for shear and tension. ASTM E488 is preferred as ASTM C1354 does not include the influence of the precast concrete backup.

- C. Stone Anchor Shear and Tensile Testing: Engage a certified testing laboratory acceptable to the Architect to evaluate and test the proposed stone anchorage system. Test for shear and tensile strength of proposed stone anchorage system in accordance with ASTM E 488 or ASTM C 1354 modified as follows:
1. Prior to testing, submit for approval a description of the test assembly (including pertinent data on materials), test apparatus and procedures.
 2. Test 12-by-12 inch (300 by 300 mm) samples of stone affixed to testing apparatus through proposed anchorages. Provide 2 sets of 6 stone samples each. One set for shear load testing and the other set for tensile load testing.
 3. Test stone anchors of the sizes and shapes proposed for the installation.
 - a. Test the assembly to failure and record the test load at failure. Record the type of failure, anchor pull-out or stone breakage, and any other pertinent information, in accordance with the requirements of ASTM E 488. In addition, submit load deflection curves of each test assembly.
- D. Minimum Anchor Spacing: Anchor spaced not less than 6 inches (152 mm) from an edge with not more than 24 to 30 inches (610 to 760 mm) between anchors depending on the local building code and wind loading.

2.17 FABRICATION

- A. Cast-in Anchors, Inserts, Plates, Angles, and Other Anchorage Hardware: Fabricate anchorage hardware with sufficient anchorage and embedment to comply with design requirements. Accurately position for attachment of loose hardware and secure in place during precasting operations. Locate anchorage hardware where it does not affect position of main reinforcement or concrete placement.
1. Weld headed studs and deformed bar anchors used for anchorage according to AWS D1.1 and AWS C5.4, "Recommended Practices for Stud Welding."

Coordinate paragraph below with Division 5 Section "Metal Fabrications" for furnishing and installing loose hardware items.

- B. Furnish loose hardware items including steel plates, clip angles, seat angles, anchors, dowels, cramps, hangers, and other hardware shapes for securing architectural precast concrete units to supporting and adjacent construction.
- C. Cast-in reglets, slots, holes, and other accessories in architectural precast concrete units as indicated on contract drawing.

Delete first paragraph below if not applicable.

- D. Cast-in openings larger than 10 inches (250 mm) in any dimension. Do not drill or cut openings or prestressing strand without approval of Architect.
- E. Reinforcement: Comply with recommendations in PCI MNL 117 for fabrication, placing, and supporting reinforcement.
 - 1. Clean reinforcement of loose rust and mill scale, earth, and other materials that reduce or destroy the bond with concrete. When damage to epoxy coated reinforcing exceeds limits specified ASTM A775/A775M repair with patching material compatible with coating material and epoxy coat bar ends after cutting.
 - 2. Accurately position, support, and secure reinforcement against displacement during concrete-placement and consolidation operations. Completely conceal support devices to prevent exposure on finished surfaces.
 - 3. Place reinforcing steel and prestressing strand to maintain at least 3/4 -inch (19 mm) minimum concrete cover. Increase cover requirements for reinforcing steel to 1-1/2 inches (38 mm) when units are exposed to corrosive environment or severe exposure conditions. Arrange, space, and securely tie bars and bar supports to hold reinforcement in position while placing concrete. Direct wire tie ends away from finished, exposed concrete surfaces.
 - 4. Install welded wire reinforcement in lengths as long as practicable. Lap adjoining pieces at least one full mesh spacing and wire tie laps, where required by design. Offset laps of adjoining widths to prevent continuous laps in either direction.
- F. Reinforce architectural precast concrete units to resist handling, transportation, and erection stresses.

Delete paragraph and subparagraph below if prestressed architectural precast concrete units are not required. Option to prestress may be left to fabricator if objective is to aid handling and to control cracking of units during installation.

- G. Prestress tendons for architectural precast concrete units by either pretensioning or post-tensioning methods. Comply with PCI MNL 117.

Revise release or post-tensioning strength in subparagraph below to an actual compressive strength if required. A release strength as low as 2500 psi (17.2 MPa) for normal-weight concrete and 3000

psi (20.7 MPa) for lightweight concrete is permitted.

1. Delay detensioning or post-tensioning of prestressed architectural precast concrete units until concrete has reached its indicated minimum design release compressive strength as established by test cylinders cured under the same conditions as concrete member.
2. Detension pretensioned tendons either by gradually releasing tensioning jacks or by heat-cutting tendons, using a sequence and pattern to prevent shock or unbalanced loading.
3. If concrete has been heat cured, detension while concrete is still warm and moist to avoid dimensional changes that may cause cracking or undesirable stresses.
4. Protect strand ends and anchorages with bituminous, zinc-rich or epoxy paint to avoid corrosion and possible rust spots.

H. Mix concrete according to PCI MNL 117 and requirements in this Section. After concrete batching, no additional water may be added.

Retain paragraph below if a separate face mix is required or is Contractor's option.

- I. Place face mix to a minimum thickness after consolidation of the greater of 1 inch (25 mm) or 1.5 times the maximum aggregate size, but not less than the minimum reinforcing cover as indicated on contract drawings.
 1. At the fabricator's option either of the following mix design/casting techniques may be used:
 - a. A single design mix throughout the entire thickness of panel.
 - b. Design mixes for facing and backup; using cement and aggregates for each type as indicated, for consecutive placement in the mold. Use cement and aggregate specified for facing mix, use cement and aggregate for backup mix complying with criteria specified as selected by the fabricator.
- J. Place concrete in a continuous operation to prevent seams or planes of weakness from forming in precast concrete units. Comply with requirements in PCI MNL 117 for measuring, mixing, transporting, and placing concrete.
 1. Place backup concrete to ensure bond with face mix concrete.
- K. Thoroughly consolidate placed concrete by internal and/or external vibration without dislocating or damaging reinforcement and built-in items, and minimize pour lines, honeycombing or entrapped air on surfaces. Use equipment and procedures complying with PCI MNL 117.
 1. Place self-consolidating concrete without vibration in accordance with PCI Interim Guidelines for the Use of Self-Consolidating Concrete.
- L. Comply with ACI 306.1 procedures for cold-weather concrete placement.
- M. Comply with ACI 305R recommendations for hot-weather concrete placement.
- O. Identify pickup points of architectural precast concrete units and orientation in structure with permanent markings, complying with markings indicated on Shop Drawings. Imprint or permanently mark casting date on each architectural precast concrete unit on a surface that will not show in finished structure.

- P. Cure concrete, according to requirements in PCI MNL 117, by moisture retention without heat or by accelerated heat curing using low-pressure live steam or radiant heat and moisture. Cure units until the compressive strength is high enough to ensure that stripping does not have an effect on the performance or appearance of the final product.
- Q. Repair damaged architectural precast concrete units to meet acceptability requirements of PCI MNL 117.

2.18 INSULATED PANEL CASTING

Delete this Article if integrally insulated panels are not required.

- A. Cast and screed supported wythe over mold.
- B. Place insulation boards, abutting edges and ends of adjacent boards. Insert wythe connectors through insulation, and consolidate concrete around connectors according to connector manufacturer's written instructions.
- C. Cast and screed top wythe to meet required finish.

2.19 FABRICATION TOLERANCES

- A. Fabricate architectural precast concrete units straight and true to size and shape with exposed edges and corners precise and true so each finished unit complies with PCI MNL 117 product tolerances as well as position tolerances for cast-in items.

Select paragraph above or paragraph and subparagraphs below. Usually retain above unless tolerances for Project deviate from PCI recommendations. PCI MNL 117 product tolerances, listed below, are standardized throughout the industry. For architectural trim units such as sills, lintels, coping, cornices, quoins, medallions, bollards, benches, planters, and pavers, tolerances are listed in PCI MNL 135.

- B. Fabricate architectural precast concrete units straight and true to size and shape with exposed edges and corners precise and true so each finished unit complies with the following product tolerances.
 - 1. Overall Height and Width of Units, Measured at the Face Exposed to View: As follows:
 - a. 10 feet (3 m) or under, Plus or Minus 1/8 inch (3 mm).
 - b. 10 to 20 feet (3 to 6 m), Plus 1/8 inch (3 mm), Minus 3/16 inch (5 mm).
 - c. 20 to 40 feet (6 to 12 m), Plus or Minus 1/4 inch (6 mm).
 - d. Each additional 10 feet (3 m), Plus or Minus 1/16 inch (1.5 mm).
 - 2. Overall Height and Width of Units, Measured at the Face Not Exposed to View: As follows:
 - a. 10 feet (3 m) or under, Plus or Minus 1/4 inch (6 mm).
 - b. 10 to 20 feet (3 to 6 m), Plus 1/4 inch (6 mm), Minus 3/8 inch (10 mm).
 - c. 20 to 40 feet (6 to 12 m), Plus or Minus 3/8 inch (10 mm).
 - d. Each additional 10 feet (3 m), Plus or Minus 1/8 inch (3 mm).

3. Total Thickness or Flange Thickness: Plus ¼ inch (6 mm), Minus 1/8 inch (3 mm).
4. Rib Thickness: Plus or Minus 1/8 inch (3 mm).
5. Rib to Edge of Flange: Plus or Minus 1/8 inch (3 mm).
6. Distance between Ribs: Plus or Minus 1/8 inch (3 mm).
7. Variation from Square or Designated Skew (Difference in Length of the Two Diagonal 8. Measurements): Plus or Minus 1/8 inch per 72 inches (3 mm per 2 m) or 1/2 inch (13 mm) total, whichever is greater.
8. Length and Width of Block-outs and Openings within One Unit: Plus or Minus 1/4 inch (6 mm).
9. Location and Dimension of Block-outs Hidden from View and Used for HVAC and Utility Penetrations: Plus or Minus 3/4 inch (19 mm).
10. Dimensions of Haunches: Plus or Minus 1/4 inch (6 mm).
11. Haunch Bearing Surface Deviation from Specified Plane: Plus or Minus 1/8 inch (3 mm).
12. Difference in Relative Position of Adjacent Haunch Bearing Surfaces from Specified Relative Position: Plus or Minus 1/4 inch (6 mm).
13. Bowing: Plus or Minus L/360, maximum 1 inch (25 mm).
14. Local Smoothness: 1/4 inch per 10 feet (6 mm per 3 m).
15. Warping: 1/16 inch per 12 inches (1.5 mm per 300 mm) of distance from the nearest adjacent corner.
16. Tipping and Flushness of Plates: Plus or Minus 1/4 inch (6 mm).
17. Dimensions of Architectural Features and Rustications: Plus or Minus 1/8 inch (3 mm).

C. Position Tolerances: For cast-in items measured from datum line location, as indicated on Shop Drawings.

1. Weld Plates: Plus or Minus 1 inch (25 mm).
2. Inserts: Plus or Minus 1/2 inch (13 mm).
3. Handling Devices: Plus or Minus 3 inches (75 mm).
4. Reinforcing Steel and Welded Wire Reinforcement: Plus or Minus 1/4 inch (6 mm) where position has structural implications or affects concrete cover; otherwise, Plus or Minus 1/2 inch (13 mm).
5. Reinforcing Steel Extending out of Member: Plus or Minus 1/2 inch (13 mm) of plan dimensions.
6. Tendons: Plus or Minus 1/4 inch (6 mm), vertical; Plus or Minus 1 inch (25 mm), horizontal.
7. Location of Rustication Joints: Plus or Minus 1/8 inch (3 mm).
8. Location of Opening within Panel: Plus or Minus 1/4 inch (6 mm).
9. Location of Flashing Reglets: Plus or Minus 1/4 inch (6 mm).
10. Location of Flashing Reglets at Edge of Panel: Plus or Minus 1/8 inch (3 mm).
11. Reglets for Glazing Gaskets: Plus or Minus 1/8 inch (3 mm).
12. Electrical Outlets, Hose Bibs: Plus or Minus 1/2 inch (13 mm).
13. Location of Bearing surface from End of Member: Plus or Minus 1/4 inch (6 mm).
14. Allowable Rotation of Plate, Channel Inserts, Electrical Boxes: 2-degree rotation or 1/4 inch (6 mm) maximum over the full dimension of the unit.
15. Position of Sleeve: Plus or Minus 1/2 inch (13 mm).
16. Location of Window Washer Track or Buttons: Plus or Minus 1/8 inch (3 mm).

Delete paragraph below if brick faced architectural units are not used. The number of bricks allowed these misalignments should be limited to 2 percent of the bricks on the unit.

D. Brick-Faced Architectural Precast Concrete Units.

1. Alignment of mortar joints:
 - a. Jog in Alignment: 1/8 inch (3 mm).
 - b. Alignment with Panel Centerline: Plus or Minus 1/8 inch (3 mm).
2. Variation in Width of Exposed Mortar Joints: Plus or Minus 1/8 inch (9 mm).
3. Tipping of Individual Bricks from the Panel Plane of Exposed Brick Surface: Plus 1/16 inch (1.5 mm); Minus 1/4 inch (6 mm) \leq depth of form liner joint.
4. Exposed Brick Surface Parallel to Primary Control Surface of Panel: Plus 1/4 inch (6 mm); Minus 1/8 inch (3 mm).
5. Individual Brick Step in Face from Panel Plane of Exposed Brick Surface: Plus 1/16 inch (1.5mm); Minus 1/4 inch (6 mm) \leq depth of form liner joint.

E. Stone Veneer-Faced Architectural Precast Concrete Units.

Tolerances below are generally appropriate for smooth-finished stone. Retain, delete, or revise to suit Project.

1. Variation in Cross-Sectional Dimensions: For thickness of walls from dimensions indicated: Plus or Minus 1/4 inch (6 mm).
2. Variation in Joint Width: 1/8 inch in 36 inches (3 mm in 900 mm) or a quarter of nominal joint width, whichever is less.

Revise or delete below for natural-cleft, thermal, and similar finishes.

3. Variation in Plane between Adjacent Stone Units (Lipping): 1/16 inch (1.5-mm) difference between planes of adjacent units.

2.20 FINISHES

- A. Panel faces shall be free of joint marks, grain, and other obvious defects. Corners, including false joints shall be uniform, straight and sharp. Finish exposed-face surfaces of architectural precast concrete units to match approved [**design reference sample**] [**sample panels**] [**mockups**] and as follows:

This Article presumes Architect has preapproved one or more design reference samples. Include complete description of design reference sample here. If preapproving manufacturers, coordinate with "Manufacturers" Article. Revise if multiple samples are approved.

1. Design Reference Sample: **<Insert description and identify fabricator and code number of sample.>**

Delete subparagraph below if not used. PCI published numbered, color photographs of 428 precast concrete finishes, see PCI's website www.pci.org. Revise below and add reference number. Add reference number combinations if more than one finish is required.

2. PCI's "Architectural Precast Concrete –Color and Texture Selection Guide," of plate numbers indicated.

Retain type of finish from subparagraphs below if needed. If more than one finish is required, add locations to finish descriptions or indicate on Drawings. Add more detailed descriptions of finishes outlined below if required when greater definition is required, such as (light), (medium), or (deep). Remove matrix to a maximum depth of one-third the average diameter of coarse aggregate but not more than one-half the diameter of smallest sized coarse aggregate. See PCI MNL 117 for more information on finishes. An as-cast finish generally results in a mottled surface or non-uniform finish.

3. As-Cast Surface Finish: Provide surfaces free of excessive air voids, sand streaks, and honeycombs.
4. Textured-Surface Finish: Impart by form liners to provide surfaces free of excessive air voids, sand streaks, and honeycombs, with uniform color and texture.
5. Bushhammer Finish: Use power and hand tools to remove matrix and fracture coarse aggregates.
6. Exposed Aggregate Finish: Use chemical retarding agents applied to concrete forms and washing and brushing procedures to expose aggregate and surrounding matrix surfaces after form removal.
7. Abrasive-Blast Finish: Use abrasive grit, equipment, application techniques, and cleaning procedures to expose aggregate and surrounding matrix surfaces.
8. Acid-Etched Finish: Use acid and hot-water solution, equipment, application techniques, and cleaning procedures to expose aggregate and surrounding matrix surfaces. Protect hardware, connections and insulation from acid attack.
9. Honed Finish: Use continuous mechanical abrasion with fine grit, followed by filling and rubbing procedures.
10. Polished Finish: Use continuous mechanical abrasion with fine grit, followed by filling and rubbing procedures.
11. Sand-Embedment Finish: Use selected stones placed in a sand bed in bottom of mold, with sand removed after curing.

- B. Finish exposed **[top]** **[bottom]** **[back]** surfaces of architectural precast concrete units to match face-surface finish.

Retain paragraph above or below if applicable. Revise below to float finish or light-broom finish if smooth, steel-trowel finish is unnecessary.

- C. Finish unexposed surfaces **[top]** **[bottom]** **[and back]** of architectural precast concrete units by smooth steel-trowel finish.

Revise finish below to light-broom, stippled, or as-cast finish if float finish is unnecessary, or upgrade to smooth, steel-trowel finish.

- D. Finish unexposed surfaces of architectural precast concrete units by float finish.

2.21 SOURCE QUALITY CONTROL

Always retain paragraph below because it establishes the minimum standard of plant testing and

inspecting. PCI MNL 117 mandates source testing requirements and a plant Quality Systems Manual. PCI certification also ensures periodic auditing of plants for compliance with requirements in PCI MNL 117.

- A. Quality-Control Testing: Test and inspect precast concrete according to PCI MNL 117 requirements. If using self-consolidating concrete also test and inspect according to PCI Interim Guidelines for the Use of Self-Consolidating Concrete.

Delete paragraph and subparagraph below if not required. PCI certification would normally be acceptable to authorities having jurisdiction without further monitoring of plant quality-control and testing program by Owner.

- B. Owner will employ an independent testing agency to verify architectural precast concrete fabricator's quality-control and testing methods.
1. Allow Owner's testing agency access to material storage areas, concrete production equipment, concrete placement, and curing facilities. Cooperate with Owner's testing agency and provide samples of materials and concrete mixes as may be requested for additional testing and evaluation.
- C. Strength of precast concrete units will be considered deficient if units fail to comply with ACI 318 (ACI 318M) requirements for concrete strength.

Review testing and acceptance criteria with structural engineer. Add criteria for load tests if required.

- D. Testing: If there is evidence that the concrete strength of precast concrete units may be deficient or may not comply with ACI 318 (ACI 318M) requirements, Precaster will employ an independent testing agency to obtain, prepare, and test cores drilled from hardened concrete to determine compressive strength according to ASTM C 42/C42M.
1. A minimum of three representative cores will be taken from units of suspect strength, from locations directed by Architect.
 2. Cores will be tested in an air-dry condition.

PCI's recommendations below are more stringent than ACI's.

3. Strength of concrete for each series of 3 cores will be considered satisfactory if the average compressive strength is equal to at least 85 percent of the 28-day design compressive strength and no single core is less than 75 percent of the 28-day design compressive strength.
4. Test results will be made in writing on the same day that tests are performed, with copies to Architect, Contractor, and precast concrete fabricator. Test reports will include the following:
 - a. Project identification name and number.
 - b. Date when tests were performed.
 - c. Name of precast concrete fabricator.
 - d. Name of concrete testing agency.
 - e. Identification letter, name, and type of precast concrete units or units represented by core tests; design compressive strength; type of break; compressive strength at breaks, corrected

for length-diameter ratio; and direction of applied load to core in relation to horizontal plane of concrete as placed.

- E. Patching: If core test results are satisfactory and precast concrete units comply with requirements, clean and dampen core holes and solidly fill with precast concrete mix that has no coarse aggregate, and finish to match adjacent precast concrete surfaces.
- F. Defective Work: Architectural precast concrete units that do not comply with acceptability requirements in PCI MNL 117, including concrete strength, manufacturing tolerances, and color and texture range are unacceptable. Chipped, spalled or cracked units may be repaired, if repaired units match the visual mock-up. The Architect reserves the right to reject any unit if it does not match the accepted samples and visual mock-up. Replace unacceptable units with precast concrete units that comply with requirements.

PART 3 – EXECUTION

3.1 PREPARATION

- A. Deliver anchorage devices that are embedded in or attached to the building structural frame or foundation before start of such work. Provide locations, setting diagrams, and templates for the proper installation of each anchorage device.

3.2 EXAMINATION

- A. Examine supporting structural frame or foundation and conditions for compliance with requirements for installation tolerances, true and level bearing surfaces, and other conditions affecting performance. Proceed with installation only after unsatisfactory conditions have been corrected.
- B. Do not install precast concrete units until supporting cast-in place concrete building structural framing has attained minimum allowable design compressive strength or supporting steel or other structure is structurally ready to receive loads from precast.

3.3 ERECTION

- A. Install loose clips, hangers, bearing pads and other accessories required for connecting architectural precast concrete units to supporting members and backup materials.
- B. Erect architectural precast concrete level, plumb and square within the specified allowable tolerances. Provide temporary supports and bracing as required to maintain position, stability, and alignment of units until permanent connections are completed.
 - 1. Install temporary steel or plastic spacing shims or bearing pads as precast concrete units are being erected. Tack weld steel shims to each other to prevent shims from separating.
 - 2. Maintain horizontal and vertical joint alignment and uniform joint width as erection progresses.

3. Remove projecting lifting devices and use sand-cement grout to fill voids within recessed lifting devices flush with surface of adjacent precast concrete surfaces when recess is exposed.
 4. Unless otherwise shown provide for uniform joint widths of 3/4 inch (19mm)
- C. Connect architectural precast concrete units in position by bolting, welding, grouting, or as otherwise indicated on approved Erection Drawings. Remove temporary shims, wedges, and spacers as soon as practical after connecting and/or grouting are completed.
1. Disruption of roof flashing continuity by connections is not permitted; concealment within roof insulation is acceptable.
- D. Welding: Comply with applicable AWS D1.1 and AWS D1.4 requirements for welding, welding electrodes, appearance, quality of welds, and methods used in correcting welding work.
1. Protect architectural precast concrete units and bearing pads from damage by field welding or cutting operations and provide noncombustible shields as required.
 2. Welds not specified shall be continuous fillet welds, using not less than the minimum fillet as specified by AWS.
 3. Clean weld affected metal surfaces with chipping hammer followed by brushing then apply a minimum 0.004 inch (100 μm) thick coat of galvanized repair paint to galvanized surfaces in conformance with ASTM A780.

Retain subparagraph above or below.

4. Clean weld affected metal surfaces with chipping hammer followed by brushing then reprime damaged painted surfaces in accordance with manufacturer's recommendations.
 5. Visually inspect all welds critical to precast connections. Visually check all welds for completion and remove, reweld or repair all defective welds, if services of AWS-certified welding inspector are not furnished by Owner.
- E. At bolted connections, use lock washers, tack welding, or other acceptable means to prevent loosening of nuts after final adjustment.
1. Where slotted connections are used, verify bolt position and tightness. For sliding connections, properly secure bolt but allow bolt to move within connection slot. For friction connection apply specified bolt torque and check 25 percent of bolts at random by calibrated torque wrench.

Revise locations and extent of grouting in paragraph below if required.

- F. Grouting Connections: Grout connections where required or indicated. Retain grout in place until hard enough to support itself. Pack spaces with stiff grout material, tamping until voids are completely filled. Place grout to finish smooth, level, and plumb with adjacent concrete surfaces. Promptly remove grout material from exposed surfaces before it affects finishes or hardens.

3.4 ERECTION TOLERANCES

- A. Erect architectural precast concrete units level, plumb, square, true, and in alignment without exceeding the noncumulative erection tolerances of PCI MNL 117, Appendix I.

Select paragraph above or paragraph and subparagraphs below. Usually retain above unless tolerances for Project deviate from PCI recommendations. PCI MNL 117 erection tolerances are listed below. If more exacting tolerances are required for Project, coordinate with fabrication tolerances for precast concrete as well as erection tolerances for supporting construction.

- B. Erect architectural precast concrete units level, plumb, square, and true, without exceeding the following noncumulative erection tolerances.

1. Plan Location from Building Grid Datum: Plus or Minus 1/2 inch (13 mm).
2. Plan Location from Centerline of Steel: Plus or Minus 1/2 inch (13 mm).
3. Top Elevation from Nominal Top Elevation: As follows:
 - a. Exposed Individual Panel: Plus or Minus 1/4 inch (6 mm).
 - b. Nonexposed Individual Panel: Plus or Minus 1/2 inch (13 mm).
 - c. Exposed Panel Relative to Adjacent Panel: 1/4 inch (6 mm).
 - d. Nonexposed Panel Relative to Adjacent Panel: 1/2 inch (13 mm).
4. Support Elevation from Nominal Support Elevation: As follows:
 - a. Maximum Low: 1/2 inch (13 mm).
 5. Maximum High: 1/4 inch (6 mm).
5. Maximum Plumb Variation over the Lesser of Height of Structure or 100 Feet (30 m): 1 inch (25 mm).
6. Plumb in Any 10 Feet (3 m) of Element Height: 1/4 inch (6 mm).
7. Maximum Jog in Alignment of Matching Edges: 1/4 inch (6 mm).
8. Joint width (Governs over Joint Taper): Plus or Minus 1/4 inch (6mm).
9. Maximum Joint Taper: 3/8 inch (10 mm).
10. Joint Taper in 10 Feet (3 m): 1/4 inch (6 mm).
11. Maximum Jog in Alignment of Matching Faces: 1/4 inch (6 mm).
12. Differential Bowing or Camber, as Erected, between Adjacent Members of Same Design: 1/4 inch (6 mm).
13. Opening Height between Spandrels: Plus or Minus 1/4 inch (\pm 6 mm).

3.5 FIELD QUALITY CONTROL

Retain this Article if field testing and inspecting are required. Revise paragraph below if Contractor engages agency.

- A. Testing: Owner will engage a qualified independent testing and inspecting agency to perform field tests and inspections.
- B. Field welds will be subject to visual inspections and non-destructive testing in accordance with ASTM E165 or ASTM E709.
- C. Testing agency will report test results promptly and in writing to Contractor and Architect.

- D. Repair or remove and replace work that does not comply with specified requirements.
- E. Additional testing and inspecting, at Contractor's expense, will be performed to determine compliance of corrected work with specified requirements.

3.6 REPAIRS

Blemishes occurring after delivery are normally repaired before final joint sealing and cleaning as weather permits.

- A. Repairs will be permitted provided structural adequacy of units and appearance are not impaired.

The precast concrete manufacturer should develop appropriate repair mixtures and techniques during the production sample approval process.

- B. Mix patching materials and repair units so cured patches blend with color, texture, and uniformity of adjacent exposed surfaces and show no apparent line of demarcation between original and repaired work, when viewed in typical daylight illumination from a distance of 20 feet (6 m).
- C. Prepare and repair damaged galvanized coatings with galvanizing repair paint according to ASTM A780.

Retain paragraph above if using galvanized anchors, connections, and other items; retain first paragraph below if items are prime painted.

- D. Wire brush, clean, and paint damaged prime-painted components with same type of shop primer.
- E. Remove and replace damaged architectural precast concrete units when repairs do not meet requirements.

3.7 CLEANING

Specify whether erector or precaster does cleaning under the responsibility of General Contractor.

- A. Clean all surfaces of precast concrete to be exposed to view, as necessary, prior to shipping.
- B. Clean mortar, plaster, fireproofing, weld slag, and any other deleterious material from concrete surfaces and adjacent materials immediately.
- C. Clean exposed surfaces of precast concrete units after erection and completion of joint treatment to remove weld marks, other markings, dirt, and stains.
 - 1. Perform cleaning procedures, if necessary, according to precast concrete fabricator's recommendations. Clean soiled precast concrete surfaces with detergent and water, using stiff fiber brushes and sponges, and rinse with clean water. Protect other work from staining or damage due to cleaning operations.

2. Do not use cleaning materials or processes that could change the appearance of exposed concrete finishes or damage adjacent materials.

END OF SECTION 03450