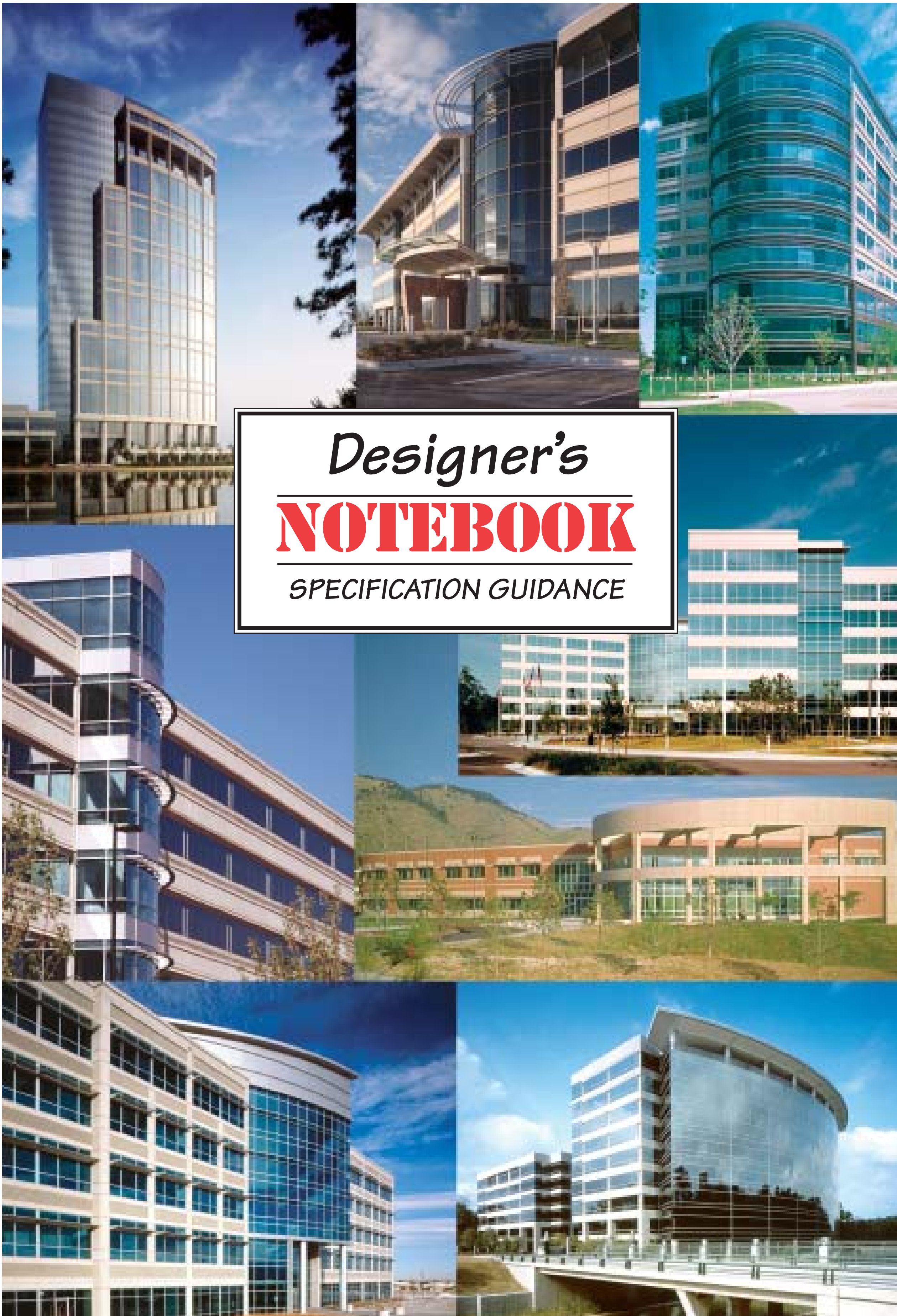
Designer's

NOTEBOOK

SPECIFICATION GUIDANCE



Part IV Guide Specification for Stone Veneer-Faced Precast Concrete Panels

PCI's Architectural Precast Concrete Services Committee shows items to consider in specifying stone veneer-faced precast panels.

A Guide Specification for Architectural Precast Concrete has been developed jointly by PCI, Gensler and the American Institute of Architects (AIA), Master Systems publishers of MASTERSPEC®. It is available on PCI's web page at **www.pci.org**. The following is an excerpt on stone veneer-faced precast.

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.

PART 1 – GENERAL

PERFORMANCE REQUIREMENTS

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 fewer than 2 anchors per stone unit of less than 2 square feet (0.19 square meters) in area and 4 anchors per unit of less than 12 square feet (1.1 square meters) and for units larger than 12 square feet (1.1 square meters) 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.

SUBMITTALS

Shop Erection Drawings: Indicate locations and details of stone facings, stone anchors, and joint widths.

Material Certificates: Stone anchors.

PART 2 – PRODUCTS

STONE MATERIALS AND ACCESSORIES

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 the 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, 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 or polyethylene sheet, 6 to 10 mil. thick.

STONE FACINGS

> 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 3/4 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 1/2 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.

3. Install 6- to 10-mil polyethylene sheet to prevent bond between back of stone facing and concrete substrate or install 1/8 inch (3 mm) polyethylene-foam bond breaker. 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 for one set shear load testing 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 pressure 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.

FABRICATION TOLERANCES

> 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): A difference of 1/16 inch (1.5 mm) between planes of adjacent units.

Match Architect's Samples: Tips for Specifying Stone Veneer-Faced Finishes

Timothy Taylor, director of specifications with Gensler, shares his perspective on writing specifications for architectural precast concrete.

The combination of architectural precast concrete that is partially or wholly clad with dimensional-stone materials has many precedents in numerous examples throughout the United States.

Marble, granite, limestone and slate used in conjunction with architectural precast concrete have achieved stunning, award-winning aesthetic designs with exceptional records for durability. Some architects believe, as summed up by Rob Jernigan of Gensler's Santa Monica, Calif., office, that "when architectural precast concrete is combined with accent materials like stone, it just makes the total effect more appealing."

As with any material intended to be exposed to the weather, quality-assurance and -control requirements are critical. This is especially important in stone-veneered precast panels, as stone materials supported by precast shapes are usually thinner than those supported by cast-in-place concrete, unit masonry, steel or wood framing, support or back-up systems.

Recommendations published by the Marble Institute of America (MIA) for precast-backed, stone-veneer thicknesses begin at not less than 1 inch for preliminary design purposes. However, current stone-veneer engineering practice sets the minimum thickness as not less than 1$^{1}/_{4}$ inches for marble, granite and slate and 2 inches for limestone. The additional thickness is required chiefly to resist handling and fabrication stresses, to allow for negative-side fabrication-cutting tolerances, to accept anchors and to resist physical dimensional changes due to environmental conditions.

The selection and specification of dimensional-stone cladding materials and their attachment to precast should primarily, and preferably, be based on previous installations using identical materials and assemblies. Alternatively, selection and specification should be made from physical-properties testing of individual component materials combined with laboratory testing of mock-up assemblies to evaluate performance under anticipated project-specific conditions.

This high-rise office building shows an example of black granite stone clad precast inset accents on architectural precast and glass and metal clad. Photos: courtesy of Gensler

Compensating For Differences

Stone-cladding materials are inherently dissimilar from precast concrete. When combined into a composite assembly, they need to behave in a compatible manner. One basic aspect of compatibility focuses on expansion and contraction caused by project-specific temperature conditions. The range of expansion coefficients for precast concrete, marble, granite, limestone and slate are indicated in Table 1. Differences between concrete and stone-veneer expansion coefficients often dictate the use of mechanical anchors over direct-bonding methods

Example of black granite stone clad precast inset accents on architectural precast and glass and metal clad high rise office building.

using mortar or direct casting stone veneer to precast concrete panel backup.

Another related aspect of expansion and contraction is volume stability. Most stone veneers are relatively volume stable, meaning that after exposure to temperature extremes, they will return to their original dimensions. However, according to MIA, some marble species have been known to experience residual expansion of about 20 percent of their original panel dimensions after they were exposed to several laboratory-controlled cycles of heating and cooling.

Material	Thermal Expansion Range (x 10^{-6})
Normal Weight Precast Concrete: siliceous aggregates calcareous aggregates	 5 to 7 3.5 to 5
Marble	3.69 to 12.3
Granite	6.3 to 9.0
Slate	9.4 to 12.0
Limestone	2.4 to 3.0

Table 1
Coefficient of Thermal Expansion of Precast Concrete and Selected Natural Stone (inches per degree Farenheit.)

This phenomena is referred to as hysteresis. Hysteresis has been described as the dilation of surface crystals on a heat-exposed surface of the stone. Excessive hysteresis often appears as an outward bowing of the stone. Expansion and contraction characteristics for stone-veneer cladding materials should be investigated before specifying, movements of these types may be restrained by direct bond or cast cladding methods resulting in stone debonding or damage.

Mechanical Anchors

Mechanical anchors used for exterior stone cladding are typically fabricated from stainless steel. Each anchor should be evaluated for its performance when attached to the precast, when attached to the stone cladding, and when functioning as an assembly. In isolating these three components of behavior, the anchorage designer can assess the ability of each proposed anchorage assembly to resist stresses imposed by handling, transportation, erection and in-service use. Anchor evaluation should be made by calculation supported with laboratory testing for large projects.

Pre-engineering of anchors is sometimes exercised by specifiers where small amounts of stone cladding are required, physical properties are historically consistent and certifiable, and the anchor being specified will be used for the project. Specifications for pre-engineered anchors usually include a minimum number, location, and placement symmetry based on the height, width, and thickness of the stone cladding unit to be anchored and on the preferred anchor model, style, or type. Criteria for the quality of drilling, insertion and setting of anchors also should be specified.

Stone Cladding Materials

The choice of stone-veneer cladding for exterior applications should be made primarily on the basis, and order of, strength, durability, color and surface finish. As a product of nature, all stone materials exhibit physical properties that can vary from block to block. Thin slabs of stone

This closeup shows stone clad precast inset accents on high rise office building. Although the building was completed in 1991 the stone has not shown visual evidence of damage due to weathering.

cladding can be weakened by natural mineral inclusions occurring as pockets or veins and by fractures and microcracks caused by nature (inherent), fabrication, and erection stresses. Therefore, all proposed stone-cladding materials should be tested for their properties of strength and durability.

Stone claddings proposed for exposure to freezing temperatures should primarily have low water-absorption characteristics or, as in the case of oolithic limestone, a pore structure that has a proven long-term history against freeze-thaw damage. According to Marc Chacon, in his book, *Architectural Stone, Guidelines for the Selection of Stone*, a volume of water expands by 8 percent when it freezes. Stone with excessive water-absorption characteristics or with an unsuitable pore structure may crack or spall when exposed to freezing temperatures. Current industry allowable limits for water absorption of dimensional stone are indicated in Table 2.

Material	Standard	Value (when tested per ASTM Standard)
Marble	ASTM C503	0.20% (ASTM C97)
Granite	ASTM C615	0.40% (ASTM C97)
Slate	ASTM C629	0.25% (ASTM C121)
Limestone:	ASTM C568	(ASTM C97)
low density		12.0
medium density		7.5
high density		3.0

Table 2 Maximum Water Absorption Values Allowed per ASTM Standard

Environmental conditions, such as polluted air when mixed with rain water and low pH rain water, have caused materials within certain stone species to develop stains. According to Erhard Winkler, in his book, *Stone in Architecture, Properties and Durability*, stain-producing materials in stone claddings include the minerals biotite, hornblende, hematite, magnetite, marcasite and pyrite (which is the most common). The stains are caused by iron leaching from these minerals, which frequently appear as yellow, rusty ocher and green discolorations.

Hematite and magnetite only occur in granites; pyrite can occur in marble, granite, slate and limestone. Minerals found in some slates that come in contact with acid rain have been known to cause the color of the slate to change or soften the stone surface. Acid rain, even dilute amounts, can quickly etch polished finishes of carbonaceous exterior stone claddings such as marble. Rainwater, when reacting with minerals that make up carbonaceous stones, also contributes to weathering, such as through surface reduction in the form of sanding and crumbling.

This example of granite is an inset accent recessed into precast panel field. Although the building was completed in 1985 the stone has not shown visual evidence of damage due to weathering.

Some stones contain minerals that are not light-fast. This is especially true of carbonaceous stones, such as marble and limestone. Winkler has observed that some limestone species increase their value or lightness by oxidation and by bleaching in the sun. Many white marbles tend to discolor to cream. Dark green Verde Antique marble can fade to light green in direct sunlight. Quarry observations can yield many clues to the weather resistance and light fastness of a proposed natural stone.

Thousands of dimensional stone products and finishes are available in the commercial stone marketplace. Color-plate books such as MIA's *Dimension Stones of the World* assist designers in the preliminary selection of stone. Some finishes are proprietary to a stone quarry or fabrication facility, but they are generically either specified as polished or textured. Polished finishes will bring out the full color, veining, and natural characteristics of a stone, while textured finishes will subdue them and cause the stone to look lighter.

Other sources for stone data include *Sweet's Catalog*, local stone installers, dimensional stone quarries, stone trade associations and stone brokers. Acquire a suitable sampling of the stone being examined, as most dimensional stone frequently features large swings of color and ranges of shades, uncontrollable veining and other natural characteristics that may not be deemed desirable.

The best performance results for thin stone-veneer exterior claddings have often been where a dense, color-fast, low-absorbing, granite or compact marble has been specified. Exterior cladding selection should always be based on strength and durability properties for project-specific applications, never on aesthetics alone.

Three Combination Approaches

Precast concrete and cladding materials are successfully combined in three formats: in precast plants as an integrally anchored component, as plant laid-up onto cast panels, and as laid-up to erected precast panels at the project site. Plant anchorage methods are the most commonly specified, as they support the advantages of panelization and factory quality control. Panelization typically lessens the time and site space necessary for precast erection, creating the potential for an earlier weathertight building enclosure and an earlier delivery time of the facility for tenant occupancy.

This example of domestic pink marble stone clad precast panels and glass and metal clad high rise office building shows minor mineral fading which has occurred since the building was constructed in 1989.

Plant laid-up claddings often require the precaster to provide special handling procedures to avoid damage from vibration caused during delivery and erection. Site laid-up claddings often result in the need for another trade at the site to erect the cladding to the precast, creating new complications that must be considered, such as the coordination of manpower, weather conditions, space allocation and, in some cases, the need for on-site scaffolding to erect overhead cladding.

Specifying plant and site laid-up cladding systems may require tighter casting tolerances in order to receive cladding backings. The tolerances should be specified to reflect the clearance required for the specified anchorage or bonding materials.

To avoid the potential of edge-to-edge misalignments and staining caused by particles with deleterious properties, it is a good specification practice to require forms to be cleaned with vacuum or oil-free air hose to remove unwanted particulate matter prior to placing cladding units into the formwork. Cleaning the cladding material on both front and back immediately prior to placing it into the formwork also will avoid the potential for staining.

— Timothy Taylor, Director of Specifications, Gensler, Washington, D.C.