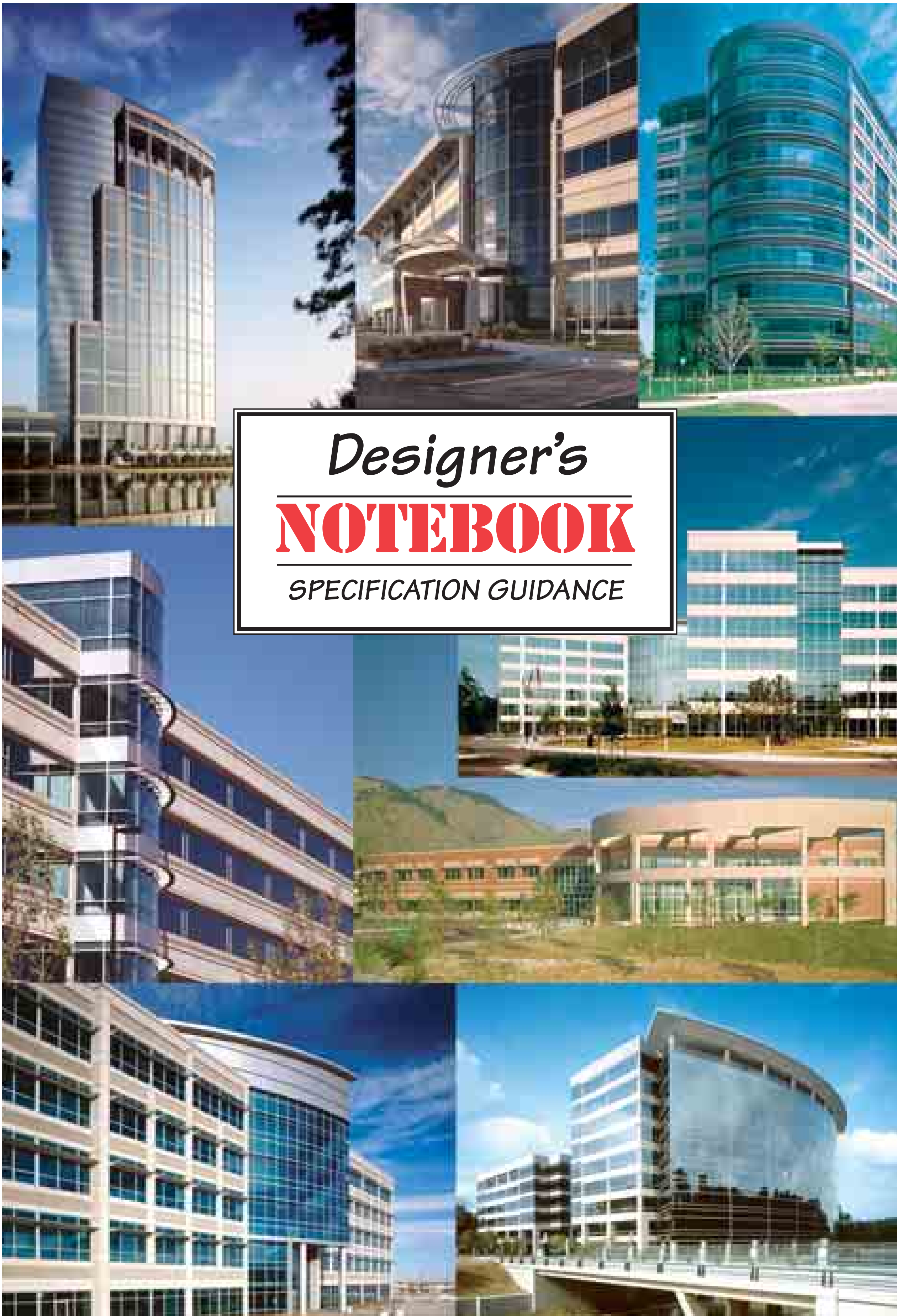
Designer's NOTEBOOK

SPECIFICATION GUIDANCE



PCI's Architectural Precast Concrete Services Committee explains key considerations in specifying architectural precast panels

Guide Specification for Architectural Precast Concrete Panels

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 panels. It does not include precast structural concrete, nor does it include coatings applied to the panels or sealing the joints between panels.

Drawing 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 panels, 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 this work and structural precast concrete if both are on the same job. Illustrate the details of corners of the structure and interfacing with other materials. Sizes and locations of reinforcement and details and locations of typical and special connection items and inserts may or may not be shown depending on local practices. If reinforcement and connections are not detailed, identify the requirements for design and design loads, and indicate load support points and space allowed for connections.

Specifications:

Describe the type and quality of the materials incorporated into the units, the design strength of the concrete, the finishes and the tolerances for fabrication and erection. It is important in the event of a performance specification that an appropriate test method be agreed upon as providing the basis of assessment.

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. This may be done by stating structural and aesthetic results to be achieved and by requiring complete details in shop drawings. Required submittals should also include range-bracketing samples for color and texture.

The panel 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 panel manufacturer. Items to be specified in other sections include any building frame support provisions required to support panels, 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. (Note: When the building frame is structural steel, erection hardware is normally supplied and installed as part of the structural steel. When the building frame is cast-in-place concrete, hardware, if not pre-designed or shown on drawings, may be supplied by the precast concrete manufacturer or general contractor. Or it can be part of the miscellaneous steel subcontract, and placed by the general contractor according to a hardware layout prepared by the precast concrete supplier.)

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 during pre-bid review, if possible. It is especially critical where outriggers and bracing may be necessary to resist torsion of the structural frame.

Assurance that type and quantity of hardware items required to be cast into precast concrete units for other trades, are specified is important. Specialty items, however, should be supplied 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.

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

- Cost of inspection by an independent testing laboratory.
- Hardware for interfacing with other trades (window, door, flashing and roofing items).
- Placing of contractor's 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 supply.
- Cleaning.
- Water repellent coatings.
- Plant-installed facing materials such as natural stone and clay products.

Guide Specification In Development

A complete architectural precast Guide Specification is in development jointly by PCI, Gensler and the American Institute of Architects (AIA), Master Systems publishers of MASTERSPEC®.

Match Architect's Samples: A specifier's dilemma

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

Thanks to PCI, a great body of information has been published on the advantages of architectural precast concrete, how to design it, how to engineer it and how to erect it. However, there is a paucity of print that guides a specifier through his or her task of converting what are esoteric or obscure architectural concepts into biddable specifications. This Designer's Notebook article is the first in a series that attempts to demystify the task of writing specifications for architectural precast concrete.

Specifications define product quality, product and system performance, workmanship and administrative procedures relative to a proposed architectural precast concrete construct. Because of the ever-increasing complexity of construction materials, standard's growth and variations in administrative procedures, it is impractical to include specifications as drawing notes for architectural precast concrete projects of any appreciable size. The drawings show size, form, quantity, relationship between materials and location of materials relative to the proposed construction. Both specifications and drawings are needed to describe a project. There should be no gaps between them nor should they overlap; the specifications and drawings should be complementary.

The process of architectural precast specification writing begins with understanding the scope of the contract documents to be created. Typically the designer's, and therefore the specifier's, responsibility extends to the selection, and documentation, of the esthetic and functional objectives for the architectural precast concrete design. In many cases, the components of these

***"A single mix design, disciplined modularity, an intuitive understanding of the capabilities of precast, strong specifications, and effective communication between members of the construction team resulted in Gensler's successful two-phase 400,000-square-foot Discovery Square Office Building Project in Reston Virginia."* Photo: Timothy Taylor**

The deft use of modularity, textures, planes, reveals and a single mix design combined with precision craftsmanship in fabrication and erection can render cost effective three dimensional architecture in precast concrete as illustrated in this close-up image at Gensler's Discovery Square Project located in Reston, Virginia. Photo: Timothy Taylor

objectives may take weeks, if not months, to determine and to specify. When asked what is the single most important task in specifying architectural precast concrete Craig Taylor of Gensler's Houston office simply states "getting the right mix."

So what are esthetic and functional objectives? Esthetic specification objectives include the selection of the cladding material(s). Architectural precast concrete mixes, texture, and veneer cladding selections are made after considering the site context of the structure, glass and glass retention framing materials, limitations in available precast concrete materials and production capabilities, and the project schedule and budget. Esthetic objectives simply rendered as "match architect's sample" can lead to bid-period and post-bid-period misunderstandings. Flustered after several decades in the architectural precast cladding business and having to bid on poorly written specifications, a precast plant manager suggests that the specifier should "glue a piece of sandpaper of the desired color and texture into the spec and have the precaster match it."

What data needs to be specified? The answer comes from a fundamental understanding of project-specific requirements and some of the basics of architectural precast panel manufacture.

Architectural precast concrete is predominantly composed of cements, coarse aggregates, natural and manufactured sands, and sometimes pigments. Color, and consequently color tone, represent relative values. They are not absolute and constant but are affected by light, shadow, density, time and other surrounding or nearby light reflecting colored surfaces. A concrete surface, for instance, with deep exposed opaque white quartz appears slightly gray. Shadows between the particles blend with the actual color of the aggregate and produce this graying effect. These shadows in turn affect the color tone of the matrix. Color tone will change as the sun traverses the sky. A clear sky or one that is overcast will make a difference as will landscaping and time. A low water/cement ratio cement paste is always darker than a high water/cement ratio paste made with the same cement.

Cement used in architectural precast concrete is available in gray or white. Each possesses inherent color and shading differences depending on its brand, type, mill, and quarry source. For example, some gray cements are nearly white while others have bluish, reddish, or greenish tones. Some white cements have a buff or cream undertone, while others may have a blue or green. Gray cement is less expensive than white cement; however, white cement provides a wider range of possible color combinations than does gray cement. White cements also are easier to patch. A finely ground gray or white cement is normally lighter in color than a coarse ground cement of the same composition. Gray cements are generally subject to greater color variation than white cements even when supplied from one source. If gray shades are desired and optimum uniformity is essential, a mixture of gray and white cement is often chosen.

Landscaping, obscured glass, light, shade, shadow and attention to detailing at glass and horizontal rib terminations add interest and crisp clean lines to an ordinary parking garage screen wall at Discovery Square. Photo: Timothy Taylor

Large amounts of carbon dioxide are generated in the manufacture of Portland cement, which many claim contributes to global warming. Seeking to reduce these emissions and garner sustainability credentials, some designers may consider fly ash or silica fume as partial substitutes for Portland-cement content in precast. These substitutes are the byproducts of power generation and manufacturing processes. Their use will benefit the environment, achieve higher strength and lower permeability; however they will slow concrete strength gain, may affect color tone if light tones are desired, and in the case of silica fume, require more mix water. According to Terry Collins of the Portland Cement Association, these materials do not have enough calcium hydroxide to completely substitute for Portland cement's role in concrete. As such, there are limitations on their proportion to Portland cement, which are published by American Concrete Institute and PCI. Many architectural precasters may object to the additional cycle time required for the precast strength to develop before they strip formwork. This may be the major reason that many precasters have not embraced the use of these materials in their production.

Most precasters want to know primarily what the coarse aggregates are to be. They have a number of good reasons. Their first concern is whether or not they will need to ship aggregates from remote quarries. Long-distance hauling, by truck or train, may have a large impact on the final panel cost. Aggregate type and size will play a major role in controlling unit water requirements, proportion of water to sand, cement content and workability. Grading variations and excessive fines can affect batch-to-batch color uniformity. Some aggregates may lack the necessary physical properties to withstand the desired finish texturing. Aggregates possessing high compressive strengths are recommended where high-pressure sandblast or ground-finish textures are required. Some aggregates may not be suitable for acid-washed finish textures as they could discolor or dissolve. Natural gravels may dislodge and shatter when exposed to bushhammer texturing. Glass and ceramics are aggregates that can be used to achieve architectural effects or sustainability goals. If these types of aggregates are being considered, they should be examined for reactivity with proposed cement alkalis and for their ability to remain in place (bonded to the cement) after proposed finish textures are applied.

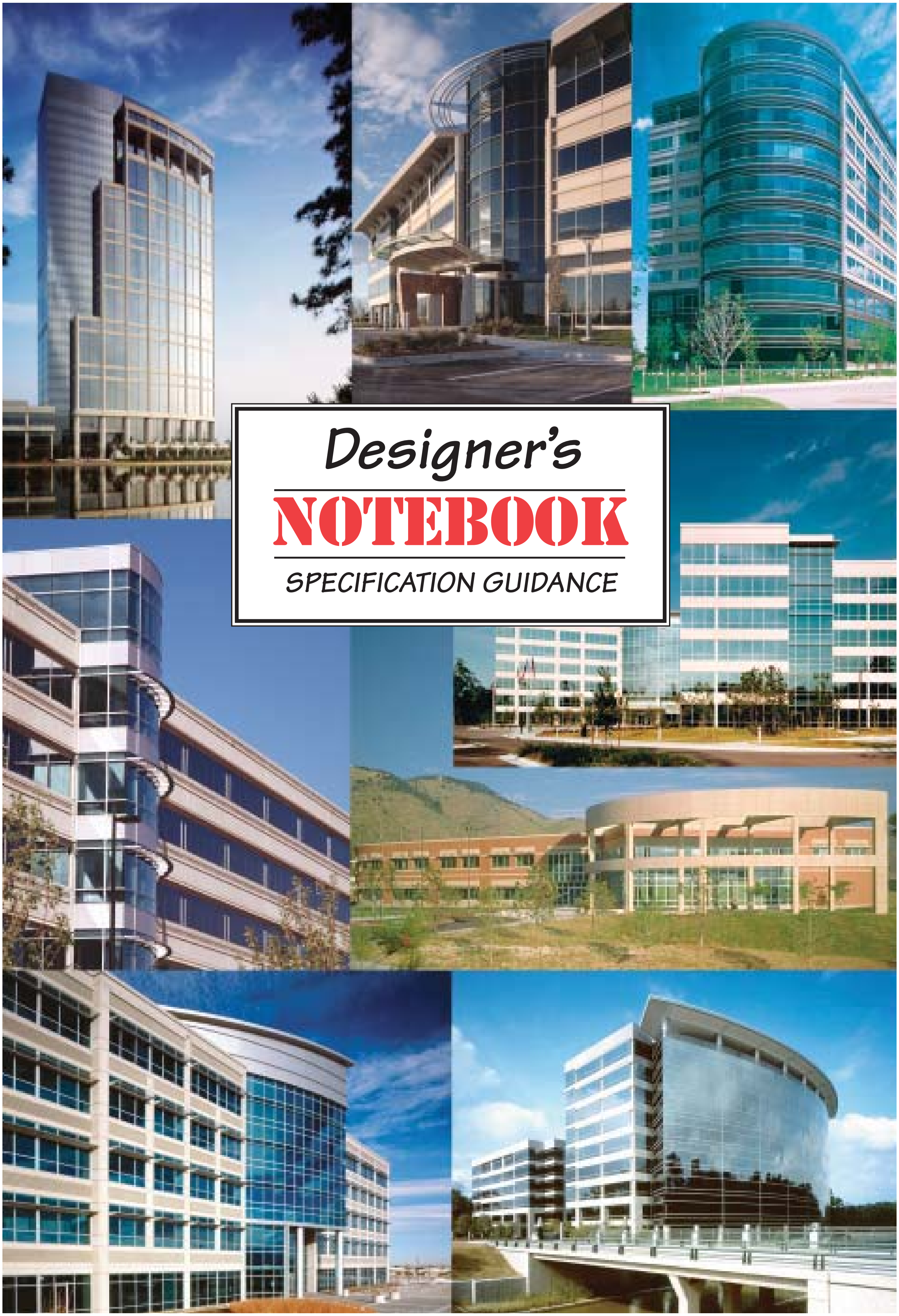
Fine aggregates (sands) also play a role in the color and texture of precast concrete. This is especially true where coarse aggregates are not intended to be exposed, such as for retarded, acid-washed or brush-blast textured finishes. A case in point would be where simulated white or buff limestone is desired. In these applications, color uniformity is critical. Therefore, gradation and source controls, either from a pit or quarry or by stockpiling, for the entire project, must be provided by the precaster. Compounding the color uniformity issue is the fact that many natural sand sources lack the necessary whiteness that is demanded to create light-colored simulated limestone. In order to compensate for lack of sources some precasters will proportion more costly manufactured local or imported sands to adjust for desired color tones.

The use of selected cements, coarse and fine aggregates predominates in the production of architectural precast panel manufacture. Occasionally, however, desired precast color tone cannot be achieved with available cements and aggregates without the use of pigments. Pigments can be manufactured from a multitude of materials, provide many shades of color, and have varying degrees of color retention. Just a small amount is perceptible to the human eye, especially when they are incorporated into pure white cement and sand mixes. Exercise prudence when pigments must be specified. Pigments in liquid form have provided better dispersion results over dry-mixed pigments. Automated processes with liquid color and batch-sized factory packaging of dry-mixed pigments have reduced the occurence of color non-uniformity within a single panel and make panel-to-panel color uniformity easier to achieve. Large amounts may reduce concrete strength. Long-term color retention may not be possible with certain pigments. If pigments must be used, obtain and evaluate testing results, not certifications, of their color-retention characteristics, and visit projects where pigments were used by the proposed precaster.

A single mix design, combined with automated batching of a liquid-dispersed pigment system, stringent attention to batching and material quality controls, and three degrees of paste removal produced these uniformly colored and textured precast panels in Tyson's Corner, Virginia.
Photo: Timothy Taylor

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

To be continued in the Winter 2003 issue.



Designer's NOTEBOOK

SPECIFICATION GUIDANCE

Part II Guide Specification for Architectural Precast Concrete Panels

PCI's Architectural Precast Concrete Services Committee explains key considerations in specifying architectural precast panels

Performance Specifications

Performance specifications define the work by the results desired. For example, architectural precast concrete panel specifications will establish: (1) drawings that govern the design and arrange the various wall components; (2) materials and finishes; (3) the loads and forces the wall panels are required to support; and (4) insulating and permeability requirements. In other words, they cover the aesthetic, functional and structural requirements and define all limiting factors.

Performance specifications can achieve 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 samples, careful review of shop drawings and architect's approval of initial production units.

Primary Advantage

Performance specifications' primary advantage is that they combine economy and optimum quality by using established tooling and production techniques. Conventional specifications often resort to stringent requirements to protect the architect and the client. As a result, they do not always produce the best price within the desired or acceptable quality range.

Performance specifications can create additional work for the architect at the design stage, because the end result must be clearly defined and 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 performed by the architect's office.

Performance specifications should define the scope (statement of needs) and quality of the precast concrete at an early stage. With performance specifications, the manufacturer is responsible for selecting means and methods to achieve a satisfactory result. When a project contains both design and performance specifications, specific areas must be analyzed to determine the degree of discretion left to the manufacturer.

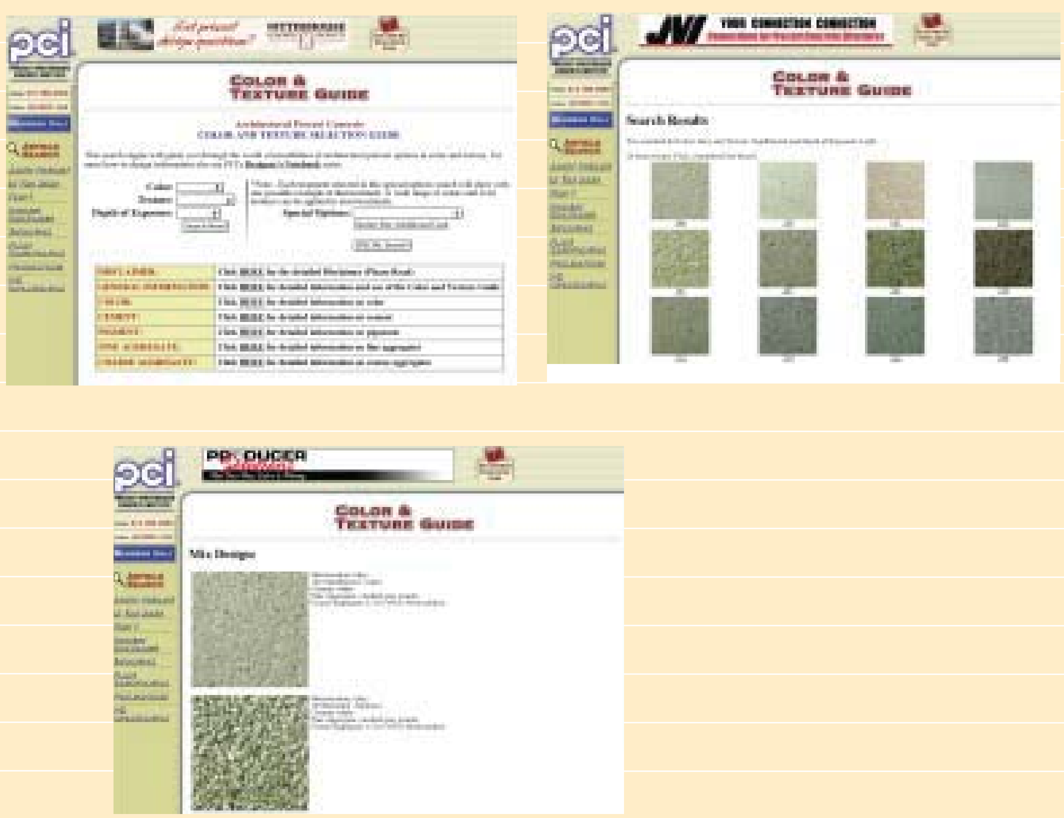
Five Key Criteria

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 and weight. 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 of each subcontract is clearly defined. All subcontracts must be properly related to each other so that they combine to produce an integrated project.

3. If a method other than simultaneous competitive bidding through a general contractor is contemplated, the scope and the nature of the precast concrete work in relation to other trades should be carefully weighed in the final assessment of the precast concrete solution.
4. The architect should request samples, design and detail submissions from prospective bidders and make pre-bid approval of such submissions a prerequisite for bidding.
5. To the degree that such requests for pre-bid approvals form a part of the specifications, the architect should adhere to the following requirements:
   a. Sufficient time must be allowed for the bidder 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. Any proprietary pre-bid submittal should be treated in confidence and the individual producer's original solutions or techniques protected both before and after bidding.

Performance specifications offer a good alternative for many projects. They may require more work in the design stage for the architect, but that work can result in the ability to take full advantage of the capabilities and expertise of the rest of the construction team.



PCI's Color & Texture Guide is available for free at www.pci.org. The online guide illustrates the world of possibilities of architectural precast options in color and texture. Visit PCI's home page, and click on About Precast > Architectural > Color & Texture Selection Guide.

Guide Specification In Development

A complete architectural precast Guide Specification is in development jointly by PCI, Gensler and the American Institute of Architects (AIA), Master Systems publishers of MASTERSPEC®.

Match Architect's Samples: Tips for Specifying Texture

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

To many, the greatest challenge after determining a precast mix design is surface-texture specification. Surface textures are used to achieve shadows and degrees of color uniformity. "As a minimum, we typically use light sandblasting to cut the paste off the fines to get some shadow and remove any splotchiness in the color," according to Norman Hoover of Gensler's Houston office.

The Anadarko Tower located in The Woodlands, Texas, was clad with light and medium sandblast textured precast panels composed of a single face mix design. Some of the panels were supplemented with thermal finished Luna Pearl granite insets. The mix was composed of 100 percent white Portland cement, coarse aggregates (Knippa Grade 4 and Delta Type 'D'), fine aggregates (Black Beauty #2 sand and TCS ASTM sand), and pigment (DCS 836). Photo: courtesy of Gensler.

What can complicate texture specification are the means, methods and even terminology that vary from precast plant to precast plant. Many plants have developed specific techniques supported by skilled workers using specialized tools. At Discovery Square (Ascent Summer 2002 Designer's Notebook), a recent project designed and completed by Gensler's Washington, D.C., office, David Epstein specified prefabricated polyethylene formliners to obtain horizontal ribbed shadow lines, as he knew that the precaster providing his pre-construction precast samples preferred their use. Another precaster, who was awarded the work for the project, used his in-plant millwork shop to shape ribbing from wood to match the specified formliner profile.

Acid-washed finishes, popular because of their resemblance to a sugar-cube textured limestone, often are substituted for light sandblasted texturing because the successful precaster can provide the building owner an attractive schedule and price but without the specified finish, which he does not have the equipment and personnel to provide.

Wide Range of Textures

The most commonly specified textures for precast include smooth, retarded and water-washed, form-lined, sand- or abrasive-blast, acid-etched or acid-washed, and tooled.

Smooth texture, as the term implies, is an as-cast finish. This texture is a direct result of the quality of the formwork surface. It is the least aesthetically pleasing but the most economical of the surface textures, especially if the surface is to be field painted. Form defects and color non-uniformities are noticeable with this finish texture, air voids are normal, and surface crazing should be expected.

Retarded and water-washed textures are achieved by using nonabrasive means to fully expose the natural color and brightness of coarse aggregate. Chemical retarders work by delaying the hardening of the cement surface paste over selected time periods and to selected depths, which is followed by water washing and brushing.

Water-washed textures simply use high-pressure water and brushes to remove surface paste prior to the hardening of the paste. Water washing, unlike retarded finishing, has a propensity for dislodging the coarse aggregate, which may require reseeding for a uniform surface texture. Retarded and water-washed textures can be applied to both formed and unformed surfaces to produce light to heavy aggregate exposure. They are easily repairable, and the form surface quality is not critical. The heavier the aggregate exposure, the more these textures will cost, making exposure-depth specification paramount. Water-washed and water based retarded texturing may be more environmentally friendly than solvent based retarded finishes and should be explored as an alternative to solvent based chemical retarders.

Form Liners Expand Options

Form liners and reveals can be used for an infinite variety of surface texturing and patterns. Frequently, they are specified in conjunction with other textured finishes. However, according to Hoover, "It is not unusual to use form reveals to create a shadow line rather than a field of texture or pattern. They can be quite useful as transitions between changes of finish texture or aggregate color. They also are convenient places to hide sealant joints between panels."

The single concrete mix shown here has three different finishes. From left to right, they are acid etch, sandblast and retarded. This multiple-finish technique offers an economical, yet effective, way to heighten aesthetic interest.

Liners can be fabricated from almost any material, with the most popular options including plastic, wood, extruded-polystyrene foam, and combinations of plaster and latex molding materials. Specification of form-liner attachment using tapes, sealants or adhesives is critical to avoid the often undesirable telegraphing of form-liner fasteners, countersunk fastener heads and edge or side laps imparted to the cast surface.

If preformed plastic formliners are selected, it is good specification practice to describe the pattern and to include a reference to the pattern and its manufacturer. Similarly, if smooth, textured, or patterned form-liner surface treatments are required, they should be described in the specification. Common examples include woodgrained plywood and board forms, brick and rock faced.

Hoover advises that, "There are also practical limitations to depth and profile that should be considered for reveals having excessive depth." Excessively deep reveals may increase shadow lines but will necessitate greater panel thickness to overcome bowing and other undesirable effects of thinner panel section.

Detail of a glass to precast plane transition at the Waterway Plaza, The Woodlands, Texas. Note how the hue of the mix design complements the window frame coating. The precast panels were fabricated from a single mix containing white Portland cement, coarse aggregate (Texas Pink), and fine aggregates (Black Star, Big Sandy Sand, and White Sand). After casting, the panels they received light or medium sandblast texturing. Photo: courtesy of Gensler.

Blast Finishes

Because they yield such a broad variety of appearance with reasonable cost, blast finishes are the most commonly specified of precast textures. There are three generally recognized degrees of sand- or abrasive-blast finish. The least aggressive is a light blast, which is commonly specified where a sugar-cube limestone surface texture is desired. Light blasting abrades the precast surface to remove surface cement/sand paste enough to just begin to reveal the coarse aggregate and can provide greater color uniformity than as-cast texturing, without exposing the coarse aggregate.

Medium blasting removes the paste to the extent that approximately half of the exposed surface area of the panel is coarse aggregate. Heavy blasting removes essentially all of the paste from the surface area of the panel, revealing the coarse aggregate in all of its glory. Like retarded and water-washed textures, the heavier the aggregate exposure, the more these textures will cost, making exposure depth specification paramount. The extent to which aggregates are exposed or "revealed" is largely determined by their size. Reveals should not be greater than one-third the average diameter of the coarse aggregate particles or one-half the diameter of the smallest sized coarse aggregate.

Blasting operations tend to brighten aggregates by fracturing their exposed faces. This causes sunlight to be reflected, and the aggregate manifests frosted, muted hues. Maintaining continuity of plant personnel, equipment and time interval from casting through finishing is essential in achieving consistent blast-surface texturing and should be specified. Blast finishes are relatively easy to patch.

Blast Alternatives

Acid-etched or acid-washed surface textures often are specified as an alternative to light blasting. Light etching removes surface cement/sand paste and imparts a fine, sandy texture similar to a sugar-cube limestone surface texture without exposing coarse aggregate. Medium etching will remove the paste enough to just begin to reveal the coarse aggregate. When specifying acid etching, wetting the surface before and after the application of the acid is essential to avoid color uniformity problems and the potential for in-service efflorescence. Light acid-etched textures are more difficult to patch than light-blast textures.

As with form liners, hand and power tools can be used to create an infinite variety of surface textures to precast. As if to confuse designers and specifiers, the precast industry simply names the use of any tool for this purpose as bushhammering. Specifications for uniformity or non-uniformity of tooled finishes are extremely difficult to write and assistance should be sought from a precaster providing the tooled finish being specified.

Examples of light, medium and heavy sandblast textures.



Examples of light, medium and heavy acid-washed textures.

Development of sample panels is essential. At the least, limitations for finishing should provide that no changes in equipment, materials, procedure or personnel are permitted. Since many tooling processes can impart large localized stresses to precast panels, additional criteria may need to be provided. Excessive localized stress can cause damage, such as through-panel cracking, exposure of panel reinforcements, and corner loss. Criteria that will limit such damage may include increased panel thickness, allowing concrete to attain 75 percent or higher 28-day strengths, increased concrete cover and holding back texturing a predetermined distance from corners.

Specifying Guidebooks

Specifying color and texture in precast can be a difficult, laborious and seemingly impossible task. Fortunately, there are resources available to the specifier that can make this task a little less onerous when the specifier does not have a sample to match. One is the PCI's Architectural Precast Concrete Color and Texture Selection Guide. The guide was specifically developed as a jumping-off point for the selection of color and texture. It contains several hundred images of colors and textures, and their associated mix materials, which can be achieved with architectural precast concrete.

PCI's Color & Texture Guide is available for free at www.pci.org. The online guide illustrates the world of possibilities of architectural precast options in color and texture. Visit PCI's home page, and click on About Precast > Architectural > Color & Texture Selection Guide.

Another resource that is useful in the development of specification text describing precast finishing is the PCI's Collection of Ideas on the Production of Architectural Precast Concrete, which is available for sale from PCI.

The availability, quantity, performance, cost and production considerations of each ingredient and finish of architectural precast concrete can have a large impact on a project's schedule and budget. Therefore, they should be determined and specified for each specific project before the project specifications are released. The time and expense required to develop samples and select mix colors and textures can be considerable and should not be underestimated by the design team.

The next part in this series will present considerations for clay-faced and stone-veneered finishes.

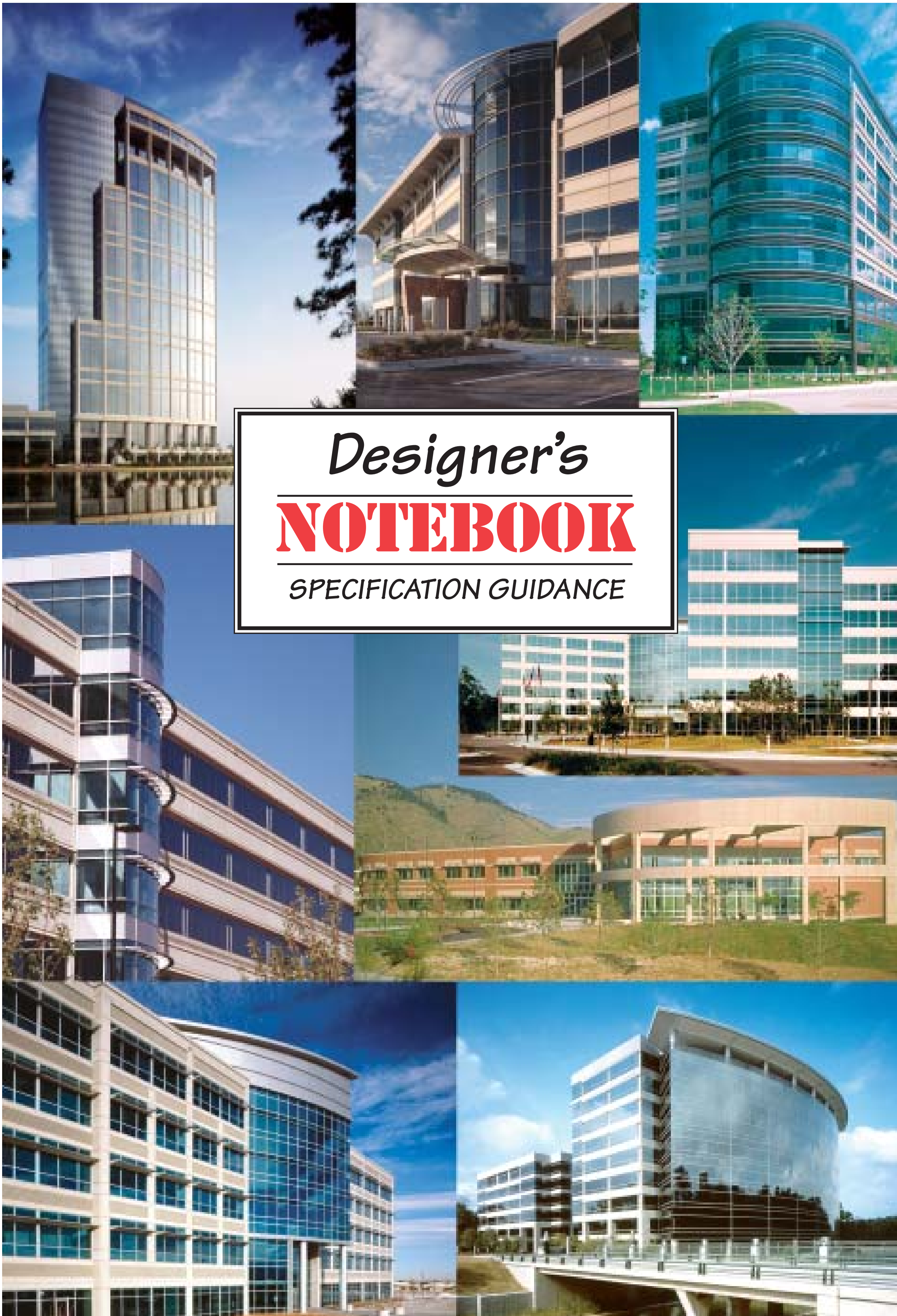
—Timothy Taylor, Director of Specifications, Gensler, Washington, D.C.

To be continued in the Spring 2003 issue.

Designer's

NOTEBOOK

SPECIFICATION GUIDANCE



Part III Guide Specification for Brick-Faced Precast Concrete Panels

PCI's Architectural Precast Concrete Services Committee shows items to consider in specifying brick-faced architectural precast panels

A Guide Specification for Architectural Precast Concrete is being developed jointly by PCI, Gensler and the American Institute of Architects (AIA), Master Systems publishers of MASTERSPEC®, and will be available on PCI's web page (www.pci.org/guide specifications) around June 2003. The following is an excerpt on brick-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 or conflicts.

PART 1 - GENERAL SUBMITTALS

Shop (Erection) Drawings: Indicate locations and details of brick units and joint treatment.

Samples: 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.

Material Certificates: Brick units

PART 2 - PRODUCTS
THIN AND HALF BRICK UNITS AND ACCESSORIES

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 1/2 inch (13 mm)] [3/4 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.>**

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

7. 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.

8. Initial Rate of Absorption: Less than 30g/30 sq. in. (30g/194 sq. cm.) per minute when tested per ASTM C 67.
9. 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.

10. 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.

11. 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.

12. Back Surface Texture: Scored, combed, wire roughened, ribbed, keybacked or dovetailed.
13. 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."

14. Products: Subject to compliance with requirements, provide one of the following:
    a. **<Insert manufacturers' names and product designations for acceptable face brick.>**

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

B. 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.

C. 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].**

D. Setting Systems
1. 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.
2. Securely place brick units face down into form liner pockets and place precast concrete backing mix.
3. Clean faces and joints of brick facing.

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

4. Thin brick Units: **[Dry-Set Mortar: ANSI A118.1] [Latex-Portland Cement Mortar: ANSI A 118.4]**
5. 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.

FABRICATION TOLERANCES

For tolerances, see Designer's Notebook (DN-8) Clay Product-Faced Precast.

Match Architect's Samples: Tips for Specifying Clay-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 clay-bodied materials has many precedents. Numerous examples throughout the U.S. where brick, ceramic tile, and terra cotta are used in conjunction with architectural precast concrete have achieved stunning, award-winning aesthetic designs with exceptional records for durability.

Some architects, such as Rob Jernigan of Gensler's Santa Monica, Cal., office, express their preference for using architectural precast concrete because it's a cladding material that is "plastic, three-dimensional and a lot of fun."

As with any material intended to be exposed to the weather, quality-assurance and -control requirements are critical. This is especially important in these designs, as clay-bodied 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.

The selection and specification of clay-bodied 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.

Compensating For Differences

Clay-bodied 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 and moisture conditions. Expansion, contraction and moisture-absorption characteristics for each of the cladding materials must be known and specified. Some clay-bodied materials possess the physical property of dimensionally increasing when wet but not decreasing when dry again. After its initial set, however, concrete materials will lose water and shrink. If a cladding material is bonded to a precast concrete backup, this shrinkage may be restrained by the cladding.

The Denver-based Gensler, designers of Gallup's Corporate Headquarters in Omaha chose two-toned, thin brick-faced precast panel accent strips supplemented with exposed monochromatic architectural precast concrete. Precast was chosen in order to avoid complications to project schedule and cost that conventional handset face brick, backup support framing, and associated scaffolding would have required. Photo: courtesy of Gensler.

Deformation resulting from this restraint to shrinkage may manifest itself as an outward bowing of the panel. In extreme cases, cracking of the cladding may occur. If a cladding possesses a large thermal coefficient of expansion, stresses in the panel under decreasing temperature may be the reverse of those manifested by shrinkage.

If the cladding materials and the precast concrete do not have similar expansion and contraction characteristics, the specification and detailing should provide for compensation or separation. Compensation is partially made by using precast concrete mixes containing aggregates that have expansion and contraction coefficients selected to be close to those of the cladding. Shrinkage is partially compensated for by mix water content. Cladding materials with large differentials of expansion and contraction, inadequate concrete bonding capabilities or a combination of the two typically are mechanically anchored and separated from the precast backup with bond-breaking sheet materials.

Mechanical Anchors

Mechanical anchors used for exterior cladding must be inherently noncorrosive under the project-specific environmental conditions. Each selected anchor should be evaluated for its performance when attached to the precast, when attached to the 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 the flexural stresses imposed by handling, transportation, erection and in-service use.

Cladding panels using mechanical anchors are usually specified with a minimum number, location and placement symmetry based on the height, width and thickness of the cladding unit and on the preferred anchor model, style or type. Criteria for the quality of drilling, insertion and setting of anchors also should be specified. Pre-engineering of anchors is sometimes exercised if small amounts of cladding material are required, their physical properties are historically consistent and certifiable, and the anchor being tested in the pre-engineering exercise will be used for the project being specified.

Clay-Bodied Cladding Materials

Clay-bodied products (brick, ceramic tile and terra cotta) are man-made and therefore engineered to a measured degree. Their properties are usually well understood by their manufacturers, so their performance is more easily assessed for use as a cladding material. Some are not suitable for exposure to the exterior elements. Brick, ceramic tile, and terra cotta units with and without glazed faces should be evaluated for their ability to absorb water and resist freeze-thaw cycling.

Some clay-bodied cladding materials have ranges in color and shade caused by manufacturing processes and variations in raw materials. On a recent project, for instance, a brick supplier had not indicated to the architect, precaster or contractor that there would be a significant amount of variation in the brick to be cast into the precast panels. The precaster's crews laid up the bricks in a normal manner, not suspecting the wide color swings that were discovered when the panels were pulled from the forms. The brick faces subsequently were stained to achieve a degree of color uniformity.

If variations are anticipated and are deemed undesirable, the specifier should require blending of the cladding units prior to being placed into the formwork or laid up onto the panels. Clay-bodied materials have successfully performed in both mechanically anchored and bonded assemblies. Clay-bodied cladding materials not supplemented by mechanical anchorage should possess grooved, keyback, dovetailed or scored-back surfaces for long-term bond performance.

Three Combination Approaches

Precast concrete and cladding materials are successfully combined in three formats: in precast plants as an integrally anchored or bonded component, as plant laid-up onto cast panels and as laid-up to erected precast panels at the project site. Plant anchorage and bonding 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.

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 is also a good practice, as it will avoid the potential for staining and bond reduction.

Joint Treatments

Joint treatment and anchorage placement for the cladding material must be carefully selected and specified. For instance, ceramic tile, and terra cotta claddings require continuous spacers and neoprene buttons to maintain joint widths, lines and levels that may shift when anchors, reinforcing, and backup mixes are being placed. Ron Huff of Gensler's Denver office adds that "detailing and modular spacing must be meticulous to get the coursing right and avoid orphaned mortar joints that can mar the overall look of a brick-faced panel." Fine sand is sometimes placed between the cladding units as an alternative to continuous spacers.

Brick-cladding joint widths can be controlled with spacers, but more typically they are controlled by placing the bricks into prefabricated form liner grids with prespaced joints. The grids are commonly manufactured from elastomeric or plastic materials and feature raised and semi-recessed joints. Raised joints may be selected for later tuck-pointing operations. Semirecessed joints may be selected to simulate various raked or tooled joints not requiring subsequent pointing.

Caution is advised in the specifying of proprietary form liners for brick claddings, as not all grids and brick products are manufactured to the same face dimensions and tolerances. Oversized grid recesses or undersized brick thicknesses may cause unacceptable levels and occurrences of tipping (rotation) of bricks from the panel plane of the exposed brick surface and brick step-in from the adjacent panel plane of exposed brick surfaces. Surface textures of brick units and exposed face-plane warpage can cause plastic precast concrete matrices to flow onto the exposed face of the brick units in the formwork. Huff observes that this flow, or seepage, “is usually more pronounced with dark-colored bricks than light-colored bricks.”

Once the forms and joint-spacing materials are removed, joint sealants or grouting materials are mixed, placed and tooled to detailed profiles. Sealant and grouting mixing and placement should be clearly specified.

Bonding Clay-Faced Units

In general, ceramic tiles are recommended by their manufacturers to be bonded to precast backup using cast-in or laid-up methods.

Close-up of orphaned light-colored, thin-brick units at accent field to vertical exposed precast column cover transition. Photo: courtesy of Gensler.

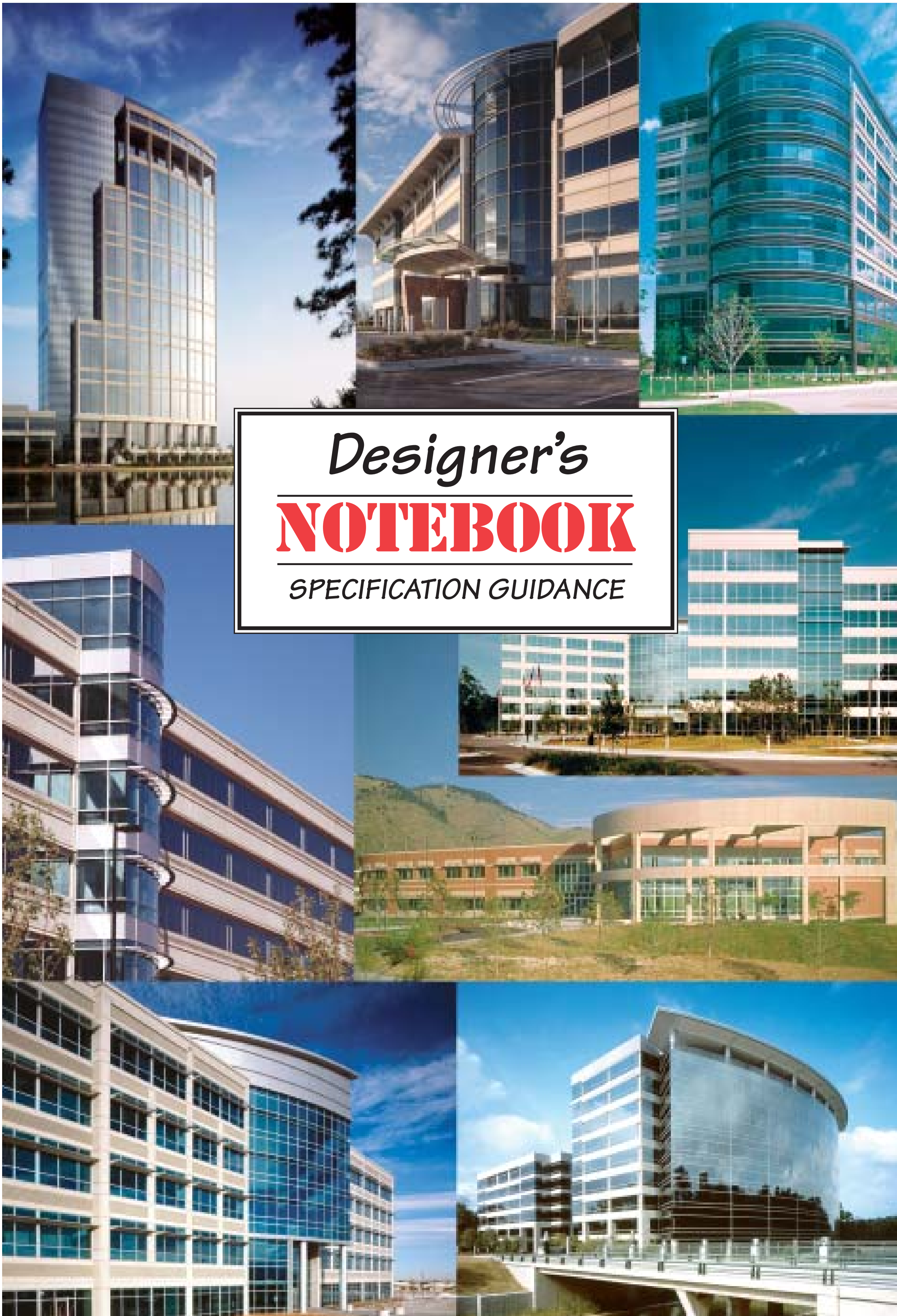
Cast-in specifications are similar to those for the factory casting of thin-brick units, wherein a grout material is applied to the back faces of the ceramic tile prior to the placement of the precast backup. However, the type of bonding material depends on the absorption characteristics of the ceramic tile being used. For example, tiles with low-absorption characteristics may result in low bond strengths with water-based, non-modified Portland cement-based grouts. Tiles with high-absorption characteristics can remove the water necessary for non-modified Portland cement based grouts to hydrate.

Terra-cotta cladding units generally are cast into the precast panels. Since terra-cotta units have high absorption characteristics, they are soaked in water for a period of time, usually an hour, to reduce suction. Then they are positioned, while damp, into the formwork immediately prior to the placement of the precast backup.

The multitude of ceramic tile and terra cotta cladding product installation variations necessitates research, detailing and specifying on a project-specific basis. Language that is specific to these types of cladding materials has not been addressed in the new specifications in response to these variations.

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

To be continued in the Summer 2003 issue.



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 1¼ 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.