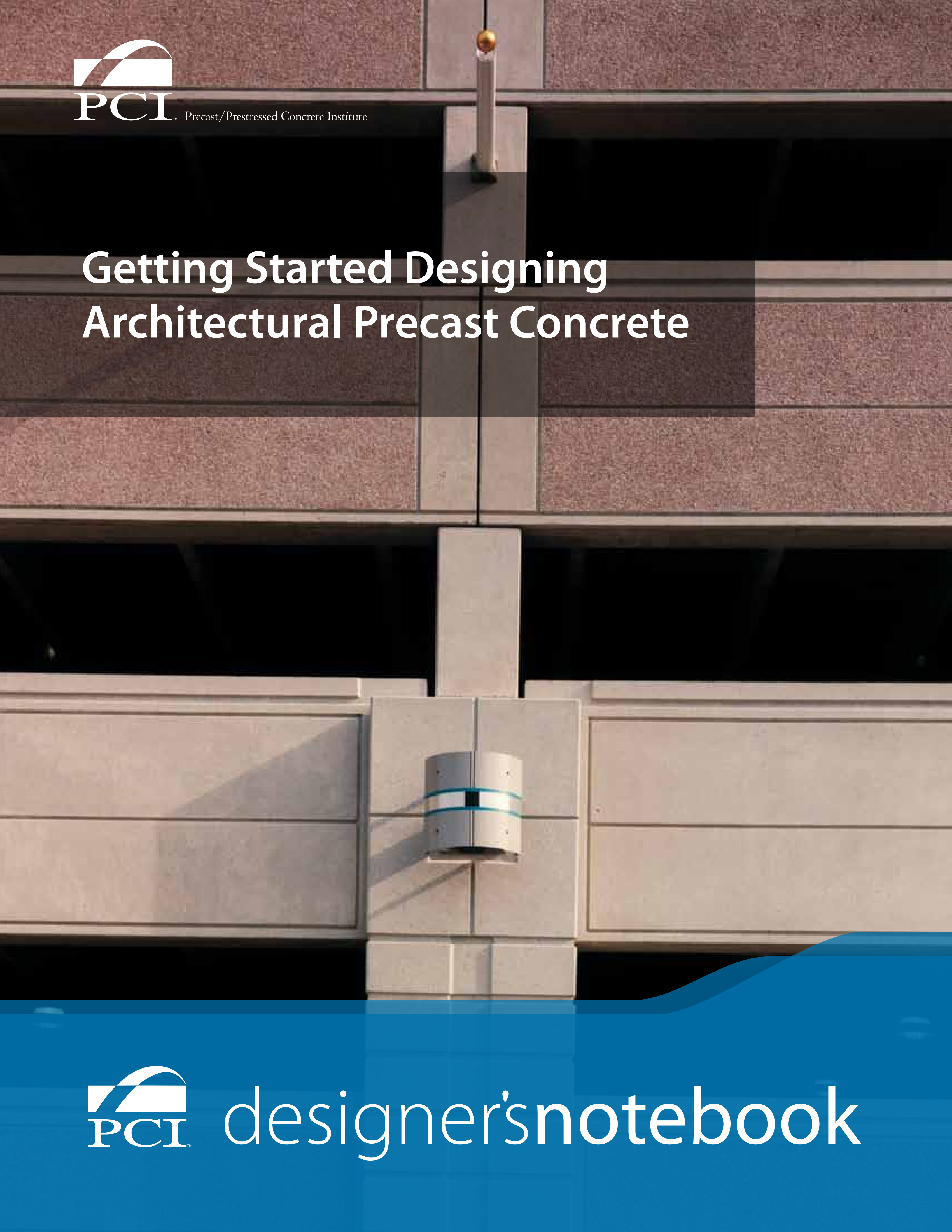
PCI Precast/Prestressed Concrete Institute

Getting Started Designing Architectural Precast Concrete



PCI designer'snotebook

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Whether the project being considered is a small one-story building or a high-rise structure, involving the precaster in the early design development stage of a project is advisable. Ideally, a precaster performs value engineering in response to performance requirements or offers design alternatives in response to identified needs early in the preliminary design phase to control construction costs, improve structural efficiency, facilitate erection, enhance precast concrete performance, and meet aesthetic objectives.

When the design team includes the precaster in early discussions of the design intent and desired aesthetic and functional aspects of the building's facade, it is more likely that the full benefits of architectural precast concrete will be realized. After being provided with concept drawings and, if available, plan and elevation renderings, the precaster can be a valuable resource to the design team. As the project develops, the design team and precaster can discuss:

- panel joint locations,
- panelization (panel sizing and weights),
- types of finishes and the sample process,
- cross sections,
- shapes,
- drips,
- reveals,
- panel returns,
- repetitive use of efficient and economical precast concrete modules,
- structural systems,
- approaches for connecting panels to a structure to substantially minimize costly supplemental structural framing or bracing,
- delivery schedule,
- access or site restrictions,

- erection procedures,
- and sequencing.

The designer should always ask the precaster what is or is not possible or cost effective.

Many precasters also employ professionals accredited by the U.S. Green Building Council as part of its Leadership in Energy and Environmental Design (LEED) program. LEED accredited professionals (APs) can identify areas where precast concrete can contribute to achievement of sustainability objectives and LEED credits.

If unfamiliar with architectural precast concrete, the designer should visit an architectural precast concrete manufacturing plant to view the production process prior to designing wall panels. It is also advantageous to visit any projects that are under construction with finish characteristics that are the same as or similar to the proposed project. This way the designer can become familiar with the manufacturing processes and installation procedures and, most importantly, establish realistic expectations for the finished product that are consistent with his or her design objectives.

During a project's conceptual or schematic design stage, the designer has many variables to consider that affect aesthetics and precast concrete cost. Piece size and unit repetition typically have the most significant cost impacts. In addition, material selection, color, textures, surface geometries, cross sections, erection details, jobsite access conditions, and connections can affect cost.

PCI's Architectural Precast Concrete Committee discusses some general design guidelines and coordination suggestions to begin designing architectural precast concrete.

Color and Texture Selection

Early input from the precaster on panelization and finishes can be beneficial in developing options for creating an economical design that also satisfies the designer's aesthetic requirements and meets the owner's budget. The designer should discuss the desired types of finishes and whether the precaster can accomplish the intended aesthetics.

Most precasters are eager to assist the architect in developing a design reference sample (12 in. x 12 in.) as early as possible. The best method in selecting a color and sample is to visit the precast concrete plant to view a multitude of samples and finished panels stored in the yard. Alternatively, a designer can refer the precaster to a selection from the PCI *Architectural Precast Concrete – Color and Texture Selection Guide*, to an existing project, or provide a piece of natural stone (or other material) to match or refer to. Samples must be made at a precaster's plant to confirm the desired colors and ensure that textures are satisfactorily matched.

Precast concrete panels may also be cast compositely with other materials to provide an entirely different finished surface. Clay products (brick, tile, and terra cotta) and natural stones (granite, marble, limestone, and sandstone) have all been used successfully as veneer facing.

Panel size, ft^2	Erection cost per piece, dollar amount per ft^2			
	500	1000	1500	2000
50	10.00	20.00	30.00	40.00
100	5.00	10.00	15.00	20.00
150	3.33	6.67	10.00	13.33
200	2.05	5.00	7.50	10.00
250	2.00	4.00	6.00	8.00
300	1.67	3.33	5.00	6.67

Table 1 Effect of panel size on erection cost per square foot. (Erection costs are for illustration only.).

Once the 12-in.-square samples are within an acceptable range, larger samples should be made to confirm that the mixture proportions, vibration, and finishing techniques necessary to make production-sized pieces could duplicate the aesthetic qualities of the small sample pieces. These panels should incorporate full-scale details of architectural features, finishes, textures, and transitions from one color or texture to another.

After award of the contract, at least three range sample panels, 15 ft^2 to 20 ft^2 (full scale, but not necessarily full size) should be produced for large projects with multiple approving entities to demonstrate actual planned production conditions. These should establish the range of acceptability with respect to color and texture variations; uniformity of returns; frequency, size, and uniformity of surface air-void distribution; surface blemishes; and overall appearance.

The designer should also view initial production or mock-up panels to evaluate conformance with approved samples. The proper use of samples and mock-ups is an important element in ensuring the project's success.

Panelization

In the interest of both economy and function, precast concrete panels should be as large as practical, while considering production efficiency and transportation and erection (crane capacity and site access) limitations. By making panels as large as possible (at least 150 ft^2 and ideally larger than that), numerous economies can be achieved: the number of required panels is reduced, fewer joints (waterproofing requirements) and connections are required, and the overall erection cost is lower (**Table 1**). The cost difference in handling and erecting a large rather than a small unit can be insignificant compared with the cost-reducing effects of fewer panels to erect resulting from the increased square footage of a large unit. Some precasters have size or weight limitations for panels based on their in-plant capabilities. Most precasters have limits to size and weight of panels based on highway department limits without permits.

The maximum panel size that can be transported is affected by local conditions such as those of bridge and overhead utility clearances, site access, crane capacity, and requirements of regulatory agencies such as state and federal departments of transportation. In general, a panel up to 12 ft tall and 45 ft long is a manageable size, although larger sizes may be appropriate in certain applications where permitted.

Panel size is also a function of the design loads and support locations for connections. Panels should be designed in specific widths to suit the building's modular planning. When such a building is designed to take the best advantage of modularity, the economic advantages are significantly increased. The designer can ensure a good average piece size by spanning a full bay with spandrels and designing multistory column covers and large wall panels.

Rustications or Reveals

When using large units, if the appearance of smaller panels is desired for aesthetic reasons, rustications or reveals can be used to achieve this effect. Also, dividing large areas into smaller ones by means of rustications or reveals can help de-emphasize the visual effects of variations in texture.

When selecting accent reveals or rustication lines, it is important to tie them in to the chosen joint size. Triangular reveals should be avoided where possible because they are difficult to affix to the forms. Instead, a trapezoidal reveal will provide a flat nailing surface for the mold builders and help minimize possible nail-hole irregularities.

When two different mixtures or finishes are used within the same panel, it is strongly recommended that designers include a reveal between the two mixtures to provide a distinct stopping point for each mixture and help reduce color bleed. This will help ensure an unwavering and smooth break line between the two colors or finishes.

When choosing a reveal size, also consider limiting its depth to $^{3}/_{4}$ in. Deep reveals decrease the effective structural section of the panel, thereby reducing panel strength and increasing the chance for panel cracking to reduce cost. Reveals and rustications should be placed in a repetitive pattern in order to minimize modifications throughout a mold's life.

Repetition

Two key elements to cost-effective production are minimizing the number of molds required for a project and mold changes and maximizing the number of castings from each mold (**Table 2**). Understanding the master-mold concept will greatly benefit the design team.

The master-mold concept is to design the largest possible mold for a particular unit, where-

Number of uses	Panel size, ft^2	Mold cost	Mold cost per ft^2
1	200	$5000	$25.00
10	200	$5000	$2.50
20	200	$5000	$1.25
30	200	$5000	$0.83

Table 2 Effect of repetition on panel mold square foot cost. (Mold cost is for illustration only.)

by several variations from the same basic (master) mold can be produced by varying mold component accessories. Units cast in this mold need not be identical, provided changes in the units can be accomplished through simple mold modifications. These modifications should be achieved with minimum change-over time and without jeopardizing the usefulness or quality of the original mold.

Cost premiums are introduced to a project when panel cross sections become more complex or intricate surface features are added. The use of bulkheads, blockouts, or reveals placed on top of the mold surface is less expensive than cutting into the mold surface for a projecting detail. Projecting cornices, bullnoses, formliners, bottom and/or top returns, and curves are the most typical features to be added. The exact sizes, shapes, and locations are some of the designer's options. Cost will also be added to the project if the locations of these features within a mold are required to be changed frequently. Alternatively, these intricate features can be added at minimal cost if they are used repetitively in the overall design or the cost can be controlled by adding details to specific forms only.

If the precaster is provided with sufficient lead time, duplicating molds to meet project schedule requirements is unnecessary. But occasionally, to meet a tight schedule, a precaster may need to construct multiple forms to produce the required number of panels within a certain time period. For designers, such a necessity can often be turned into a benefit, allowing for the creation of a completely different form that adds variety to a facade without additional cost.

With panel profiles, it is important to consider the draft required to strip the precast concrete unit from the mold as well as the draft required to achieve a specific finish. Generally, the minimum positive draft for ease of stripping the unit is 1:12, with 1:8 preferred. The draft should be increased to 1:6 for units with many openings, for narrow ribbed panels, or for very delicate units. Vertical sides or reverse drafts are to be avoided when possible, because they could entrap air voids and require costly form breakdowns and repairs after each production cast. Designers should consult their local precasters for specific draft recommendations.

Functional Aspects

One of the early decisions that the design team needs to consider is the functional attributes of the panels. In addition to acting as cladding panels, the precast concrete panels may perform other functions: they may be load bearing, be wall supporting, serve as formwork or shear walls, or be used as grade beams; they may be insulated or may provide the interior finish; they may serve partly or fully as containers of mechanical/electrical services; or they may combine several of these functions to become a wall subsystem. The total cost of an architectural precast concrete wall system may be lowered by taking full advantage of the ability of the precast concrete portion to serve multiple functions.

To take maximum advantage of load-bearing and wall-supporting units, the decisions as to their functions should be made before structural design of the building frame has progressed to a stage where revisions become costly for a given project schedule. Both the engineer of record and precast concrete design engineer should be involved from the initial concept stage of the project. Considerations should include the load effects on member dimensions, coordination of temporary bracing, connections, and erection sequencing. When using load-bearing units, it is usually necessary to award the precast concrete contract earlier than for non-load-bearing facades (cladding). See the representative project schedules given in **Figures 1 and 2** showing that the precaster is a member of the design team during the schematic design phase for

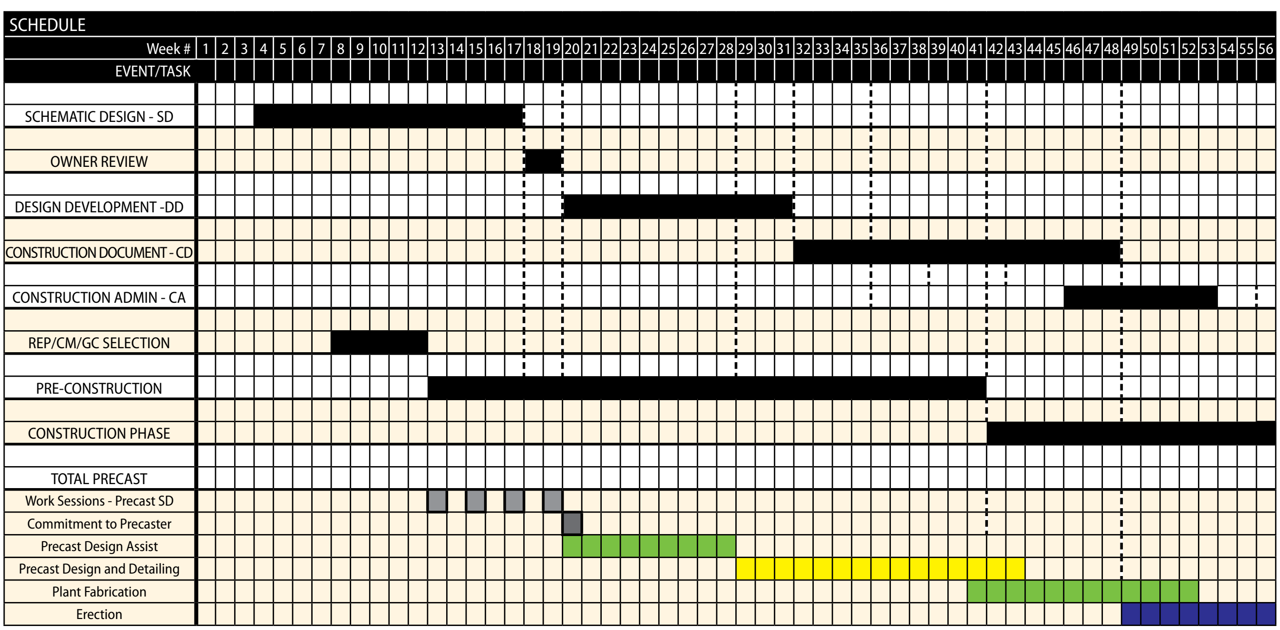

Figure 1 Schedule for load-bearing precast concrete projects.

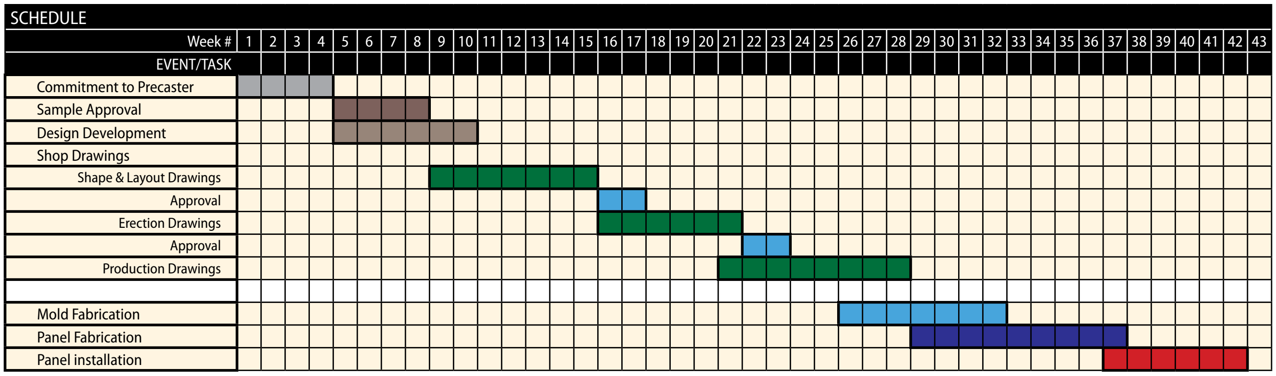

Figure 2 Architectural precast concrete cladding project schedule.

load-bearing projects. For cladding, the precaster usually becomes part of the team during the design development phase.

In some building configurations, the most economical application of architectural precast concrete is as gravity- and lateral-load-bearing aesthetic/structural elements. Each load-bearing element plays an essential role in the structural integrity or stability of the building. Load-bearing panels can eliminate a separate perimeter structural frame and may reduce or eliminate interior columns, a structural core, or interior shear walls, particularly in buildings with a large ratio of wall area to floor area. The increase in floor space gained by eliminating columns can be substantial and, depending on the floor plan, partition layout flexibility can be enhanced.

Wall-supporting panels, similar to cladding panels, are designed to carry no loads from the floor or roof slabs. The building frame carries only lateral loads from the panels, as all axial loads from the wall panels are supported by the foundation. This reduces the need for larger structural members around the perimeter of the building, resulting in a more economical superstructure.

Corners and Edges

Each individual project requires special attention to the design and detailing of its corners to create optimum appearance, jointing, and economy. For this reason, corner detailing should be decided early. Economy results when the building elevations are designed from the corners inward, using typical panels and avoiding special-sized end or corner pieces. Wherever possible, the designer should avoid fragile edge details.

All edges of precast concrete units should be designed with a reasonable radius, chamfer, or quirk, rather than leaving them as sharp corners, to reduce edge damage and mask minor irregularities in alignment. This is particularly important where the panels are close to pedestrian or vehicular traffic. The size of the edge's radius should be discussed with the local precaster because determination of the optimum radius depends on the selected aggregate size, mold materials, and production techniques.

Window Frame Location

Consideration should be given to the relationship between window frames and architectural features such as reveals and projecting elements on a precast concrete panel. For example, window installers discourage attempts to align the frame exterior with a series of reveals. A more successful design features window returns that create a smooth surface against which the installer can set and plumb the frames. Also, the window connection system needs to be reviewed with the precaster.

More-accurate opening sizes are produced by panels incorporating punched openings rather than ribbon windows created by a column and spandrel system. This can be an important factor if the glass system is preordered on the job.

Contract Documents

The contract drawings prepared by the design team should provide a clear representation of the configurations and dimensions of individual architectural precast concrete units and their relationship to the structure and to other materials. Isometric sketches can help the precaster visualize details, particularly in the case of nontypical conditions such as outside and inside corners, intermediate roof levels, nontypical floors (such as ground level or mechanical floors), and entrances. Dimensional locations of details should always be tied back to a structural grid or column line.

The contract documents should supply the following information:

- Elevations, wall sections, and dimensions necessary to define the sizes and shapes (profiles) of each different type of precast concrete element along with drip details beneath soffitted pieces;
- Locations and dimensions of joints and reveals, real (functional) or false (aesthetic) (the architect's drawings may only show reveals or design articulation, allowing the precaster to determine panel sizes suitable to their handling and erection capabilities in order to achieve economy and flexibility in production and erection);
- Required materials and color and finish treatment for all surfaces, with a clear indication of the extent of all surfaces to be exposed to view when installed;
- Identification of the various precast concrete finishes on the elevations and a specification or finish schedule that identifies that finish type or procedure or sample reference number;

- Corner and return details;
- Sandwich panel construction and insulation systems independent of the precast concrete;
- Details for jointing and interfacing with other materials (coordinated with the general contractor), including windows, roofing (connections should not puncture flashing), and other wall systems;
- Openings for services and equipment, with their rough opening size and location;
- Details for special or unusual conditions and, if the project requires fire-rated panels in specific locations, the locations and hourly ratings for these;
- Governing building codes, design loads including concrete strength requirements, deflection limitations, and temperature considerations;
- Specified dimensional tolerances for the precast concrete and the supporting structure, location tolerances for the contractors' hardware, clearance requirements for proper interfacing with other elements of the structure, and erection tolerances for the precast concrete along with clearance between the back of the panels and the structural frame of the building (in accordance with PCI's *Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products* (MNL-117);
- Support locations for gravity and lateral loads as well as supplemental framing or bracing to support the precast concrete (it is preferable to leave actual design of connections to precasters so they can design details and connections suitable for their production and erection techniques);
- Building location and site access; and
- Delineation of lateral bracing for structural beams or any unusual erection-sequence requirements.

The contract documents should make reference to MNL-117, which includes Category A-1 certification of the production facility, as the industry guideline for production of architectural precast concrete elements. Exceptions to this standard or other specific requirements should be clearly set forth in the contract documents.

Prebid Meeting

It is recommended that a prebid meeting for all precasters intending to bid the project should be held at least three weeks before the bid date. At this meeting, the design team presents the precast concrete concept drawings along with plans and elevation renderings, if available, so that competitive and accurate bids will be obtained. Providing this information improves communications and resolves outstanding questions prior to preparation of cost estimates and bids. Items to be discussed at the prebid meeting include:

- Specifications, PCI plant certification requirements, and any special provisions;
- Design responsibilities and lines of communication;
- The architect's approved finish samples with information on the mixture proportions, where applicable;
- Prebid submittal requirements, such as proposal drawings and finish samples;
- Project schedule, shop drawing submittal requirements, and architectural review turnaround times;
- Panelization of precast concrete units;
- Mock-ups, if applicable;
- Potential problems, discrepancies, or both, found in the contract documents;
- An explanation of how and where the project's precast concrete units will be structurally attached to the building frame;
- Interfacing with other trades;
- Responsibility for designing, providing, and installing embedded items, anchor bolts, connection hardware attached to structural steel, bracing, and other structural items;
- Hardware and reinforcement finishes;
- Special erection needs (access, crane limitations, and sequence) and logistics; and
- Responsibility for caulking of precast concrete panel joints.

Production Drawings

The precaster uses the information from the contract documents to generate shape and erection (coordination) drawings and design calculations. These drawings detail elevations showing panel sizes (panelization), surface features, and panel relationships; sheets showing panel cross sections, special edge conditions, and feature details; and connections showing mechanisms and locations of load transfers to the supporting structure. If a natural stone- or brick/tile-type finish is desired, detail the stone panel to panel joints or the brick bond pattern. Panel dimensions may be dictated by brick unit dimensions to eliminate the cost of cutting the brick.

The architect reviews the precaster's erection and shape drawings in a timely manner primarily for conformance to the contract documents, then passes them along to the engineer of record for review of conformance to the specified loads and connection locations.

Penetrations and Cast-In Material

Penetrations through the precast concrete that may be required for wall hydrants, pipe penetrations, and light fixtures can be cast into the panels if locations and sizes are provided early in the precast concrete shop drawing preparation. Ideally, the location and size of these penetrations should be given to the precaster about eight weeks prior to fabrication. This amount of time ensures that the information can be incorporated into the shop and fabrication drawings. For openings less than 2 in. square or round, it is recommended that the penetrations be field cut.

Precasters can also cast various items needed by other trades into the precast concrete. These items are generally designed and supplied by others and installed in the manufacturing plant during production. It is important to coordinate this information and provide the precaster with locations and details of the cast-in items well in advance of production. As with penetrations, the precaster should be provided with locations and part details at least eight weeks prior to the start of manufacturing in order for them to be detailed into the precast concrete shop drawings. The hardware should be delivered to the precaster at least four weeks prior to the start of fabrication.

Wall-mounted devices such as canopies, awnings, flagpoles, or antennae should be clearly identified on the contract drawings (along with design loads). These devices should then be discussed with the precaster so the structural forces transmitted into the panels by those items can be evaluated and adequate panel reinforcement designed.

Mock-ups

If desired for the project, the architect and owner should authorize an expenditure for mock-ups—either of a full-scale portion of a panel or the entire typical unit—to evaluate the production methods and the finished product, including window elements. The mock-up is also an ideal mechanism for coordination of all trades with abutting materials. Mock-ups may be several modules wide by one or two stories high. Investing in such mock-ups removes uncertainties held by both the architect and owner and may lead to modifications that improve the appearance and possibly reduce the overall project cost.

If mock-ups are implemented in a timely manner, cost and schedule implications associated with revisions to the design may be avoided and measures adopted promptly to address items requiring attention, if any. Also, it may be desirable to separate the mock-up costs from the base bid so the cost can be evaluated separately.

After Award of Contract

Once the precast concrete subcontract is awarded, the designer should discuss realistic precast concrete engineering and production lead times for the project with the precaster. In addition, the architect will be asked to approve finishes and samples and promptly respond to requests for information to ensure that erection or, at least, shape drawings are approved and mold manufacture can begin on schedule.

Because mold production requires the greatest amount of production lead time, the common goal of both the architect and the precaster at the shop drawing stage is to expedite all of the details regarding the size and shape of the precast concrete panels. Shop drawings may be approved initially for mold production and subsequently for panel production.

It is vital to include precast concrete scheduling information with the bid documents. Key schedule items, such as mock-up panels, shop drawings and design submittals (including review time), mold production, production start and durations, and erection start and durations (if applicable) should be discussed with the selected precaster. The architect should work with the precaster to understand their overall schedules, not just the project schedule.

Teamwork

Properly implemented, an early and continuing partnering dialogue between the design team and the precaster will ensure optimum product quality and appearance at a minimum installed construction cost.

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