Chapter 2
Planning and Design Criteria

2-1. Structural Guidelines

This chapter delineates structural design parameters that are essential in architectural concrete construction and must be addressed by the designer. These parameters emphasize the need for designs that are in excess of those for structural concrete construction.

a. Crack control (cast-in-place). Due to natural drying shrinkage of concrete, stresses are produced in structural concrete where restraint occurs and cracks may develop. In as-cast finishes, cracks are of minor importance when sufficient reinforcement is used to hold them to fine widths. Surfaces to be sandblasted for treatment cannot tolerate any cracking, as the sandblasting tends to widen very fine cracks or accentuate discernible cracks. To minimize visible cracking, sufficiently deep rustication joints can be placed at regular intervals to draw the cracking where sealants can be used to seal against leaking and conceal the cracking. Placement of concrete can be limited by section in long walls to allow for the anticipated volume changes. The recommended maximum spacing of vertical construction joints for a wall placement is 60 ft and the recommended vertical contraction joint spacing is as follows:

Wall height	Vertical contraction joint spacing
0.6-2.4 m (2-8 ft)	3 times wall height
2.4-3.7 m (8-12 ft)	2 times wall height
>3.7 m (12 ft)	1 time wall height

b. Crack control-(precast). Precast architectural units should have some flexibility after erection to allow for distortions due to temperature and shrinkage and movements of the building's structural frame without cracking.

c. Deflections. Architectural concrete requires more rigid control of deflections for long span smooth concrete girders to prevent an appearance known as "optical sag." As limitations are determined by personal preference, deflections should be minimized by overcorrection of the camber needed to offset the total deflection. Total deflection is the sum of all individual computed deflections due to all loadings plus those due to time-dependent effects. Specific information is given in ACI 435R-95 (ACI 1995b).

d. Reinforcement. Sufficient reinforcement is required at window corners and other openings to prevent the formation of cracking. Horizontal steel in walls should be increased 50 percent above the ACI 318 (ACI 1995a) minimum requirements. Where rustication is used or aggregate is to be exposed on the surface, remaining cover should be sufficient to protect the reinforcement against the environment. If the cover is minimal, reinforcement can be protected by an epoxy coating, or the use of stainless or galvanized steel. The amount of horizontal reinforcement crossing a planned crack control joint should not exceed 50 percent of the normal wall reinforcement.

e. Reinforcement chairs and spreaders. Plastic chairs or spreaders are best for the architectural face to avoid rusting. In girders having large amounts of horizontal reinforcement, chairs must be sufficient to prevent compression of the soffit wood form and possible exposure of the chair legs after form removal. Investigation is needed to determine the effect or exposure of chairs by surface treatments such as sandblasting or bush hammering. For information on the use of plastic-coated chairs, attention is directed to ACI 315 SP-66.

2-2. Architectural Guidelines

Innumerable choices of patterns, finishes, color oxides, aggregate colors, and cements are available to the architectural designer to achieve a desired effect. Once the desired combination is achieved, responsibility for obtaining the architectural product is shared by the contractor and the contracting officer. In order to judge acceptability, general guidelines contained in ACI 303R state that acceptable architectural surfaces should have a pleasing appearance with minimal color and texture variations, and minimal surface defects when viewed from a distance of 6.6 m (20 ft). For surfaces such as stairwells having close contact with the public, specifications should contain more stringent requirements.

a. Finishes and patterns. Architectural concrete surfaces can be as-cast, where the mortar surface appearance is determined from the type of forming used to mold the concrete and the end result is smooth or patterned. Surfaces can also be textured by removal of the mortar surface in order to expose the aggregate. This technique may remove all of the pattern due to forming. Either method can be used to break up the large, smooth, open, and flat surfaces which accentuate all variations from a plane surface in the forming. For specific information, attention is directed to ACI 1974.

b. Colored concrete. The color of architectural concrete can be varied with the use of color oxides, color and brand of cement, or stains. As acceptance is usually determined by individual preference, most publications do not contain detailed criteria for judgement. Generally, colored architectural concrete having minor color differences but exhibiting excellent uniformity on separate building elevations or elements, will be acceptable. Precast panels are vulnerable to such judgement upon erection and must be manufactured with materials chosen for their uniformity and using personnel and methods known to produce uniform coloration. A good quality control program will check color and texture uniformity in the plant prior to shipment. Color variations for field cast-in-place concrete can be held to a minimum by maintaining uniformity in materials, concrete production, delivery, and placement, construction procedures, curing and finishing.

c. Rustication and joints. The use of rustication and joints will simplify and ease the construction of architectural concrete surfaces as it allows the planning of efficient placement of the concrete and still achieves a pleasing result. Patterns of rustication and joints can be used to break up large flat areas, isolate placements to eliminate any possible leakage traces, cover form joints and control shrinkage cracking to desired locations.

(1) Chamfer strips. Chamfer strips are recommended for internal form corners to aid in form removal without damage to the concrete. Wood chamfers should have a minimum face width of 1 in., the same texture as the adjacent form, be sealed to prevent absorption, and edge-sealed to prevent leakage behind the chamfer. Acute and right angle corner details are possible but require special form details to allow easy form removal without damage to the corners.

(2) Wood rustication strips. Recommended dimensions and details for wood rustication strips are as follows:

(a) Depth of 19 mm (3/4 in.) for small rustication grooves.

(b) Depth of 37.5 mm (1-1/2 in.) for crack control joints and panel lines.

(c) Widths equal to depth for wooden strips.

(d) Minimum draft (angle or taper in side) of 15 deg for form removal.

(e) Uniform cross section and strength for good alignment.

(f) Other types of strips. Strips made of metal or similar stiffness should be 19 mm (3/4 in.) in width or wider. Extreme care is needed during fastening and sealing of openings.

d. Drainage. To prevent staining, drainage water must be restricted from running down the face of the architectural concrete by designing drip molds at soffit edges of all angular and horizontal offsets. The drip molds should be a minimum distance of 25 mm (1 in.) from the face of the concrete or a distance equal to the maximum size of the aggregate. To assist self-washing of air pollutants deposited on the architectural surfaces and openings, downward slopes should be provided on sills and top surfaces of projecting details. Upward slopes should be provided for the upper surfaces of recesses. Such slopes can be 1:12 for smooth surfaces to 1:1 for textures. Rainwater should be directed away from the architectural face on the upper surfaces of parapets.

2-3. Design Reference Sample and Mockups

In order to properly specify and construct an architectural concrete structure, use of the design reference sample and mockup can lead to proper decisions during the bidding and construction stages.

For some projects, the mockup may become an interior wall which is to be eventually covered. All projects incorporating architectural concrete should have an acceptable sample mockup constructed by the contractor's forces for control purposes. Architectural specifications should state that no architectural production forming will be constructed until a completed mockup has been approved.

a. Design reference sample. Prior to finalization of the contract documents, the architectural designer should supervise the production of a design reference sample, which will show the desired surface as to color and texture only. Source of materials, and type of texture treatment should be identified on the design reference sample and in the specifications. Other materials may be used if they match the color and texture of the design reference sample and meet requirements of American Society for Testing and Materials (ASTM) C 33 (ASTM 1993), ASTM C 150 (ASTM 1995b), ASTM C 618 (ASTM 1996), ASTM C 595 (ASTM 1995C), and ASTM C 989 (ASTM 1995a). Final approval should depend on the results obtained in a field mockup. Minimum size of the reference sample is usually 0.5 m by 0.5 m (18 in. by 18 in.) for convenience in handling with a thickness of 50 mm (2 in.), unless more thickness is required by the maximum size of aggregate or to prevent breakage of the sample during the texturing process. A typical design reference sample is shown in Figure 2-1. Due to numerous proprietary sealers available, any specified sealer should be applied to a portion of the design reference sample for use in comparison with contractor-proposed substitutions. Decisions for sealer use on architectural concrete surfaces should be made in accordance with the recommendations of paragraph 9-5a contained in this manual. Placement of the concrete should be similar to field construction for proper orientation of any exposed aggregate. If an existing building is to be matched, it can be used as the reference sample if located nearby. Use of materials from the same sources may not produce a concrete that matches an existing building that has undergone weathering.

b. Job-site mockup. In order to ensure that the contractor understands the specifications and has the capability of producing the specified architectural concrete, a job-site mockup should be required by the contract specifications. A satisfactory job-site mockup is illustrated in Figure 2-2. For large major projects, a separate contract may be let to construct a special full-scale mockup using the proposed design materials. Any conflicts or construction difficulties can be found before going to bid and appropriate changes can be made.

2-4. Precast Options

a. General. The choice of precast or cast-in-place concrete is based upon economics and availability of materials and personnel. In order to obtain satisfactory results in remote areas, where experienced construction personnel are not available, precast concrete may be the best alternative, although not always competitive. In some cases, desired appearance requires imported aggregate or cement. It may be more convenient and economical to have the units precast at a well-established plant with good quality control and a capability to properly stockpile the aggregate. Competition between plants will usually be determined by haul distances and local labor rates. If rail facilities are available, longer haul distances will be competitive.

b. Precast concrete facing. Precast architectural concrete has been successfully used as facing with cast-in-place concrete. The expensive and difficult facing unit is cast, under excellent control and plant conditions, then placed on the building as an envelope for normal structural concrete. This option requires excellent protection in the field against mortar leakage. This is generally handled by casting recesses into the precast facing for compressible rubber gaskets to prevent leakage.

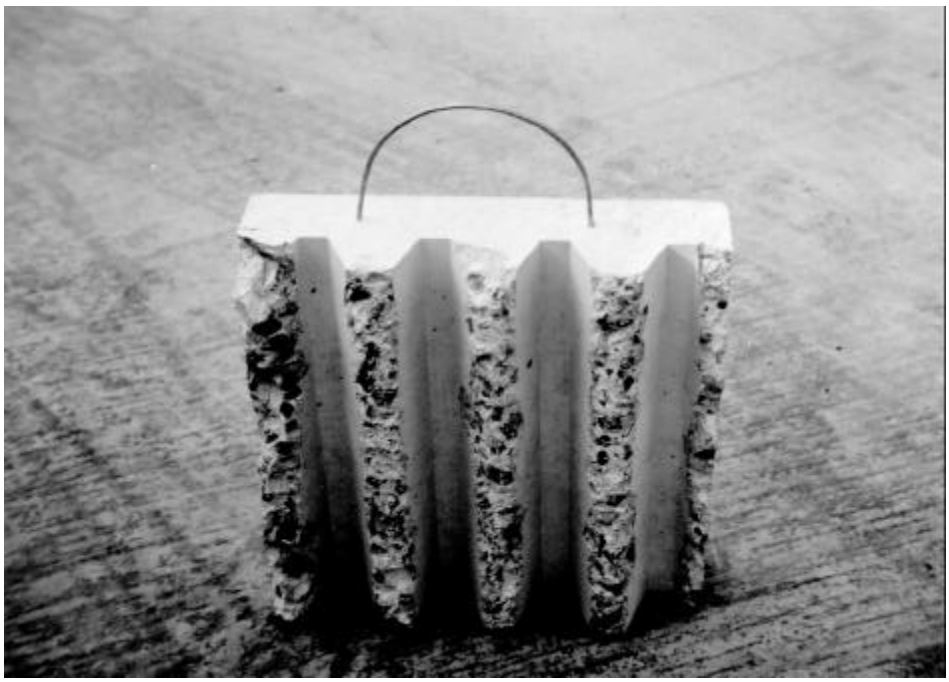

Figure 2-1. Typical design reference sample

Figure 2-2. Example of field mockup sample