PCI Precast/Prestressed Concrete Institute

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Design Factors Affecting Aesthetics of Architectural Precast Concrete

PCI designer's notebook

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Architects find that precast concrete panels provide an unlimited vocabulary that allows design concepts to be executed in a broad range of architectural styles, shapes, and sizes. The material offers limitless potential for developing and manipulating mass, color, form, texture, and detail to obtain simple, clean shapes yielding an interesting play of light and shadow.

Proper selection of color, form, and texture for a building's precast concrete exterior is critical to creating a successful aesthetic appearance. The decisions depend not only on cost, delivery schedule, and client preferences but on the local and regional context as well. The desired colors and textures can be achieved by varying aggregate selection, matrix color, size of aggregates, finishing processes, and depth of exposure of the aggregate. This textural flexibility allows designers to use combinations of different finishes using the same or different concrete mixtures, within a single precast concrete unit. Multiple finishing techniques or concrete mixtures with differently colored matrices exposed at the face of the same panel offer an economical, yet effective, way to heighten aesthetic interest through the use of tones and texture in façade treatments. The use of multiple finishes means the designer must make an early decision to ensure that the overall concept allows for the change in finish color and texture. A suitable rustication (that is, some demarcation) needs to be detailed to separate the different colors and/or finishes.

The building's appearance results from the architect's use of light, shadow, texture, and color. Color and, consequently, color tone represent relative values. They are affected by light and shadow, intensity, time of day, and nearby colors. Thus, color selection should be made in lighting that replicates the light and shadows of the site's natural daylight.

The ***Architectural Precast Concrete: Color and Texture Selection Guide***, 2nd Edition (CTG) published by PCI, helps architects define and achieve their aspirations. The guide's photographs serve as a visual reference for initial selection of color, texture, and finish and should be followed by producing samples at a precaster's plant to aid in the final selection of color and texture.

The initial plasticity of concrete makes it responsive to the designer's creative

needs. It allows the designer to achieve a high level of detail in the profile, scale, and character of a building that cannot be economically matched by other materials. Precast concrete mold-building techniques allow designers to enhance a building's visual interest through elements such as ribs, bullnoses, reveals, chamfers, or textures. Designers can economically incorporate details such as cornices, quoins, arches, and decorative relief panels. In addition to these benefits, the ability to manipulate color, form, and texture make precast concrete an excellent material to consider in situations where the relationship of a building to its existing context is an important design consideration. Precast concrete can be designed to harmonize with and complement other materials. Natural stone, brick, tile, or terra cotta can be cast into panels allowing designers even more choices for panel finishes. Precast concrete provides the freedom and flexibility of shaping concrete into structure and architecture.

Uniformity and Development of Samples

Because acceptable color uniformity and shading intensity are evaluated visually, they are generally a matter of an individual's subjective judgment and interpretation. Acceptable variations in color, texture, and uniformity should be determined at the time the sample, mockup, or initial production units are approved. A suitable criteria for acceptability requires that the finished concrete surface should have a pleasing appearance with minimal color and texture variations from the approved samples. The finished face surface should show no obvious imperfections other than minimal color and texture variations from the approved samples or evidence of repairs when viewed in typical lighting with the unaided eye at a 20 ft (6.1 m) viewing distance. Appearance of the surface should not be evaluated when light is illuminating the surface from an extreme angle, as this tends to accentuate minor surface irregularities. Appearance of the surface should also be evaluated when the concrete is frost-free and completely dry.

Uniformity

Concrete contains natural materials, and it is these materials' inherent beauty that is most often expressed in architectural concrete. The limitations of these natural materials with respect to uniformity must be considered, and the requirements for uniformity of the precast concrete product must be set within these limitations.

Some color difference between nominally identical precast concrete units is inevitable, but color variation, between and within panels, should be kept within an agreed range. Therefore, it is important, at the sample stage, to reconcile the ex-

pectations of the owner and architect with the practical limits of color uniformity. Some designers prefer to see color variation akin to timber and natural stone, while others desire the consistency and uniformity of paint. Where uniformity is essential, the precaster can provide significant input in balancing colors, textures, and shapes to achieve this uniformity.

Color control is, thus, about ensuring that panels or other precast concrete elements for a project have an acceptable tonal range.

Uniformity of color and texture requires the precaster to manage a complex set of variables, including raw materials, mixture proportions, mixing, casting and consolidation, curing, finishing, and weathering. When fabrication continues over extended periods, color can vary because of the changes in the physical characteristics of cements, coarse aggregates, and sand, even though they may be from the same sources. Colors can also change because of natural variations in ambient weather conditions.

The color of a concrete is dependent on, among other factors, the cement and other materials used. Variation in the color can occur from day to day in the product from a single cement plant, and color differences are to be expected among cements obtained from different plants. Cement color reflects chemical composition and processing conditions. Usually, cement colors vary from white to shades of gray and brown. Greater color uniformity results can be expected when using white cement than when using gray cement.

The type and brand of cement must also remain consistent. Changing from Type I to Type III portland cement within one job will cause color variations because Type III portland cement is a finer grind of cement than Type I. Even though the color changes of the cement would be minimal, it is recommended that types or cement brands not be changed.

Because the largest portion of a concrete mixture is aggregate, the color or gradation of aggregate can influence the color of concrete. A substantial change in aggregate color can make a noticeable difference in surface color, especially if an exposed aggregate finish is specified. Therefore, the precaster should stockpile, either at the plant or quarry, the fine and coarse aggregates for each type of exposed finishes.

Coarse aggregates should be reasonably uniform in color. A mixture can have more than one aggregate type to get the desired color. Light and dark coarse aggregates require care in blending so that color uniformity is achieved within a single unit. Choosing aggregates with a small color difference between the light and dark aggregate will enhance uniformity. The architect should specify that the matrix's color or tone match that of the coarse aggregate so that variations in the depth of exposure and concentration of aggregate will not be as noticeable. Panels containing aggregates and matrices of contrasting colors will appear less uniform. Also, as the size of the coarse aggregate increases, less matrix is seen.

If a sample is stored indoors, its color will vary from a panel stored outdoors. A panel stored outdoors and exposed to precipitation is cured differently than the controlled environment of the sample. It is difficult to exclude the influence of the climatic changes on color over a year if the precast concrete units are placed in storage for long periods of time, as may be dictated by contractual conditions or by operations at the construction site beyond the control of the precaster.

The last production process that affects panel aesthetics and needs to be controlled is the finishing. A smooth-off-the-form finish is extremely difficult to produce consistently. Any type of finish that has some degree of aggregate exposure will appear more uniform than a smooth finish because the natural variations in the aggregates will camouflage subtle differences in the texture and color of the concrete. The degree of uniformity normally improves with an increased depth of exposure. Some variation is to be expected in color and texture, even after finishing. Assessment of color uniformity of the panels prior to finishing offers little information. Dividing large surface areas into smaller ones with reveals or rustications also helps to lessen visible variations in color and texture.

Many finishes cannot be achieved with equal visual quality on all faces of the unit because of several factors, such as mixture designs, variable depths (pressures) of concrete, and differences in consolidation techniques, particularly in the case of intricate shapes with complex flow of concrete.

During consolidation, the effect of gravity forces the larger aggregates to the bottom and the smaller aggregates, plus the sand and cement, upwards. Consequently, the down-face in the mold will nearly always be the most uniform and dense surface of the unit. The final orientation of aggregates may also result in differences in exposure between the down face and the returns in exposed-aggregate surfaces. Emphasis should be placed on choosing suitable concrete mixtures with aggregates that are reasonably spherical or cubical in shape to minimize differences. For large returns, or situations where it is necessary to minimize variations in appearance between adjacent surfaces, concrete mixtures should be selected where the aggregate gradation can be uniformly controlled and preferably fully graded. Exposures on returns should be medium to deep, and color differences between the ingredients of the mixture should be minimal.

The color of any concrete product can be expected to change to some degree over time. Atmospheric pollution and any accumulated grime or soot will darken the surface. These effects can be controlled by producing well-detailed precast concrete units with high-quality concrete. Just like all material surfaces left in the open, precast concrete occasionally must be cleaned to remove pollutants and restore color. Efflorescence may occur randomly on the product surface during its first several years of exposure. This can cause it to look faded or lighter in color if not cleaned off. After years of exposure, the cement paste may erode from the surface depending on environmental conditions, such as acid

rain. This will expose more fine aggregate and shift the color of the concrete to the color of the aggregate.

The sample's appearance should be assessed during both wet and dry weather. White concrete usually produces less of a difference in tone between wet and dry panels. In climates with intermittent dry and wet conditions, drying-out periods may produce temporary mottled appearances in all-gray cement façades, particularly on fine-textured surfaces. On the other hand, dirt (or weathering) normally will be less objectionable in gray panels.

Although material and production factors may cause differences in color or texture, lack of uniformity will be minimized if the following recommendations are followed. These include creating pre-bid samples to establish the general color and texture for the project, producing approval samples after the contract award to evaluate the same mixture under sample production conditions, producing 4 × 4 ft (1.2 × 1.2 m) sample panels to show the range of anticipated color and texture variations, and viewing initial production panels to see the final outcome of the process based on bulk ordering of currently quarried materials and full scale production operations.

Achieving the desired textures and colors with feasible production techniques is a process that requires the precaster to produce samples that satisfy the architect's design concepts. This may be accomplished by producing a few samples, or it may require a series of samples integrating the development of corresponding production and finishing techniques.

The use of a separate concrete face mixture and a subsequent backup concrete or the use of a uniform concrete mixture throughout a unit depends on the practice of the particular plant and the configuration of the unit. The choice on the use of backup mixes should be left to the precaster.The face mixtures contain specific decorative aggregates, often in combination with white portland cement and pigment and are specially designed to achieve the desired surface appearance. Backup mixtures are composed of inexpensive aggregates and gray cement, thus reducing material costs in large units with decorative face mixtures. A face mixture will be used for the full thickness when the material savings do not warrant the added costs of working with two mixtures.

The drafts required for finish consideration are a function of the shape of the panel, the specified stripping strength of the concrete, production techniques, and the desire for long-term durability. The architect is urged to consult local precasters for specific recommendations, particularly at openings where windows, doors, or louvers will be mounted. At areas where negative draft is required, it may be necessary to incorporate slip blocks (removable plugs) to aid in stripping the precast concrete panel from the mold. Vertical sides or reverse (negative) drafts will create entrapped air voids, which, if exposed, may be

objectionable. Remediating these surface blemishes will incur extra cost. Mold and production costs also increase with negative draft because a slip block must be incorporated with the side rail and removed with each panel during stripping or the side rail must be removed in order to strip the panel. When the side rail is removed, dimensional tolerance becomes a daily variable. Before requiring a negative draft on the top of a parapet panel, consideration needs to be given to the roofing or flashing details required for the parapet and the finish. In general, the greater the positive draft the architect can allow, the more economical and uniform the finish. A compromise may be required between the finish and the shape of a precast concrete unit.

Reveals and Demarcation Features

A reveal or demarcation feature is a groove or a step in a panel face generally used to create a desired architectural effect, or separating finishes or concrete mixtures. Another name for it is rustication or false joint. Reveals can take vertical, horizontal, diagonal, or curved forms, as well as any combination of these, and there may be several bands of them on a building. They can be narrow and delicate or deep, wide, and bold; they can offer a rectangular profile or take on any sectional shape desired, such as concave or triangular.

Reveals can be much more than a joint or line of demarcation between textures or finishes. Designing reveals in varying shapes, sizes, and depths for a precast concrete wall can transform what initially might be considered a mundane, solid surface into a rich texture of shade and shadow, bringing visual interest to the building's façade. Used effectively to create shadow lines, reveals offer the simplest way to reduce or change the building's apparent visual scale or to keep the visual appearance from focusing on any differences that may occur in texture or coloration between panels. Reveals typically measure ½ to $^{3}/_{4}$ in. (13 to 19 mm) deep and $^{3}/_{4}$ to 4 in. (19 to 100 mm) wide, with 45° to 75° beveled surfaces allowing for ease of stripping, usually $^{1/}_{16}$ in. (1.6 mm) taper per $^{1}/_{4}$ in. (6.3 mm). Designers can increase the draft to articulate and manipulate the way the reveal or panel joint is perceived.

Reveals typically are designed where there are changes in the precast concrete's surface. For example, a shift in the panel's finish from smooth to textured can be emphasized using a reveal at the point where the surface texture changes. Reveals also work well where fundamental materials change within a precast concrete panel, such as from an exposed-aggregate finish to a non-exposed-aggregate finish. Reveals allow a crisp, clean transition between these different textures, finishes, colors, or profiles within a panel.

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Review the learning objectives below.

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Complete the online test. You will need to answer at least 80% of the questions correctly to receive the 1.0 HSW Learning Units associated with this educational program.

Learning Objectives:

1. Explain the finish options of precast concrete.
2. Describe the methods used to achieve color, form and texture for precast concrete finishes.
3. Explain how clay products and natural stones can be veneered to precast concrete to speed construction.
4. Describe what composite casting is, it's advantages and the next time to use it.

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