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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

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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 expectations 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 downface 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.

Sculpturing

Today, buildings are more sculptural in form. There is greater freedom in the design of the façade. Volumes, surfaces, lines, and difference in planes are becoming increasingly important in providing architectural interest. Designers are conceiving of form organically, generating fluid surfaces in place of rigid structures. Design focuses on space, structure, and proportion. Architectural precast concrete provides the designer with virtually complete sculptural freedom and flexibility in shaping concrete into an articulated structure. Concrete shapes are not limited to volumes enclosed within plane surfaces; they may also be radiused or rounded.Sculptured panels can produce building façades with distinctive, strongly modeled elevations having flat interior wall surfaces. High and low relief, straight-line geometric patterns, and practically any free-form shapes are possible. The light and shadow effect achieved by sculpting the exterior surface produces the major visual effect of precast concrete units. Textures and colors are only of secondary importance when a building is viewed in its entirety or from a distance.

The visual impact made by the relief sculpture depends mainly on two factors: profile and lighting. The profile or cross-section should consist of strong elements with edges that produce well-defined highlights and shadows. Surfaces that flow smoothly into each other should be avoided. A bold treatment is most effective with subtle or gradual changes in the profile. These limitations are very important for the cross-section, but do not apply to the front or elevation view of the design. If it is possible to control lighting, make sure it plays across the relief from the side rather than straight from the front.

Relief sculpture can be enhanced by contrasting surfaces on projecting elements with textures on the background.The viewing distance of the surface should be considered when deciding on the scale of the relief. As a rough guide, design elements smaller than about $^{1}/_{300}$ of the viewing distance are difficult to "read" and tend to get visually lost in their surroundings.

Bullnoses

The bullnose offers a useful tool with which architects can increase visual interest by adding dimensionality and allowing the design to avoid simple flat surfaces. Three-dimensional pieces that extend from a flat surface change the reading and proportion of that surface. The light and shadow variations achieved with a bullnose produce a major visual impact and contrast when a building is viewed from a distance. Also, shadows cast by a horizontal bullnose profile create strong lines that reduce the apparent height of the structure.

Cornices and Eyebrows

A cornice consists of a horizontally projecting overhang comprising multiple surfaces, planes, and profiles with thousands of variations. It usually is located along a parapet or at the top of a given plane. The cornice crowns or finishes the part to which it is affixed.

A cornice, as an element of the façade, has three primary functions:

- It provides "the termination" of the vertical spread of the building. It's the top, pure and simple.
- It provides a balance and proportion to the entire façade, acting as a counterweight to the aesthetically heavier base of the building.
- When cantilevered 12 to 24 in. (300 to 600 mm) away from the plane of the main façade, the cornice serves a function, acting as a rain shield for the lower floors and helping to minimize dirt streaking and water stains.

When used as a horizontal projecting element that is not situated at the building's top, the traditional cornice-shaped element becomes an "eyebrow" or "shelf" offering additional aesthetic proportion and definition to the entire façade. If one believes that buildings encompass the three basic parts of base, middle, and top, these eyebrows can define the transition from one part to another or provide the transition from one type of building element to another, such as with articulated column capitals.

Edges, Corners, and Returns

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.

All edges of precast concrete units should be designed with a reasonable radius, chamfer, or quirk, rather than leaving them as sharp corners. This is particularly important where the panels are close to pedestrian or vehicular traffic. The treatment of building corners, as well as smaller-scale, building-component corners, is critical to the final perception of the architecture. The corners are focal points where wall planes and materials change or continue. The corners outline and define the form of the building and the corners are where the light falling on the surfaces of the façade transitions dramatically. The size of the edge's radius should be discussed with the local precaster. Determining the optimum size depends on the selected aggregate size, mold materials, and production techniques. When the edge is sharp, only fine aggregate collects in these locations and this weakens the edge. Voids also occur due to the interference of larger aggregate. Sharp corners chip easily, both during handling and during service on the finished building. Chamfered or radius edges reduce edge damage and also mask minor alignment irregularities of the precast concrete panels.

Returns in Relation to Finishes

The precast concrete unit's finish should be considered before its shape is finalized. Many finishes cannot be achieved with equal visual quality on all faces of the unit. Any portion of a panel cast in a vertical position (relative to its position in the form) will not show the same concentration or positioning of aggregate as the flat surface (face down in form). Panels with large or steep returns may be cast in separate pieces (the two-stage or sequential production technique) in order to achieve matching high-quality finishes on all exposed faces, and then joined with dry joints. This method of casting enables all faces to be cast face-down with the same aggregate orientation and concrete density using conventional precast concrete forming methods.

Sculptured panels may have visible air voids on the returns that become accentuated when the surface is finished. Normally, smooth finishes also will have air voids on return surfaces. If air holes are of a reasonable size ($^1/_8$ to $^1/_4$ in. [3 to 6 mm]), it is recommended that they be accepted as part of the texture. Filling and sack-rubbing will eliminate the voids, but this method is expensive and may cause color differences with adjoining surfaces.

Colors and Textures

Architectural precast concrete can be cast in almost any color, form, or texture to meet aesthetic and functional requirements of the designer in an economical manner. Complementary combinations of color and texture can aesthetically improve any project.Design flexibility is possible in both color and texture of precast concrete by varying aggregate and matrix color, size of aggregates, finishing processes, and depth of aggregate exposure. Combining color with texture accentuates the natural beauty of aggregates. Aggregate colors range from white to pastel to red, black, and green. Natural gravels provide a wide range of rich warm earth colors, as well as shades of gray.

Specifying color and texture in precast concrete is not a difficult, laborious, or seemingly impossible task. Fortunately, there is a resource available to the specifier that can make this task easy when the specifier does not have a sample to match. It is PCI's ***Architectural Precast Concrete: Color and Texture Selection Guide***, 2nd Edition**.** The guide was specifically developed as a starting point for the selection of color and texture. It contains several hundred images of architectural precast concrete colors and textures, as well as their associated mixture materials. PCI's ***Color and Texture Selection Guide*** is available for viewing at www.pci.org.

Color, and consequently color tone, represent relative values. They are not absolute and constant, but are affected by light and shadow, intensity, time, and other surrounding or nearby light-reflecting colors. A concrete surface, for instance, with deep-exposed opaque white quartz appears slightly gray. This is due to the shadows between the particles blending with the actual color of the aggregate and producing the graying effect. These shadows in turn affect the color tone of the matrix.

Similarly, a smooth concrete surface will change in tone when striated. Also a white precast concrete window unit with deep mullions will change tone when bronze-colored glass is installed. Color tone is constantly changing as the sun traverses the sky. A clear sky or one that is overcast will make a difference, as will landscaping and time. In large city and industrial environments, air pollution may cause color tone to change.

Color selection should be made under lighting conditions similar to those where the precast concrete will be used, such as the strong light and shadows of natural daylight. Muted colors usually look best in subdued northern light. In climates with strong sunlight, much stronger and brighter colors are used with success.

Surface texture also affects color. A matte finish will result in a different panel color than does a smooth finish. Texture helps to determine the visual importance of a wall and, hence, the color. For example, moderately rough finishes usually are less obtrusive than shiny surfaces.

Matrix color (cement plus pigment) exerts the primary color influence on a smooth finish because it coats the exposed concrete surface. As the concrete surface is progressively removed and the aggregates are exposed, the panel color increasingly reflects the fine and coarse aggregate colors. Nevertheless, the matrix color always has an effect on the general tone of the panel.

Different combinations of gray cement, white cement, pigments, and aggregates offer an extensive range of possible color combinations. If gray is the desired color of the matrix and the optimum uniformity is essential, a mixture of white and gray or white cement with gray pigment is recommended. Uniformity normally increases with increasing percentages of white cement, but the gray color remains dominant. White portland cement must be used to create light pastel shades such as buff, cream, ivory, pale pink, and rose tones, as well as bright intense yellows, oranges, and reds. Tan, black, dark gray, some reds, and other hues are produced very satisfactorily using gray cement.

Coarse aggregates should be reasonably uniform in color. In general, a light-colored aggregate is preferable to avoid shaded or toned areas. Light and dark coarse aggregates require care in blending to provide color uniformity within a single unit. With a small color difference between the light and dark aggregates and a small variance in total amounts of each aggregate, the chances of uniformity are enhanced. It is advisable to match the color or tone of matrix to that of the coarse aggregate so that minor segregation of the aggregate will not be noticeable. Panels containing aggregates and matrices of contrasting colors will appear less uniform than those containing materials of similar colors.

Some finishing processes change the appearance of aggregates. Sandblasting will frost aggregates, while acid etching may increase their brightness. A bushhammered finish will give a similar appearance to sandblasting without dulling the aggregates. Exposure by retardation normally leaves the aggregates unchanged. The method of exposing aggregate alters the color of the surface by affecting the color of the aggregate and by the amount of shadow cast by the exposed particles.

Textures

Textures allow the nature of the concrete ingredients to be expressed, provide some scale to the mass, express the plasticity of the concrete, and improve its weathering characteristics. A wide variety of textures is possible, ranging from a honed or polished surface to a deeply exposed one.

The surface finish enhances the character of the building by contributing a presence to complement the building aesthetics. However, a small, solitary concrete sample can mislead the architect in the value of a finish compared to its appearance when viewed in the building scale from a distance.

As a general rule, a textured surface is more aesthetically pleasing (greater apparent uniformity) than a smooth as-cast finish. The surface highlights and the shadings of aggregate color camouflage subtle differences in texture and color of the concrete. Also, any damage is more easily repaired on textured surfaces than on smooth or acid-etched finishes.

A texture may be defined, in comparison with a smooth surface, as an overall surface pattern. The range of textured finishes for architectural precast concrete includes the characteristic imprint or patterns created from a form liner or mold. Typical textured finishes may be produced by removing the surface mortar to expose the coarse aggregate in the mixture by various methods.

A profile may be defined, in comparison with a flat surface, as a shape rather than a texture, produced from a specially made mold or form liner.

Profiled surfaces can be either smooth or textured, in a similar way flat surfaces can be either smooth or textured. This gives four possible combinations. It is also possible for part of a panel to be given more than one finish. This design feature allows for a wide range of appearance options.

There are four important factors to be considered in choosing a texture:

1. **The area of the surface.** This affects the scale of the texture. Coarse textures usually cannot be used effectively for small areas. Dividing large, flat areas or surfaces into smaller ones by means of rustications tends to deemphasize variations in textures.

2. **The desired effect at a viewing distance.** The designer may seek a visually pronounced texture or may use texture as a means to achieve a particular tone value. The visual effect desired at the normal viewing distance influences the texture and size of aggregate chosen for the panel face.

3. **The orientation of the building wall elevation.** This determines the amount and direction of light on the surface and how the panel will weather.

4. **Aggregate particle shape and surface characteristics.** For exposed-aggregate textures, the aggregate particles may be rounded, irregular, angular, or flat. Their surfaces may be glossy, smooth, granular, crystalline, pitted, or porous. Both the shape and surface characteristics determine how the surface will weather and reflect light.

In addition to the visual effect of texture within reasonable distances, textures may be used to achieve colors based on the natural colors of the exposed aggregates and matrix.

The size of the aggregate should be related to the configuration of the panels. The larger the aggregate, the more difficult it will be to detail edges, reveals, and returns.

Exposed-aggregate finishes are popular because they are reasonable in cost and provide an infinite variety of colors and textures. This is achieved by varying the type, color, and size of aggregate, color of matrix, method of exposure, and depth of exposure.

The different degrees of exposure are:

> **Light Exposure** — where the surface skin of cement and some sand is removed, just sufficiently to expose the edges of the closest coarse aggregate. This imparts a fine, sandy texture. Matrix color will greatly influence the overall panel color.
>
> **Medium Exposure** — where further removal of cement and sand has caused the coarse aggregate to visually appear approximately equal in area to the matrix.
>
> **Deep Exposure** — where cement and sand have been removed from the surface so that the coarse aggregate becomes the major surface feature.

The extent aggregates are exposed or "revealed" is largely determined by their size. Exposure 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.

Finishes

General

The appropriate finish should be carefully chosen and clearly specified. The designer should base the final choice of surface finish on a balance between appearance (uniformity of color and texture) and cost with consideration of the limitations in materials and production techniques. The appearance can be judged using a combination of samples and reduced-scale or full-scale mockups. These samples or mockup panels can then be made available at the precast concrete plant so that all concerned can be assured that standards of finish and exposure are being maintained. The appearance, colors, and textures of the surface finishes of all units should match within the acceptable range of the colors, textures, and general appearance of the approved sample panels and range samples.

During the manufacturing process different panels may be subjected to varying levels of ambient humidity. Initially, tonal variations in color might be considered unsatisfactory, but are likely to moderate when the panels have aged and have a balanced moisture content.

Generally speaking, if two different colored aggregates are contemplated, the difference in appearance (colors) should not be too prominent, and similarly, the color difference between aggregates and matrix should also be weighed against the practicality of obtaining a uniform appearance.

Smooth As-Cast

A smooth as-cast finish shows the natural look of the concrete without trying to simulate any other building product. Fine surface details and sharp arrises can be achieved with a smooth finish. This finish is perhaps the most difficult to produce. When a high level of color uniformity is required, its use is strongly discouraged. There is also the question of how the surface will change when exposed to the weather. Smooth surfaces tend to weather unevenly and become discolored from rainwater and airborne particles.

Color variations tend to be most pronounced when the mold face is glassy and impermeable. While a rough concrete surface will scatter reflected light and soften the impact of blemishes, a smooth surface will make variations more conspicuous. Color uniformity is difficult to achieve on gray, buff, and pigmented concrete surfaces. The use of white cement yields better color uniformity than gray cement. Allowable color variation in the gray cement is readily apparent on the uninterrupted surfaces of smooth off-the-mold concrete, and any variation is likely to be regarded as a surface blemish.

Smooth, as-cast precast concrete panels usually have some surface imperfections. Minor variations in texture of mold surface reflected on the smooth concrete surface, color variations, air voids (bug/blow holes), and minor surface crazing and blotchiness are to be expected, especially on non-profiled flat panels. Of all precast concrete finishes, this finish is the most misunderstood when it comes to acceptability. An acceptable smooth finish can be very difficult and expensive to achieve if a high degree of uniformity is anticipated by the architect or owner. If the surface is to be painted or stained, this finish will provide an excellent surface, while keeping costs to a minimum.

Many of the aesthetic limitations of smooth concrete may be minimized by the shadowing and depth provided by profiled surfaces (fluted, sculptured, board finishes, etc.), by subdividing the panels into smaller surface areas by means of vertical and horizontal reveals or rustications, or by using white cement. Any introduction of shapes to provide shadow effects will also enhance the final finish.

Exposed Aggregate by Chemical Retarders and Water Washing

If the bright, natural colors of the aggregate are the prime concern, exposed aggregate from retarded surfaces is the best way to achieve this result. The mixture proportions, aggregate gradation and physical characteristics of the aggregate, and matrix/aggregate color compatibility are important. It is advisable to vary the color or tone of the matrix wherever possible to match or blend in with the color of the aggregate. This match can be achieved by careful selection of cement, sand, and pigment colors. A good matrix-to-coarse-aggregate color match will minimize mottled effects (minor variation in aggregate distribution) from being noticeable. Mixtures should be designed to contain significantly more coarse aggregate than normal mixes.

Chemical retarders may be used for all three degrees of exposure, but they are most commonly used for medium or deep exposure.

Form Liners

Concrete's plasticity offers the opportunity for innovation and individual character in the surface textures, patterns, and shapes, which can be achieved by casting against the various types of form liners. A large pattern offers ever-changing details due to the play of light and shadow. A fine texture offers a muted appearance that is subtle but not drab. Smooth surfaces bring out the elegance and richness of simplicity. Form liner textured surfaces also mask minor imperfections that would otherwise be obvious in a smooth as-cast surface, yielding a more uniform appearance.

Light and shade created by modeling or sculpturing with liners may be used for visual effect to enliven large concrete surfaces with low relief patterns. The options with combination finishes, involving one or more basic finishing methods together with form liners, are almost infinite. Innovative patterns and designs can now be achieved by utilizing a combination of CAD and CNC machining to produce custom form liners.

An important consideration is selecting the texture and/or type of form liner best suited to the project. If there are large wall expanses, a texture like fractured fin with greater depth may give a more noticeable appearance with deeper shadowing. Shallow flutes, bushhammered, or subtle textures are often better for relatively small areas. When shallow patterns are used over large areas, subtle imperfections in the liner can give a mottled effect on the finished panel. Concrete can be produced with vertical ribs or striations in a range of sizes to suit a particular structure and the distance from which it will most often be seen.

Sand or Abrasive Blasting

Sand or abrasive blasting of surfaces can provide all three degrees of exposure. Different shadings and, to some extent, color tone will vary with the degree of aggregate exposure.

A light blast will emphasize visible defects, particularly bugholes, and reveal defects previously hidden by the surface skin of the concrete. A light blast does minimize crazing by removing the cement skin at the surface of the concrete. Sculptured units may have air voids on vertical and sloped returns that might be accentuated by a light blast.

A sandblasted finish is not widely used to achieve a deep, heavy texture because of the time and labor associated with deep exposure. Unless it is the intent of the architect to achieve a severely weathered look, deep exposed-aggregate finishes are more readily achieved with other methods. For example, to obtain a medium or deep exposure with a sandblasted appearance, retarders may be used initially followed by sandblasting to obtain a matte finish. This approach reduces blasting time and lessens the abrasion of softer aggregates. Using sandblasting to achieve the final texture allows for correction of any variations in exposure, so this method can result in a more uniform surface. The end result is a matte finish, as opposed to a brighter finish achieved with traditional retarder finish.

To improve uniformity, the cement and sand colors should be chosen to blend with the slightly "bruised" color of the sandblasted coarse aggregate, as the matrix color will dominate when a light sandblast finish is desired. With a light sandblasting, only some of the coarse aggregates near the surface will be exposed. Finish uniformity is more difficult to maintain with light sandblasting. With a medium or deep exposure, contrasting matrix and coarse aggregate colors should be avoided if uniformity of color is desired.

Blasting will cause some frosting of the face of the coarse aggregate, and softer aggregates will show this to a greater extent beyond a medium exposure. Frosting of the aggregate surface is more noticeable on dark-colored aggregates that have an initial glossy surface texture. This will produce a muted or frosted effect, which tends to lighten the color and subdue the luster of the aggregate. For example, white concrete tends to become whiter when blasted. Depth of sandblasting should also be adjusted to suit the aggregate and abrasive hardness. Soft aggregates tend to erode at the same rate as the mortar. There is a tendency to round off edges of soft aggregates during sandblasting and soften sharp edges and corners.

Acid Etching

Acid etching is most commonly used for light to medium exposures with retention of detail. An acid-etched finish is typically used to produce a fine sandy texture closely resembling natural stones such as limestone or sandstone. It is often substituted for a light sandblast texturing. The aggregates on an acid-etched surface present a clean or bright look. However, after normal weathering, the aggregates lose this brightness and will closely resemble their original condition. Because of variations in surface color and texture possible in large fields, the panel surface should be broken with rustications or other details to minimize the visual effect of the variations.

When the acid etching is light or used on a large, plain surface, concentrations of cement paste, under and over etching of different parts of a concrete surface and variation in sand color or content may cause some uniformity problems. With light textures, the color compatibility of the cement and aggregates become more important to avoid a mottled effect.

There is a minimum depth of etch that is required to obtain a uniform surface. Attempts to go any lighter than this will result in a blotchy panel finish. This depth will expose sand and only the very tip of the coarse aggregate. It is difficult to achieve a totally uniform light exposure on a highly sculptured panel. This is due to the acid spray being deflected to other areas of the panel, particularly at inside corners. This may, however, be acceptable if the sculpturing creates differential shadowing.

Tooling or Bushhammering

Concrete can be mechanically spalled or chipped with a variety of hand and power tools to produce an abraded, exposed-aggregate texture. Each type of tool produces a distinctive surface effect and a unique shade of concrete color. All tooling removes a layer of hardened concrete while fracturing larger aggregates at the surface. It produces an appearance somewhat different from other types of aggregate exposure. The color of the aggregate, but not necessarily the aggregate shape, is revealed. The finish obtained can vary from light scaling to deep bold texture. Because of the large amount of labor required to achieve a tooled finish, this method can become quite costly.

Tooled finishes affect the appearance, color, and brightness of the aggregate. Color tends to be lightened by the fracturing, which on dark materials has a dulling effect, but it often improves the light grayish and, in particular, white tones. By increasing or decreasing the shadow content of the texture, tooling alters the panel reflectancy and changes the tone value.

Bushhammering at outside corners may cause jagged edges. If sharp corners are desired, bushhammering should be held back from the corner a distance of 1 to 2 in. (25 to 50 mm) or more. It is quite feasible to execute tooling along specific lines. If areas near corners are to be tooled, this usually is done by hand. Chamfered corners are preferred with tooled surfaces.

A hammered rib or fractured fin finish may be produced by casting ribs on the surface of the panels and then using a hammer or bushhammer tool to break the ribs. The effect is a bold and deep texture. Uniformity of cleavage may be obtained by alternately striking opposite sides of the flute or rib. This finish is expensive but may be justified if the panels will be viewed at close hand such as for ground-level walls and interior walls. On upper walls a similar effect may be achieved at much less cost by retarding or sandblasting the ribs. Also, a simulated fractured fin finish may be obtained with form liners. Specifications for uniformity or non-uniformity of tooled finishes are extremely difficult to write and assistance should be sought from the precaster who is providing the tooled finish being specified.

Clay Product-Faced Precast Concrete

Clay product-faced precast concrete is being used increasingly as another choice to obtain an aesthetic façade while blending in with surrounding structures. It gives the architect the flexibility to combine the visual appearance of traditional clay products with the strength, versatility and economy of precast concrete. Among the types of materials that can be embedded in precast concrete are brick, ceramic tile, porcelain and architectural terra cotta. These clay product-facings may cover the entire exposed panel surface or only part of the concrete face, creating accents.

Precasting techniques allow complex and intricate details such as arches, radii, ornate corbels, and numerous bonding patterns to be incorporated into the finished panel. This freedom of aesthetic expression cannot be achieved economically with site-laid-up masonry. Precasting also allows a high level of dimensional precision and quality control. Concrete mixtures and batching, together with curing conditions, can be tightly controlled, whereas site-laid masonry may have variable curing and mortar qualities.

The height and length of the panels should be multiples of nominal individual masonry unit heights and lengths for effective cost control in the precast concrete production process. The actual specified dimensions may be less than the required nominal dimensions by the thickness of one mortar joint. For economical production, the precaster should be able to use uniform and even coursing without cutting any units vertically or horizontally except as necessary for precast panel joints and bond patterns. The PCI Standard for embedded brick in precast concrete panels should be specified to ensure size uniformity, long term durability, and material compatibility.

The appearance of clay product-faced precast concrete panels is achieved principally by the selected clay product, with type, size, and texture contributing to overall color. Also, the degree to which the clay product units are emphasized will depend upon the profile and color of the joint between units. Both stack and running bond patterns have been used widely in precast concrete panels. These patterns can be interchanged with soldier courses, basket weave, or herringbone patterns. Running bond patterns are typically less costly and visually more appealing when courses start and finish with half or full brick.

Variations in brick or tile color will occur within and between production runs. The clay product supplier must preblend any color variations and provide units that fall within the color range specified and are approved by the architect. Defects such as chips, spalls, face score lines and cracks should be culled from the bulk of acceptable units by the clay product supplier according to the architect's requirements and in accordance with applicable ASTM specifications.

Stone Veneer–Faced Precast Concrete

Natural stone veneer–faced precast concrete has become widely used in building construction because of its strength, durability, aesthetic effect, availability, and inherent low-maintenance costs.

The purchaser of the stone should appoint a qualified individual to be responsible for coordination, which includes delivery and scheduling responsibility and ensuring color uniformity. Color control or blending for uniformity should take place at the stone fabricator's plant, because ranges of color and shade, finishes, and markings such as veining, seams, and inclusions are easily seen during the finishing stages. Acceptable stone color should be judged for an entire building elevation rather than as individual panels. The responsibility for stone coordination should be written into the specifications so it can be priced. The owner, architect, and/or stone purchaser should visit the stone fabricator's plant to view the stone veneer and establish criteria and methods for color-range blending on the project.

Weathering

A primary consideration in the architectural design of buildings should be weathering, that is, how the appearance changes with the passage of time. Weathering affects all exposed surfaces and cannot be ignored. The action of weathering may enhance or detract from the visual appearance of a building, or may have only a slight effect. The final measure of weathering's effect is the degree to which it changes the original building appearance and distorts the designer's original intention by streaking or shading.

Visual changes occur when dirt or air pollutants combine with wind and rain to interact with the wall materials. The run-off water may become unevenly concentrated because of façade geometry and details. The manner in which water is shed off the structure depends primarily on the sectional profiles of the vertical and horizontal discontinuities such as drips and other architectural elements designed into the wall.

To prevent atmospheric pollution that, over time, discolors concrete with an uneven soot-like coating that distracts from the architecture, a self-cleaning cement is available. This photocatalytic cement with nanoparticles of titanium dioxide reacts with sunlight or ultraviolet light to trap organic and inorganic airborne pollutants in a nanoparticle matrix on their surface, then decompose them. The photocatalytic cement acts as a catalyst to accelerate natural oxidation and is not consumed in the process. The aesthetic quality of the precast concrete is thereby preserved.

Unfortunately, concrete produced with this cement will not always eliminate graffiti. Many paint suppliers are producing inks/paints with UV resistance to prevent fading, which diminishes the photocatalytic process. When the graffiti is removed the photocatalytic process will continue.

Summary

Color, form, and texture are refinements of appearance in architectural precast concrete that may be achieved, within any given budget, by choosing appropriate aggregates and textures, combined with effective production and erection details.

It is recommended that the designer seek design assistance from a local architectural precast concrete producer in the early design stages and throughout the development of the contract documents. This will provide optimum utility and quality of the product and its installation at minimum construction cost.

If unfamiliar with architectural precast concrete, prior to designing wall panels, the architect should visit an architectural precast concrete manufacturing plant, as well as any projects that are under way. This way the designer can become familiar with the manufacturing processes and installation procedures and, most importantly, establish realistic expectations for the finished product. Elements such as the fabrication of molds, challenges to casting and finishing specific designs or shapes, relative material costs, handling methods at the plant and jobsite, approaches for connecting panels to a structure, and establishing acceptable color and texture ranges are important to fully understand precast concrete and maximize its potential.

Precast concrete is a quality material whose initial plasticity is incredibly responsive to the designer's creative needs. For the owner and tenant precast concrete provides long term durability, fire resistance, sound attenuation, energy conservation and general life-safety attributes that are inherent in the material. For the viewer, a well-designed precast concrete structure can match the mood of its surroundings or create an exciting counterpoint of visual excitement.

An anonymous quote states the concept of aesthetics well. "Beauty Itself Doth of Itself Persuade the Eyes of Man Without an Orator."

For further information refer to PCI's ***Architectural Precast Concrete*** (MNL-122) and Designer's Notebooks (www.pci.org).

Ascent 2013 – Design Factors Affecting Aesthetics of Architectural Precast Concrete

About AIA Learning Units

Please visit www.pci.org/elearning to read the complete article, as well as to take the test to qualify for 1.0 HSW Learning Unit.

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Review the learning objectives below.

Read the AIA Learning Units article. Note: The complete article is avaliable at www.pci.org/elearning

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.
4. Describe what composite casting is, the advantages and when best to use it.

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