Acceptance of Architectural Precast and Architectural Cast Stone

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. 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 prior to application of water repellents or sealers. 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 also should not be evaluated when light is illuminating the surface from an extreme angle, as this tends to accentuate minor surface irregularities.

Samples of architectural precast concrete are intended to represent the materials and finish used. The concrete's color or appearance likely will vary during production, so samples showing that expected range should be required. Product appearance is influenced by factors such as quality, complexity of the casting, and physical mass, as well as the natural characteristics of the concrete ingredients..

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 and cast stone, 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, cast stone, and 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.

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 of cement 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 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.

The fineness modulus (FM) of the fine aggregates and the content of fines (particles passing a #200 [75 μm] mesh sieve) can have a significant impact on final appearance. Units made with a higher content of fines will be lighter colored due to the increased surface area of fine particles and their light-scattering characteristics. Elimination of fines, or keeping them to a minimum, will help to prevent color variations.

Chemical admixtures and pigments affect final color. They need to be added in the same amounts and in the same sequence throughout the job to avoid color variations.

Each factor discussed here affects color consistency, but daily variations in moisture content are probably the single most common cause of color consistency problems. A change in the water-cement ratio can result in color inconsistency from batch to batch.

The water-cement ratio in a concrete batch is affected by the moisture content of the raw materials, primarily the sand, and the amount of mixing water. Automatic moisture

control of the sand and adjustment of the mixing water volume for every batch help to minimize such color fluctuations.

The mixing time required to achieve complete dispersion of all materials varies from plant to plant depending on the type of mixer and the aggregates used. If pigmented concrete is not mixed long enough, the color is less intense. Also, if the concrete batching sequence s varied, color uniformity will be affected.

The color of precast concrete can vary between adjacent elements due to daily variations in the curing conditions for the concrete. The concrete and mold temperatures should remain as consistent as possible throughout the job to minimize color variations.

If a sample is stored indoors, its color will vary from product stored outdoors. Precast 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 architectural cast stone 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 precast prior to finishing offers little information. Dividing large surface areas into smaller ones with reveals or rustications also helps to lessen any variation in texture that might be visible.

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

During consolidation of wet cast products, 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, concrete mixtures should be selected where the aggregate gradation can be uniformly controlled and preferably fully graded. Exposures 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, which 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.

Some factors are outside the precaster's control:

- Changes in cement color. This is more likely to be associated with gray cements than with off-white or white because the latter are manufactured to very close color tolerances.
- Variations in curing as a result of changes in ambient temperature and humidity.
- Variations between horizontally and vertically cast units.

Although material and production factors may cause differences in color or texture, lack of uniformity will be minimized if the recommendations of this section 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 sample castings to show the range of anticipated color and texture, and viewing initial production to see the final outcome of the process based on bulk ordering of currently quarried materials and full concrete batches.