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Manufacturing Colored Concrete Masonry

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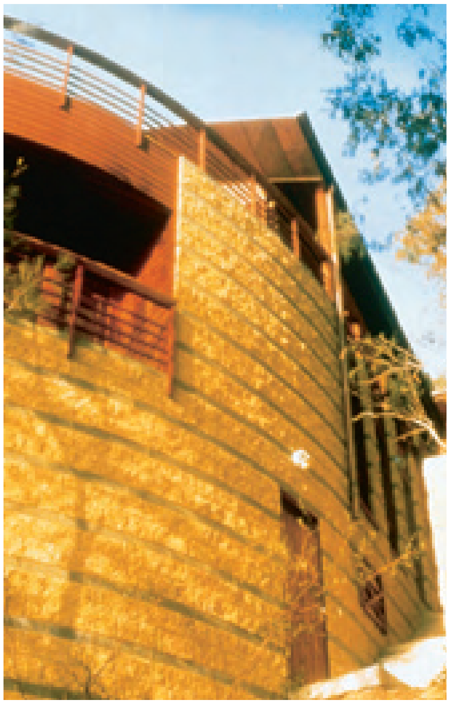
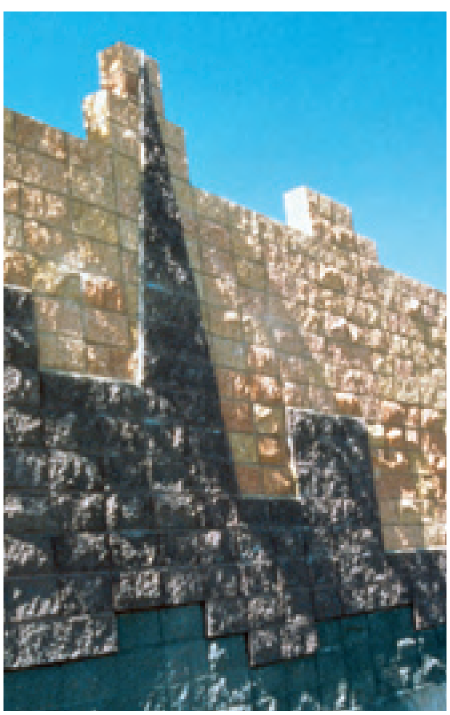
Colored Concrete Masonry



Colored units have opened new construction markets for concrete masonry products



Color is increasingly contributing to the profit and success of most concrete masonry and paver producers. Not only do colored units command higher prices, they create extra marketing opportunities. When builders and architects discover concrete blocks, pavers or retaining wall units are available in colors other than gray, they dream up new ways to use them.

While this extra versatility increases the market available to most producers, it carries the burden of meeting higher customer expectations for appearance and consistency. Meeting these expectations can be easier with an understanding of the causes of inconsistency, especially if you're new to using color or are experiencing an increase in projects demanding exposed colored architectural units.

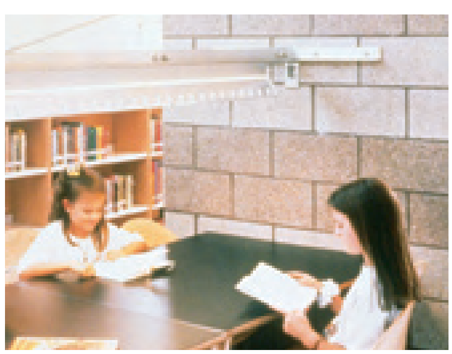
While an architect, builder or contractor can decide a manufacturer's fate with a simple visual inspection of a concrete masonry unity (CMU) wall or shipment, a producer's success depends on managing a complex set of variables, among them: raw materials, mix design, manufacturing technique, curing, weathering and, in the case of colored units, color pigment additives. This article is an introduction to the key components that impact the surface consistency of colored and uncolored CMUs.

Color Additives

The first variable to control in producing consistently colored masonry units is to eliminate any variation in the color pigment additive. Whether you use a powder, liquid or granulated form, choose a reputable supplier with a proven record for consistency and an open-door quality control policy. The color additives with the longest history of proven performance in concrete products are made from oxidized metals: iron (red, brown, orange, tan, yellow, black); chrome (green); titanium (white); and cobalt (blue). These comply with ASTM-C979 *Pigments for Integrally Colored Concrete*, a standardized test to certify pigments are water-wettable, lightfast, alkali resistant, stable under curing and will not have a detrimental effect on concrete strength or consistency when used at recommended dosage rates.

Pigments which comply with these standards can be either produced in a synthetic process or refined from naturally occurring ore deposits. The most widely used color additives are made of synthetic iron oxide. "Synthetic" refers to the wet process of precipitating yellow or black iron oxide (rust) from cast iron, steel or ferrous salts in large reacting tanks, drying and grinding it into an extremely fine powder and packaging it for sale. Red iron oxide is made by roasting yellow or black or by direct precipitation.

Liquid color is made by mixing powdered or semi-dried iron oxide with 30 to 40 percent water, surfactants and stabilizers to form a "suspension." Granules are made by mixing a binder and dispersant with the liquid color and spray-drying the mixture. Both liquid and granule color



Mineral oxide pigments for concrete are available in a wide spectrum of colors.

forms offer improved housekeeping versus powdered iron oxide, but powder holds the edge in economy of use.

Pigments made of carbon black are inexpensive, have extremly high tinting power and comply with ASTM-C979 but are not recommended for coloring masonry products. Black or brown pigments containing carbon black can fade or discolor significantly when exposed to weathering.

A spectrum of color hues and shades can be created by utilizing different base pigments or increasing or decreasing the amount of pigment or the amount of cement in the batch. The amount of pigment added is usually expressed as a percentage (by weight) of the batch cement content. Cement, pigment, admixtures, pozzolans or silica fume, if used, must be measured into the mix accurately. Water metering must be accurate as well.

Color reaches a saturation point when increasing the dosage rate fails to make an appreciable difference in the color intensity of the final product (see photo 4), Pigments with high tint strength reach saturation at a lower dosage rate. Black iron oxide has the highest tint strength, generally achieving saturation at 6 percent dosage. Brown has a slightly lower tint strength, leveling -off at approximately 7 percent dosage, followed by 8 percent for red and 9 percent for yellow. ASTM C979 permits dosage rates up to 10 percent at which point strength can be affected due to the displacement of cement. Most color suppliers avoid recommending dosage rates above 7 percent.

Quality control practice within the pigment industry is to classify “within standard” lots that may vary +/- 5 percent in color from the manufacturer’s reference standard using spectrophotographic measurements. A few color suppliers adhere to a +/- 1 percent standard. These are tight tolerances considering uncolored concrete blocks measured with unit-to-unit variations of up to 15 percent are often acceptable for most applications. The Cast Stone Institute has established a standard which allows the color of concrete to deviate a maximum of 5 percent unless specified lower and follows an ASTM D2244 test method to certify architectural precast panels. A 5 percent color variation is less than would be seen in natural cut limestone, but more than would be encountered with high-quality, sandblasted architectural precast panels.

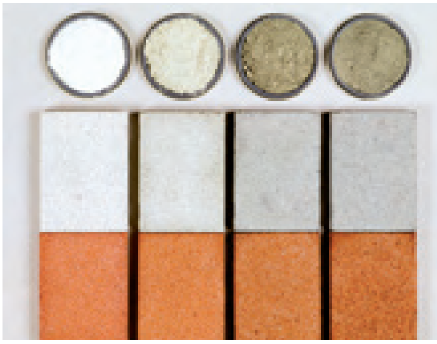
1. Adding water to a concrete mix tends to lighten the concrete and produce a paler color. The darker samples have a 0.37 water-cement ratio; the lighter samples have a 0.49 ratio.

A recent trend in the color industry is the adoption of standards for quantifying color hue, shade and intensity with computerized measuring instruments. These instruments utilize CIELAB or CMC computer software to compare light reflected off color samples prepared in a constant method to a calibrated reference standard. The software produces a printout that shows values for light vs. dark, green vs. red, blue vs. yellow, chroma (saturation) and hue. Multiple differences in each of these five measures are converted into a single “Delta” values are combined into one value called “Delta E.” Most color suppliers evaluate a combination of Delta values in addition to visual inspections before approving a pigment batch for sale. Many can provide certificates for colors that conform to a Delta value of 1.0 or less, well below perception by the human eye when mixed into concrete.

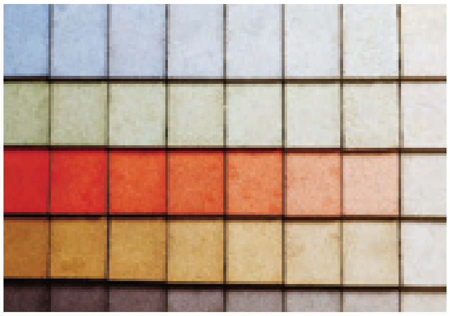
Raw Materials

Cement color is the second most important variable impacting final product appearance. (see photo 3) Cement’s coloring effect is especially important for uncolored units and colored ones made with low pigment dosage rates, such as light buff shades. Cement manufacturers have recognized the effect that variations have on appearance. Many offer “Cement

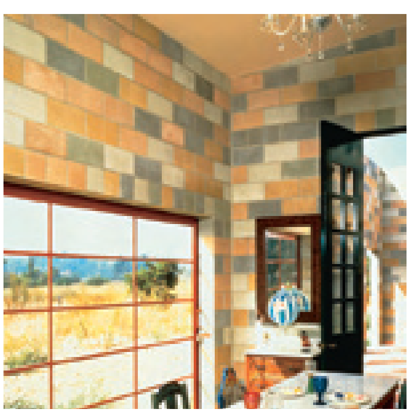
2. Unpigmented CMUs from around the U.S. show the range of colors found in plain gray concrete. Color variations are due to the cement color, mix, ingredient water-cement ratio, surface texture, and manufacturing and curing techniques used by different producers. These variables also affect colored CMU and must be considered when selecting pigments and dosage rates.



3. Variations in portland cement color affect CMU appearance. The gray samples are unpigmented; the red samples contain the same pigment dosage rate, but vary in appearance due to cement colors.



4. These samples have pigment dosage rates (weight of pigment to weight of cement) of 0, 1, 3, 7 and 10 percent (left to right). Note how the change in color between 7 and 10 percent is minimal, indicating that the pigments are approaching their saturation point.



Mill Certificates" for each shipment with values for Blaine, color and reflectance. A responsive cement supplier will give notice of a chemistry or source change and provide ASTM C917 reports. As part of a complete quality program, monitor incoming shipments, retain samples and the certificates. A variation of +/- 3 percent in reflectance will produce a noticeable difference in final concrete color. Cement with higher reflectance values will produce lighter, more vivid color.

While not as critical as cement, a substantial change in aggregate color can make a noticeable difference in final color. Even minor changes in aggregate color will be readily apparent in split-face or ground-face units. Variations in aggregate water content can affect the mix water-cement ratio.

The fineness modulus (FM) of fine aggregates as well as the content of fines (particles passing a #200 mesh sieve) can have significant effect on final appearance. Masonry products made with higher content of fines will be lighter colored due to the increased surface area of fine particles and their light-scattering characteristics. Request sieve analysis reports from your fine aggregate supplier to help determine an acceptable range of variation in these materials.

Mixing and Production

A constant water-cement ratio is important for achieving uniform color and surface texture. High water-cement ratios produce masonry units rich in cement paste at the surface. This produces a smoother, more reflective surface and lighter color units. But don't add too much water; high water-cement ratios can decrease strength and make the surface too creamy and thus unable to withstand erosion. Low water-cement ratios produce darker, coarse-textured units. Changes in water-cement ratio impact color shade (see photo 1). Manufacturers should inspect moisture probes or metering systems on a regular basis to ensure an accurate amount of water is added to each batch.

Plasticizing or densifying chemical admixtures are often used to create smoother, more reflective surfaces at normal water-cement ratios. Some also improve strength, reduce absorption or brighten colors. When evaluating a new admixture or altering the dosage rate of one currently in use, be sure to record these changes and monitor the effect they may have on product appearance.

The order in which batch materials are placed into the mixer can affect how pigments disperse through the batch. The following sequences have been found to be effective:

Typical Batching Sequences for Dry and Granulated Colors

Aggregate + pigment (pre-mix 30 seconds) + cement + water

Aggregate + cement + pigment + water

Aggregate (pre-wet) + pigment + cement + final water

Typical Batching Sequences for Liquid Colors

Aggregate + liquid color (pre-mix 30 seconds) + cement + water

Aggregate + cement + 80 to 90 percent batch water + liquid color + final water

Adding pigments to the mix with fine and coarse aggregate and mixing for a short time before adding cement and water will speed full dispersion. The time required to achieve full dispersion varies from plant to plant depending upon the type of mixer and aggregates used. Incomplete dispersion may result in streaks of color on the surface of units or excess pigment consumption. To eliminate these conditions, adjust mixing time or sequence.

Monitor and record manufacturing equipment settings. A variance in vibration or compaction times may change the texture of the surface enough to cause a variation in the color appearance. Once a satisfactory manufacturing process is established, a continuous effort should be made to maintain consistent procedures from batch-to-batch.

Curing and Weatherability

It is important to minimize sources of inconsistency in curing operations. Keep humidity levels in curing chambers consistent from day-to-day and from room-to-room. Maintain curing equipment and rooms in good repair to obtain the best results. Good air circulation can help to improve color consistency between units in the same chamber by reducing condensation of water on CMU surfaces.

Longer pre-set times will yield darker colored units than those produced with shorter pre-sets. Three to four hour pre-set times are generally preferred.

Steam curing and autoclaving produce very light colored masonry products. This is the result of the growth of many small crystals during cement hydration. These small crystals increase the light scattering characteristics of the cement paste and yield a lighter surface appearance. Air curing or curing at lower temperatures produces crystals larger in size, but fewer in number. The result is less light scattering and a darker product.

High quality concrete pigments exhibit excellent durability when exposed to sunlight and water. However, the surface of any masonry product can be expected to change in time due to factors which are beyond the control of the manufacturer. Efflorescence may bloom 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. This will expose more fine aggregate and shift the appearance to the color of the aggregate. In time, portland cement itself yellows although this effect is masked somewhat in colored units.

It may seem impossible to completely eliminate all the variables which can impact the uniformity of concrete masonry products. In reality, significant improvements in consistency can be made by simply narrowing the range of variations that occur and by paying particular attention to the accuracy of scales and metering systems. Raw material variations can have an impact on product strength and long term durability. In addition, inconsistent appearance in uncolored as well as colored units may be an indication that product quality could be suffering or raw materials are being wasted. Optimizing product consistency is a goal that should be considered as part of every overall quality program, even for uncolored CMU production.

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