Photos courtesy Butterfield Color

Creating Colorful Concrete

How to design for durability and aesthetics

by Howard Jancy, CSI, CDT

The addition of color, texture, and/or pattern to new or existing concrete has gained significant acceptance by design professionals and their clients. With the evolution of materials and processes, along with the talent to install architectural treatments, concrete is no longer viewed as just a structural building material, but also as a creative medium suitable for flatwork installations such as residential and commercial hardscapes, natural-looking and artistic floors, and even custom countertops. Durable and attractive installations are ensured if the basics of selecting, specifying, and handling architecturally enhanced concrete are fully understood.

Product and color selection

Generally, manufacturers provide a different color chart for each product. Although there may be comparable hues among coloring systems, each has its own distinct palette and attributes, often dictating which product to use.

Integral color

This coloring system encompasses subtly muted earth tones. It is based on synthetic oxides for ultraviolet (UV) stability and conforms to ASTM International C 979, *Standard Specification for Pigments for Integrally Colored Concrete.*

Integral color is typically added to ready-mixed concrete with gray portland cement. Green and blue, as well as lighter colors, may require white portland cement, which substantially increases the cost of the colored concrete. However, lighter colors are generally less expensive than darker shades when based on gray portland cement.

Shake-on color hardener

Shake-on color hardener comes in light colors, rich hues, and select greens and blues that may be cost-prohibitive as an integral color. Topically applied and finished over fresh horizontal concrete, this system is a prepackaged blend of synthetic oxides, graded silica quartz aggregate, and portland cement. Shake-on color hardener also lends wear-resistance to the surface.

Chemically reactive stains

Including a limited range of translucent, variegated, and mottled earth tones, chemically reactive stains consist of metallic salts in an acidic solution that react with the calcium hydroxide formed as cement hydrates. These stains are applied to hardened concrete and cementitious overlays, with surface preparation being important.

This residential floor has been chemically stained with dark brown, amber, and yellowish green colors. The pattern was cut using a 102-mm (4-in.) diamond blade on an angle grinder, typically 3.2 mm (0.125 in.) deep. Saw cuts prevent the different colors from bleeding together.

Green and blue stains are only suitable for interior use, as they may oxidize when exposed to water from rain or a garden hose, creating dark blotches that obscure the originally applied color. Sealing is recommended after the staining process is complete.

Figure 1

The various colored leaf shapes were created on portions of this concrete walkway by chemically staining over a buff integrally colored concrete.

Surface preparation prior to staining is essential, particularly for older, dirtier concrete. If the substrate's pores are soiled or contaminated, chemical stain penetration is inhibited. As the stain must penetrate or 'wet' into the surface for the coloring reaction to occur, the surface must be free of sealers, wax, mastic, grease, oil, and other contaminants that can block the substrate's pores. Surfaces with a hard trowel or burnished finish may also impede staining.

Penetration can be evaluated by wetting the surface with water. If water is readily and evenly absorbed and darkens the surface, extensive preparation may not be required. However, if the water beads up and the surface does not darken, cleaning is necessary before chemical staining begins.

Dirt, soil, grease, and oil can be removed by detergent washing combined with scrubbing with a black pad on a rotary floor machine. Sealers and coatings may require mechanical grinding and sanding. Mechanical preparation, even scrubbing with a black pad, may change the surface texture and color. Cleaning with muriatic acid is not recommended because it changes the color achieved by the chemical stain. All cleaning procedures should be evaluated with test sections before proceeding. Once surface cleaning and preparation is completed, water penetration should be retested.

Non-reactive stains and dyes

This coloring system covers a broad range of translucent, mottled hues, and is based on pigment concentrates mixed with water or acetone, depending on the manufacturer. As with the chemically reactive kind, non-reactive stains and dyes are also applied to hardened concrete and cementitious overlays.

Non-reactive stains and dyes are often used when chemical stains cannot produce the desired color with their limited palette or when their chemical reaction is inhibited. Additionally, if applying an acid-based material is seen as problematic, non-reactive coloring systems can be used.

Surface preparation for non-reactive stains is similar to chemically reactive ones, as they must also be able to penetrate the surface to ensure the color's longevity. Again, sealing is recommended after staining.

Choosing the right product

These coloring systems are distinctly different in use and application, and cannot be employed interchangeably.[1] When selecting from a color chart, it is imperative to ensure the product in question is aesthetically and functionally appropriate for the installation in question. For example:

- integral color cannot be applied to the surface of fresh concrete because it will not permanently bond to the concrete (as shake-on color hardeners do);
- shake-on color hardeners cannot be added to ready-mixed concrete as the pigment load in a pail or bag of the product is too low to color the full depth of a concrete slab, (unlike packaged integral color); and
- stains cannot be applied to uncured concrete because the calcium hydroxide needed for the coloring reaction is more readily and consistently available once the concrete hardens.

Though coloring systems are not interchangeable, they can be combined for more colorful and creative effects. Figure 1 depicts a concrete walkway that combines coloring systems.

Another component factoring into product selection is installation cost. For a 102-mm (4-in.) thick slab, the price of integrally coloring concrete or using a shake-on color hardener is very close— about $6 to $7 per 0.09 m^2 (1 sf). Stamping or imprinting either system costs approximately $9 to $11/sf. As slab thickness increases, integral color costs rise, whereas shake-on color hardener costs remain relatively constant.

Stains applied to existing concrete generally start at $3/sf for a single color. Once multiple colors are introduced and shallow saw cuts are employed to create a pattern or design, expenses can jump to $5 to $6/sf. Costs of all coloring systems vary by job size, locale, and degree of difficulty and creativity.

A clean slate: Coloring fresh concrete

Concrete colored integrally or with a shake-on color hardener poses several challenges that can be greatly minimized or managed with consistent practices from start to finish (*i.e.* from mix design to curing). Projects poured over many days, weeks, or even months should

Figure 2

This image shows a broom-finished, red-integrally colored concrete with an apparent white cast on the surface. The whitish color was caused by excess moisture introduced when the contractor broomed the concrete. During brooming, the bristles were periodically cleaned with water. Rather than vigorously shaking the broom out to remove excess water, it was immediately pulled across the surface, which inadvertently added moisture to the concrete to create efflorescence (*i.e.* a white deposit). Clearly, a small amount of water can substantially impact concrete color.

stick to the same mix design, tools, and techniques employed from the beginning. If adjustments need to be made, their potential impact on the decorative finish must be assessed.

Mockups

When multiple colors, patterns, or textures are used, a mockup is very important. This practice helps all parties—designer, client, and contractor—come together with respect to the final finish's appearance and the steps necessary to achieve it. The mockup panel should be large enough to incorporate all materials, tools, and techniques to be employed during the actual installation. Adjustments to specifications and expectations are best made at this time—not after the concrete has cured, when one may have to resort to using a jackhammer to make changes.

Color changes

Once concrete placement has started, the mix design should not be randomly changed, particularly the cement source. Cement can be light to dark gray; an integral color can shift with a different cement color, as well as changes made with cement substitutes such as fly ash (which can vary from buff to tan in color). When writing specifications, the specifier should indicate the mix design and cement source remain unchanged during construction.

This Harley Davidson store in St. Charles, Illinois, had its floor chemically stained with black, reddish brown, and light green colors in a random, free-style fashion.

Mix design changes have less of an impact on shake-on color hardeners because the concentration of pigment and cement components of the product create an opaque layer that would hide any color variations in the underlying concrete.

Water

Maintaining a consistent concrete slump—typically 102 to 127 mm (4 to 5 in.)—is adequate for placing and finishing. Water should not be added to the drum of the ready-mix truck or the concrete during finishing. Not only does this create the potential for strength loss with a change in the maximum water/cementitious material (w/cm) ratio, but it also yields color change. Contrary to popular belief, the use of color hardeners does not require a particularly wet mix. Again, a 102- to 127-mm slump is adequate for placing and finishing the product. Figure 2 illustrates how randomly adding water can affect concrete color.

Admixtures

Most admixtures are compatible with colored concrete installations. The primary exception is accelerating admixtures used to speed up strength development of concrete as air temperature drops below 16 C (60 F). Calcium chloride ($CaCl_2$)-based accelerators should not be used because they may cause dark, blotchy areas on integrally colored concrete. If necessary, only non-chloride accelerators should be specified, which, if used correctly, will not affect concrete color.

Figure 3

This colored and stamped concrete patio has distinct color changes or breaks about 0.9 m (3 ft) from the edge of the pour, as shown by the irregular white line. The slightly lighter perimeter color and irregular white line, labeled on the picture as 'trowel marks,' was caused by the timing and frequency of hand-finishing. The contractor hand-floated the edge of the patio, with a reach of about 0.9 m, but neglected to continue the floating process into the interior of the slab. The color difference became obvious once the concrete cured.

Figure 4

The 'zebra stripes' on the center of the slab are caused by using a plastic sheet during concrete curing. The unavoidable wrinkles in stretched plastic on concrete create an irregular surface, leading to varying cement hydration and concrete discoloration.

Consulting the ready-mix supplier is beneficial—he or she can recommend the correct use of admixtures to minimize the impact of weather or changes in site conditions. Due to modern admixture technology, the properties of concrete can be adjusted to better suit project conditions.

Finishing tools

The various tools for finishing concrete look similar, but have different functions and effects on the concrete's surface. For example, the bull float is a large, flat, bladed tool moved across the concrete surface with an extension handle; it is used immediately after the concrete is placed and leveled to the top of the formwork. The bull float initially smoothes the surface by eliminating high and low spots. Bull floating is done before bleed water reaches the surface.

Like bull floats, hand floats smooth the surface. However, they are smaller in size and more effectively used near form edges. Hand floats are also used over the whole surface to further remove surface irregularities not corrected by the larger bull float. Hand floating can be simultaneously performed with bull floating or immediately after.

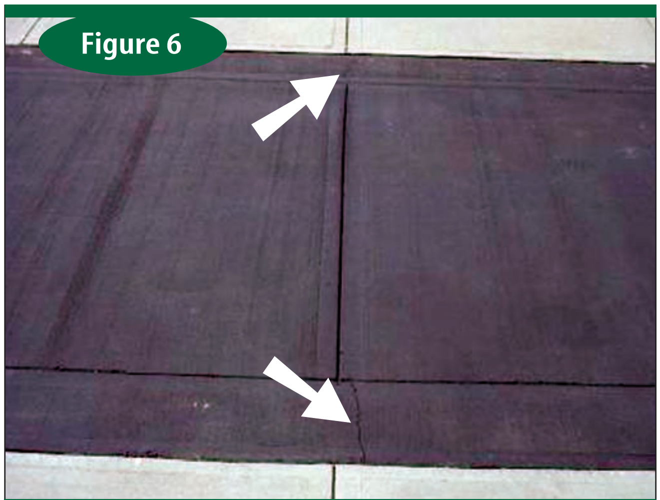
Edgers create a rounded edge or radius around the slab's perimeter. Edging is usually done in conjunction with hand floating. Compared to squared edges, rounded edges tend to look better, and are more resistant to chipping during form removal or when the slab is open to foot or vehicular traffic.

Jointers or groovers make shallow grooves in concrete. The jointer has a protruding fin running along the bottom of the tool blade, which uniformly cuts the concrete surface leaving a permanent joint when the concrete hardens. The joints can be used to create interesting designs, and more importantly, for crack control (as discussed later in this article).

Troweling is the next step, and produces a very smooth, dense surface, which can be desirable for interior floors. Exterior concrete should not be troweled. Smooth troweling exterior concrete may contribute to surface failure, particularly in freeze–thaw climates. Exterior concrete is typically left with a float finish or broomed to create a slip-resistant surface.

None of these finishing processes should commence when bleed water is present. Prematurely finishing concrete when bleed water is present adversely affects the w/cm ratio at the surface, again contributing to surface failure in freeze–thaw climates, as well as causing a color change in the cured concrete. Another error is 'over-finishing,' which is caused by too many passes of a tool over the concrete surface or the use of excessive pressure on the tool. This error seals the surface, leading to failure and color changes. Timing and consistency in use of tools is important for all forms of architectural concrete. Inconsistencies can cause color disparities, as illustrated in Figure 3.

This concrete slab has three integral colors. The colors looked uniform until the curing compound was sprayed. During spraying, the pressure of the hand pump canister varied, the spray wand was moved randomly over the surface, and a nozzle producing a conical spray pattern instead of a fan pattern was used, contributing to an uneven film of curing compound. The apparent color variation of the concrete is caused by light reflecting differently off the varying film thicknesses, and has nothing to do with the quality of the coloring product. This problem was resolved by applying more curing compound to produce the desired even film thickness.



The charcoal gray integrally colored concrete exhibits random cracking. When the concrete was placed, hand-tooled joints were cut parallel and perpendicular to its run. The jointing pattern was for crack control and aesthetics. The cross-joints terminate at the parallel joints. When stresses developed in the cross-joints, cracking occurred as expected and designed. However, once the cracking started in the control joint, it continued as a random crack across the parallel joint to the edge of the concrete. The jointing pattern looked good in design, but failed because it was not installed correctly (*i.e.* edge to edge).

Plastic problems

A key factor governing concrete's strength is its curing conditions, particularly the rate of water loss seven to 28 days after initial placement. Covering it with polyethylene sheets is a common and effective means of curing gray concrete, but should be discouraged for colored surfaces.

A plastic sheet is not recommended because it never lays completely flat without wrinkles (no matter how many times it is pulled or stretched across the surface). Moisture loss, and hence cement hydration, varies depending on where the plastic is touching the concrete and where it is wrinkled. This disparity can create visible, and often permanent, discoloration on the concrete's surface (Figure 4, page 48). Liquid-applied curing compounds, either roller- or spray-applied (discussed later), are recommended over integrally colored or shake-on color-hardened concrete.

Curing decorative concrete

As previously mentioned, curing to control moisture loss of newly placed concrete is critical for the decorative slab's long-term performance. Liquid-applied curing compounds conforming to ASTM C 309, *Standard Specification for Liquid Membrane-forming Compounds for Curing Concrete*, are preferred over sheeting made of plastic or similar materials.

Left uncured—particularly when the concrete surface is exposed to windy, hot, or low humidity conditions—it can encounter plastic shrinkage cracking. This cracking occurs while the concrete is still soft and is caused by the surface drying rapidly during hot and dry weather. Plastic shrinkage cracking generally does not lead to surface failure, but is unsightly. Improper curing can also cause color variations.

Liquid curing compounds can be roller- or spray-applied with a hand-pumped spraying unit to create an even and consistent wet film. Excessive overlaps and under-/over-application should be avoided. If the material is misapplied and dries to an uneven film thickness, the underlying colored concrete may appear blotchy. Figure 5 illustrates the consequences of such misapplication.

Once the concrete has cured sufficiently for two to four weeks, applying a sealer is recommended for additional protection. In combination with the originally applied curing compound, a sealer defends concrete against weather, dirt, and spills. If a curing compound is applied too heavily, it can act as a sealer while the concrete is initially curing and trap mix design water completely, causing aesthetic and durability issues. Typical cure-and-seal products weather and wear, requiring periodic maintenance and reapplication to maintain the protective coating.

Minimizing random cracking with control joints

As concrete cures and hardens, it loses moisture through hydration and evaporation, causing the slab to contract and produce drying shrinkage cracks. These cracks occur as the tensile stresses induced by the slab's contraction or volume change are relieved naturally by random cracks through the slab. Random cracking looks unsightly and can adversely affect the concrete's structural integrity. Cutting control joints by hand (Figure 5) as the concrete is placed or by mechanically sawing (Figure 6) soon after finishing, confines the drying shrinkage cracks within the vertical plane of those control joints (instead of letting them spread randomly across the surface). Control joint depth and placement is the same for gray and colored concrete, following these dimensions:

- joint depth (in inches) should be 0.25 times the slab thickness (in inches) (*e.g.* a slab 152 mm [6 in.] thick requires a joint depth of 38 mm [1.5 in.]);
- joint spacing (in feet) should be 2 to 2.5 times the slab thickness (in inches) (*e.g.* a slab 102 mm [4 in.] thick could have joint spacing 2.4 to 3 m [8 to 10 ft] apart); and
- length to width ratio of the jointed sections of concrete should be 1 to 1.5.

Random cracking is guaranteed if basic jointing guidelines are ignored. A joint should never arbitrarily be installed or eliminated simply because it looks better. However, whenever possible, the joint can be visually minimized.

Coloring hardened concrete

A popular technique for decorating existing concrete is staining, which produces translucent and mottled hues that often mimic colors found in nature. When combined with faux application techniques (similar to many creative strategies used with paints), floors and hardscapes can become a truly unique installation. Stains are relatively simple to apply, yet results may be less than desired. Generally, disappointment stems from inadequate surface preparation or misapplication of materials, causing poor stain penetration as described earlier, and a designer or client's misguided expectations.

As chemical stains create color by reacting with concrete, and are affected by surface texture and porosity, the end result may vary from the color chart. A mockup produced on the actual concrete prior to full-scale application can lessen surprises.

Shake-on color hardener in a shade of terra cotta was used to visually enhance this restaurant floor.

Materials

The most commonly used stain products create color by chemically reacting with the substrate, which can be gray or colored concrete, or cementitious overlays. As is typical with chemical stains, only a narrow palette of earth tones is available from manufacturers. However, colors can be combined or manipulated during application to broaden their range and create unique effects.

Non-reactive water-based stains or dyes offer a wider array of colors. Unlike their chemical counterparts, non-reactive stains are unaffected by the concrete's mix design for a coloring reaction. These stains can also be combined and applied for dramatic results. Figure 7 shows a restaurant floor colored with non-reactive, water-based stains.

Chemically reactive stains potentially leave an acidic residue that needs to be neutralized and flushed from the surface before sealing. Residue disposal may become an issue depending on local environmental guidelines.

In contrast, non-reactive stains and dyes do not create a comparable residue and may require little to no cleanup prior to sealing. They also do not contain volatile organic compounds (VOCs), making their use eligible for credits under the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design (LEED) program.

Figure 7

The restaurant floor in the above photo utilized two stain colors. The stylized green dragon's tail was produced by dispersing the green stain with blasts of compressed air before it penetrated and dried.

Staining 101

When pouring new concrete floors slated to receive chemical or water-based stains, the surface should not be sealed, hard-troweled, or cured with a liquid-applied, film-forming compound. The stains must wet into the substrate for proper coloration, which a cure-and-seal prevents. In this situation, a curing paper conforming to ASTM C 171, *Standard Specification for Sheet Materials for Curing Concrete*, would be preferable as is wet curing. The concrete should be stained after it is 21 to 28 days old.

Hard-troweling dramatically closes the concrete surface, making it resistant to stain penetration. A float finish or single pass with a trowel is the better finishing technique. If a floor has a repellent finish—due to curing compounds, sealers, wax, dirt, grease, or hard trowel—surface preparation by chemical cleaners or mechanical means is required. If the surface is improperly prepared, the stain application will not last long.

As stains produce a translucent color, shade variations in the concrete prior to staining will likely remain noticeable after application. Therefore, stains should not be used to hide construction errors or dramatic color variations in the substrate. For the same reason, a randomly patched concrete floor may not be a good candidate for staining. Not only will the patched areas remain visible, but they may also create a very different coloration from the adjacent concrete surfaces.

Concrete surfaces of different ages, textures, porosity, and cement content can also produce different results with the same chemical stain color. Experience with a particular chemical stain on a previous project does not guarantee the same result on the next one using the identical color. (Non-reactive stains and dyes tend to provide a more predictable, consistent result.) Therefore, a mockup is vital—it should be done on the actual concrete to be stained, as opposed to a surface associated with another area.

Once the chemical stain is applied, it needs to remain on the surface for about four hours to complete the coloring reaction. After this time, a small area may be cleaned and assessed, and if needed, additional stain can be applied for a darker coloring. When the staining is finished, the surface should be thoroughly neutralized, scrubbed, flushed with water, wet-vacuumed, and then allowed to dry completely before sealing. Wet-mopping alone is inadequate cleanup after staining. Any stain residue not fully removed is a bond breaker for the sealer, compromising the surface's aesthetic longevity. A sealer is highly recommended over stained concrete.

Unlike chemical stains, properly applied water-based stains and dyes require minimal cleanup after staining and before sealing. Therefore, these stains may be more suitable for sites where using water to clean up chemical stain residue is problematic.

Maintaining concrete's good looks

New concrete colored integrally or with a shake-on color hardener share characteristics with color-stained existing concrete. These colorful concrete surfaces are rigid sponges susceptible to dirt accumulation by anything dripped or dropped onto them. While concrete surfaces can be cleaned, it is more practical to seal out grime than scrub out embedded dirt. Some blemishes (*e.g.* oil) are difficult to completely remove and certain cleaning procedures may chemically etch (*e.g.* acid-based cleaners) or abrade (*e.g.* excessive scrubbing or grinding) the concrete, marring the decorative surface.

Typical concrete sealers are solvent- or water-based acrylics.[2] Neither type lasts forever and most products are prone to scratching and scuffing, eventually requiring reapplication with exposure to weathering and wear. The initial application (and reapplication) must be factored into the budget and expectations for the decorative surface.

Particularly for interior floors, job callbacks often arise when proper sealing and maintenance practices have been ignored. Good colored concrete begins with good gray concrete; decorated or not, there is no such thing as a maintenance-free concrete floor.

As mentioned, clear sealers scratch and scuff. If neglected, the sealer eventually wears from the surface. At this point, reapplication can be costly and disruptive for a business. A more proactive approach is the periodic application of a maintenance wax over the sealer. Typically liquid emulsions, these waxes become sacrificial surfaces; if regularly reapplied, they protect and spare the sealer from scratching,

Photo courtesy Marshalltown

The above photo displays a selection of typical concrete finishing tools.

excessive wear, and eventual loss from the concrete. As an added benefit, waxes can be handled by in-house maintenance personnel and do not require the expertise, time, and costs associated with stripping and reapplying the original sealer.

Guidelines for the gray area

Numerous references and standards exist for designing and installing quality gray concrete. American Concrete Institute (ACI) 302.1R, *Guide for Concrete Floor and Slab Construction*, is an excellent reference for proper mix design, delivery, finishing, and curing of plain gray concrete. Information is also available from the Portland Cement Association (PCA) and the National Ready Mixed Concrete Association (NRMCA). The American Society of Concrete Contractors (ASCC) and its Decorative Concrete Council (DCC) are good sources of information on concrete handling and finishing.

These guidelines are also important for decorative concrete—the quality of a decorative concrete installation depends on that of the gray concrete base material. Therefore, standards for gray concrete must be adhered to for decorative concrete as well. These rules are also important when stains and dyes are used to color existing concrete.

In addition to ACI and ASTM references and standards, many manufacturers provide three-part guide specifications that can be adapted for a particular project. Referring to a manufacturer's specifications can be advantageous because unique aspects of a decorative concrete installation or coloring product may not be adequately addressed in the more general ACI and ASTM documents. A product's technical data sheets can provide valuable information and help compare various manufacturers' offerings.

Boundless creative opportunities exist for decorative concrete. The ready-mix and decorative concrete industries have partnered to produce this engineered building material that can be sculpted to a specific color, shape, and pattern. Contractors, or maybe more appropriately, 'concrete artisans,' are strengthening their skills. All that is needed is a creative design to challenge them.

Notes

[1] For more information on these coloring systems and polished concrete floors, see this author's "High-gloss Finishes," in *The Construction Specifier*, December 2006.

[2] For a comprehensive discussion of other types of sealing systems, see "Protective Treatments for Decorative Concrete Investments," by Jennifer Crisman (*The Construction Specifier*, March 2006).

Additional Information

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Abstract

As concrete has evolved into a decorative construction material that can be colored, patterned, and shaped, simply specifying decorative concrete based only on engineered principles may yield less than aesthetic results. This article compares the various coloring products for decorative concrete flatwork and highlights specific decorative concrete mixing, handling, and finishing techniques for quality installation. Adjustments to standard concrete specifications are also discussed.