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Color in Concrete: Beauty and Durability

by Nick Paris and Michael Chusid

Some colors in nature are as fleeting as a flower in full bloom or autumn foliage at the height of its glory. Other colors are more enduring. Among the most long-lasting hues are those found in rock and stone. These colors are as unchanging as a granite peak and as old as the sandstone walls of a canyon.

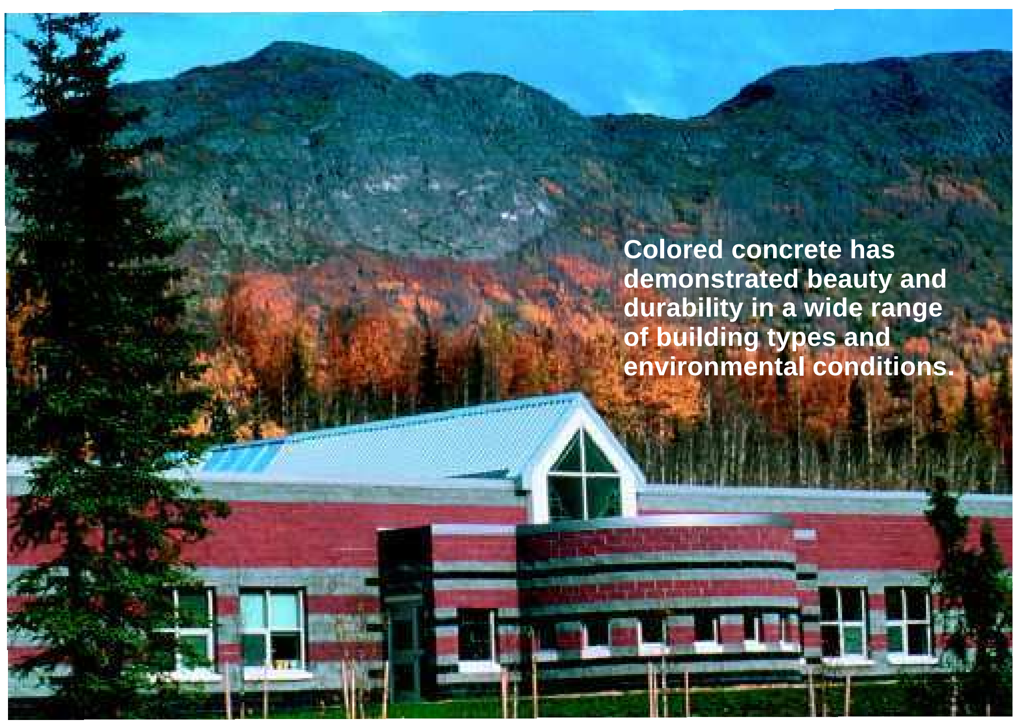
Constancy and change — there is a place for both in design and construction. A changing seasonal display may be desirable in a landscaping design. But when specifying buildings, pavement and structures, most designers prefer greater permanency.

Fortunately, the hues in colored concrete can be as durable as those found in nature; the pigments used are the same ones responsible for nature's palette. Available in a wide spectrum of shades, the mineral oxides and other recognized pigments used in concrete color additives are color-fast, weather-resistant, and economical. Integrally mixed into the concrete, the pigments bind with portland cement to become a permanent part of the concrete matrix. Combined with the intrinsic durability of concrete, integral color delivers long-lasting beauty to complement any design.

The use of color is increasing in almost every type of concrete, from cast-in-place, precast, and tilt-up construction to manufactured concrete products like concrete masonry units, segmental retaining walls, and interlocking pavers. It is no surprise how much beauty and value color adds to concrete. The surprise is in the aesthetic benefits possible when textures, exposed aggregates, imprinted patterns, architectural form liners, and other decorative finishes are considered. On many architectural projects, colored concrete is an economical alternative to expensive building materials like stone or tile.

While the extra cost of color additives must be taken into account, integral colors can be installed and finished in most types of concrete work using techniques similar to those required for plain concrete, so additional installation costs are not unrealistic. Furthermore, the permanence of integral concrete coloring means a significant life-cycle cost saving compared to the expense of applying and maintaining toppings, coatings, stains, or painted finishes.

Evidence of the durability of concrete colors can be seen in colored concrete projects around the world that have maintained their appeal for as much as 25 years or more. But just how permanent are the hues in colored concrete? And how should specifications be written to assure the desired results? To answer these questions, prudent specifiers need to understand how concrete is tinted, factors that influence weathering, and the results of laboratory and field testing for colorfastness.



Colored concrete has demonstrated beauty and durability in a wide range of building types and environmental conditions.

Coloring concrete

Concrete is produced from portland cement, sand, crushed rock or aggregate, and water. Pigmented color additives augment this basic recipe to create colored concrete. Because the color additives are mixed into the concrete, color goes all the way through each placement or concrete product. This means that, unlike surface-applied treatments, color will remain visible even at chipped corners, split faces, and saw cuts, or when sandblasted.

The most popular color additives are made with iron oxide pigments — the same compound found in common rust. While the color of rust is generally reddish orange, iron oxide also occurs in yellow, brown, and black hues. By blending these four primary tones, a wide palette of colored concrete can be produced. Iron oxide can be refined from naturally occurring ores and minerals such as ochre.

However, more intense colors are available from synthetic iron oxides that are recycled from iron. These pigments are chemically inert, fade resistant, and environmentally safe. As anyone who has ever had to drink water from a rusty pipe knows, iron oxide is nontoxic. And if you have ever tried to remove rust stains from a kitchen sink, you know it is one tough coloring agent.

Other mineral pigments extend the concrete color palette. While they come at a premium, chromium oxide yields greens and cobalt produces blues. Titanium dioxide can be used to whiten a mix or produce pastel shades, but the same effect is usually accomplished more economically by using white portland cement. While carbon black is an economical alternative for tinting black and gray concrete, concrete containing it must be protected from water penetration.

While the carbon black pigment itself does not fade, some grades of carbon black can slowly leach out of concrete that is not adequately sealed, creating a faded appearance. In air-entrained concrete or concrete exposed to repeated wetting and drying cycles, black iron oxide should be substituted for carbon black.[1]

The color additives are pulverized into microscopic particles, about one-tenth the diameter of a grain of portland cement. Their small size helps them bind with the cement and increases their tinting strength. Added to a concrete batch, the color additives disperse into the cement paste which then coats the sand and aggregate in the concrete. The addition of color additives does not reduce the strength of the concrete when used at dosage rates of up to 10 percent of the weight of the cementitious materials in a mix.

Color additives are available in a variety of forms and delivery systems to make concrete coloring clean, simple, and accurate.

Most color additives, however, are used at dosage rates between 2 and 6 percent. The lower end of this range produces subtle shades that offer just a hint of a tint and gives the concrete an inviting cast. At the higher dosage rates, concrete approaches a state of color saturation where the addition of more pigment does not further enhance the visual effect.

Until recently, most concrete producers used dry powdered pigments which had to be manually weighed and added to the mixer. Now, new color additives and material handling techniques make it easier and more economical to color concrete. Ready-mixed producers, for example, use color additives in disintegrating bags which can be tossed right into mixers without opening or pouring.

Other concrete plants increasingly use computer controlled machinery to meter and dispense liquid or granulated pigments. These automated systems allow concrete producers to buy just a few primary shades of color additives in bulk and blend them as needed to produce a wide range of standard or custom concrete colors. These new color handling methods are virtually dust-free and simplify the challenge of keeping a job site or concrete plant clean.[2]

Concrete producers who maintain high standards of quality control will be able to deliver consistent colors from one batch to the next. The key to uniform color is to use the same raw materials, mix proportions, and production methods throughout a job. In addition to the shade and dosage rate of the color additive, other variables that affect the appearance of concrete include: the color of the sand, types of aggregate and portland cement in the mix; the water-cement ratio; and how the concrete is cured. These same factors are just as critical when producing uniform-looking plain gray concrete.

The color of the sand and aggregate is especially important in exposed aggregate finishes or split-faced concrete masonry units since these materials become exposed on the surface of the concrete.

From a design standpoint, the surface texture of concrete must also be considered. A lightly sandblasted or rough textured concrete surface will appear different than a smooth finished surface even if both are identically pigmented. Some concrete products are manufactured with several colors intermingled to give each unit a flashed or mottled look. It is also popular to specify blends or patterns composed of concrete masonry units in a variety of hues. Textured and variegated options offer an added feature of hiding any minor scars or stains an installation may suffer over time.

Durability of colors

The pigments used in color additives are chemically stable and will not significantly change their hue under normal environmental exposures. The colors in cave paintings for example, created with iron oxide from the soil and carbon from charcoal, have been preserved for thousands of years. Concrete today must survive in somewhat harsher environments: polluted urban areas, high service roadways, and along the sea coast. The good news is that high quality color additives are able to resist fading due to sunlight, alkalinity in fresh concrete, chemical reactions during the concrete curing process, deicing compounds, and the weather.

Even though the color additives themselves are fade resistant, all concrete structures can change appearance over time, even those built with uncolored concrete. Some changes that go virtually unnoticed in plain concrete may be more conspicuous in colored concrete. By understanding the dynamics of concrete weathering, specifiers will be better able to evaluate products and have more realistic expectations of the long-term appearance of colored concrete structures.

Efflorescence

Efflorescence is a white powdery deposit that can form on the surface of concrete. It occurs when moisture dissolves salts in concrete and carries them via capillary action to the surface. When the moisture evaporates, it leaves behind a mineral deposit. While efflorescence is not a structural problem, it can be aesthetically objectionable. On ordinary gray concrete, the white deposit frequently goes unnoticed. But on dark-colored concrete, the deposit can have the effect of lightening or fading the surface color.

To minimize the potential for efflorescence, structures should be designed to minimize entry of moisture into the concrete. For example, tops of concrete masonry walls should be covered during construction if rain is possible. The back side of retaining walls should have a drainage system to collect water before it enters the walls. Walls should also have weep holes to allow water to escape. And concrete pavements should be installed on well-drained base courses.

Efflorescence often occurs shortly after a building or pavement is installed. If construction occurs during a dry season, this "new building bloom" may not occur until after the first wet spell. This efflorescence will often be removed naturally by rain water or traffic. In cases where heavy or continuing deposits occur, it is advisable to investigate and correct the source of the salts and moisture contributing to the problem. Efflorescence should then be removed as soon as possible to prevent the formation of calcium carbonate, a mineral deposit that is very difficult to remove.

Most efflorescence can be removed by dry-brushing followed by flushing with water. More stubborn deposits may require the use of a proprietary efflorescence remover. Follow the chemical manufacturer's instructions and test on a small section of concrete to determine the visual impact of the cleaning solution. Rinse the concrete thoroughly after cleaning. Note that the use of acid cleaners can affect the appearance of colored concrete. "Control and Removal of Efflorescence," available from the National Concrete Masonry Association, has more information on this subject.[3]

Yellowing of concrete

Another factor in weathering is that concrete can yellow as it ages. The impact of the yellowing is more noticeable in uncolored or lightly tinted concrete than in concrete with high dosage rates of pigment. While the color shift is usually slight, it may still be a consideration when trying to match new materials to old construction.

Erosion

Over the course of time, the appearance of a concrete structure can shift due to the wearing away of the surface of the concrete. In new concrete, colored cement paste coats each grain of sand or piece of aggregate and the overall color of the concrete is determined primarily by the pigmentation.

As the colored cement paste erodes or wears away, sand and aggregate become visible at the surface and may influence the overall color of the concrete. Any change in the texture of the concrete will also affect appearance. If concrete will be subjected to flowing water, wind-blown sand, heavy vehicular traffic, or other conditions that may cause accelerated or uneven wear, the specifier should evaluate the weathered appearance of concrete as well as the color of new work.

Sealing and cleaning

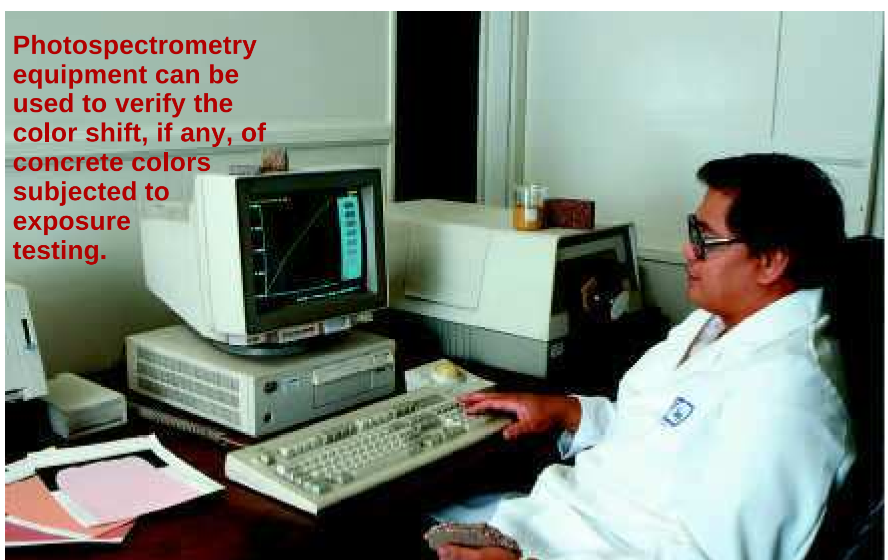
For optimum color retention, specifiers should consider applying a water repellent or sealer to concrete surfaces. A good quality water repellent or sealer reduces the potential for the concrete to become soiled or stained and makes it easier to clean. By reducing the penetration of moisture through the face of the concrete, water repellents or sealers may also reduce efflorescence.

Glossy sealers can create a wet look which darkens the apparent color of the concrete. Other sealers are available in a matte finish. In general, sealers should not be applied until after the concrete has cured at least 28 days, efflorescence has been removed, and the concrete given an overall cleaning.

With or without water repellents or sealers, however, colored concrete will provide years of serviceability and good looks. If desired, an occasional scrubbing with mild detergent followed by a thorough rinse with clean water is all that is required to keep concrete clean and looking its best.

Industry standards and testing

The durability of colored concrete has received the attention of scientists and colorists around the world. One of the earliest formal studies on the colorfast-



Photospectrometry equipment can be used to verify the color shift, if any, of concrete colors subjected to exposure testing.

Tarmac, Inc.

ness of colored concrete was conducted by researchers at the University of Maryland over 30 years ago.[4] In addition to questions about the colorfastness of pigments, they were also interested in whether pigments affected other properties of the concrete. Working with several colors and dosage rates of iron oxide pigments, colored concrete specimens were subjected to a battery of laboratory tests. They reported that, "In summary, the pigments were found to be relatively inert when incorporated in concrete and were not detrimental to its more important properties. Strength showed slight improvement when pigments were used, but the magnitude was probably of little practical importance. The colors were reasonably permanent even when the concrete was exposed to natural weathering." According to a recent interview with the report's principal investigator, observations of the samples continued for over a decade after the report was published and verified the long-term retention of the concrete colors.

This and other studies were codified into ASTM C 979-82, Standard Specification for Pigments for Integrally Colored Concrete, the industry-wide standard for coloring agents used in concrete. It establishes procedures and evaluation parameters for factors affecting the manufacturing of colored concrete, such as the ability of pigments to disperse in a concrete mix, resistance to the alkalinity of cement, and stability under curing conditions. With regard to weathering, the standard requires pigments to be non-water soluble and resistant to light exposure.

The real world is more complex than a laboratory, so accelerated testing must be corroborated by long-term field exposure. Two technical papers have examined the durability of colored concrete products. Jungk and Kurz[1] examined data from concrete test sites in Germany, Sweden, Ireland, and Netherlands and identified the characteristics of pigments capable of providing long-term performance. Büchner and Kündgen[5] examined test sites where colored concrete had been exposed to up to 25 years or more of weathering. These and similar studies conducted by concrete producers provide an empirical basis for specifiers to have confidence in the color additives and coloring methods now employed by most concrete producers around the world.

The real proof is underfoot

The word "concrete" is practically synonymous with permanence in our language. And with good reason — colored concrete has withstood the test of time. Consider, for example, the following case: A decade after it was first installed, a driveway in front of an office building had to be removed to allow for an addition to the structure.

Fortunately, the drive had been constructed of interlocking colored concrete pavers. The architect allowed the salvaged pavers to be re-installed in front of the new addition. After the old pavers were washed, they were almost indistinguishable from brand new ones used in an adjacent area.

This is not to say that color and appearance of concrete does not change. Like any natural material, minor variations in the color or appearance of concrete are to be expected, whether colored or not. And like many other architectural products, colored concrete takes on a patina of age.

Designers, however, are able to visualize how their projects evolve with the passing of time. They foresee that the twig they plant this year will grow to be a mighty oak. Like that oak, buildings and pavements specified with colored concrete will remain beautiful, season after season.

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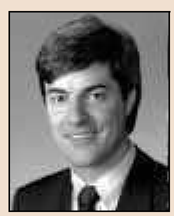
Selected for reader interest by the editors.



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