Coloring Concrete Using Integral Pigments

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An Introduction to Iron Oxide Pigments

Although there are number of methods for coloration of concrete, iron oxide pigments are the most commonly used by the construction industry. There are a wide variety of reasons why Iron Oxide Pigments are the preferred method of coloration, including:

- Available in a wide variety of colors
- Water wettable
- Alkali resistant
- Not water soluble
- Chemically stable
- Light resistant
- Relatively inexpensive

ASTM C979 Standard Specification for Integrally Colored Concrete includes tests for many of these characteristics as well as testing to insure the pigments are within the allowable tolerances for total sulfates, that they do not affect time of setting, and do not affect air content or compressive strength of the concrete. All pigments used to integrally color concrete should pass ASTM C979.

Iron oxide pigments can be broken down into two basic classes: Synthetic and Natural. Any concrete pigment can be wholly composed of either natural or synthetic iron oxides, or it can be a blend of the two classes. There are some basic differences between synthetic and natural iron oxides, but in general they all offer good longevity and color consistency from lot to lot. To describe their differences, it is important to understand some basic pigment concepts first.

Tinting strength is the ability of a pigment to change the color of a given mix. Thus, if a pigment changes the color of a mix substantially with a small addition of color; that pigment is said to have a high tinting strength. The tinting strength of a pigment depends both on the iron content and the fineness of the pigment in question.

Saturation Point is the point at which color intensity stops rising proportionally to the rate of addition of the pigment. Meaning, at some point of addition, there is a smaller and smaller change in color proportionate to the amount of pigment added.

The color wheel to the left shows Synthetic Red Iron Oxide Pigment Additions from ¼% to 7% in white cement. Note how the last several samples look virtually the same. This is at or near the saturation point for this pigment.

Synthetic Iron Oxide Pigments

Synthetic Iron Oxide Pigments are a manufactured product. The most common way that Synthetic Iron Oxide Pigments are manufactured is to use a source of known metal and oxidize it under very controlled conditions. Synthetic iron oxides can produce intense colors, are relatively expensive, and have high tinting strengths. When making pastel colors, however, they require a very low pigment addition rate, sometimes as low as ¼ to ¾% of the weight of the cement. The saturation point for synthetic iron oxides is typically around 7%. Synthetic iron oxides are manufactured in red, yellow and black shades.

Addition rates on the samples below, from top to bottom, are 5%, 3% and 1% based on cement weight. White cement used for samples.

Synthetic Red Iron Oxide

Synthetic Yellow Iron Oxide

Synthetic Black Iron Oxide

Natural Iron Oxide Pigments

Natural Iron Oxides come from naturally occurring ore deposits that are mined around the world. These ores are dried, classified, and pulverized. Natural iron oxides when used to color concrete produce earth tone type colors. They have lower tinting strength than Synthetic Iron Oxide. Because of this, natural iron oxides tend to be used at higher addition rates. It is often easier to control concrete color consistency using natural iron oxides. This is because a small amount of natural iron oxide pigment does not change the color of the concrete dramatically, and therefore, a small change in the amount of pigment used also does not change the color of the concrete dramatically.

Natural iron oxides are relatively inexpensive, so even with higher addition rates, they are affordable. The saturation point for naturals is closer to 10%, however, except on rare occasions, it is best to stay at a 5% addition rate or below for precast applications. For concrete and masonry applications, up to 10% is acceptable. Natural iron oxides that are suitable for coloring concrete are available in reds, browns and yellow ochres. Natural black iron oxides exist, but they do not have sufficient tinting strength to be appropriate for use in colored concrete.

Addition rates on the samples below, from top to bottom, are 5%, 3% and 1% based on cement weight. White cement used for samples.

Natural Red

Natural Yellow Ochre

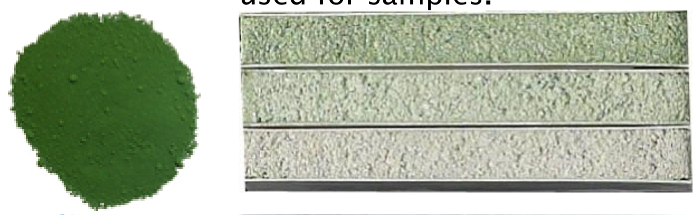
Additional Pigments Appropriate for use in Colored Concrete

Titanium dioxide, a white pigment, can be used to lighten concrete made with gray or white cement. It will never make concrete made with gray cement truly white, but it will lighten it to a lighter shade of gray. Titanium dioxide is also used in some pigment blends to lighten and brighten them. It is approximately 25-50% more expensive than synthetic iron oxides.

Chromium Oxide is used to color concrete green. It is very durable, but is more expensive than iron oxides. It costs approximately three to five times as much as synthetic iron oxides. Blue is also available in the form of cobalt oxide. Cobalt blue is extremely expensive. It can be up to thirty times more expensive than synthetic iron oxides. The cost impact of both blue and green, therefore, must be carefully considered when they are to be used in any colored concrete project.

Addition rates on the samples below, from top to bottom, are 5%, 3% and 1% based on cement weight. White cement used for samples.

Chromium Oxide



Cobalt Oxide

Forms of Pigment

Powder

Powder pigments have been used in the construction industry for the longest time, well over 100 years.
They are still the most common form of pigment used by all concrete producers. They are the least expensive form of pigments and are typically available in either 50 pound bags or batch size bags as required. Powder pigments have unlimited shelf life when stored properly. It is best to keep them dry, so they don't get lumpy and the bag doesn't disintegrate. For best results, they should to be added early in the batching sequence in order to achieve maximum dispersion and color development of the colored concrete.

Liquid

Liquid color has been used in the United States for over 30 years. It basically consists of the powdered pigments suspended in a water-based dispersion. Liquefying the pigment simplifies the conveying process and therefore allows pigment additions to be automated through the use of dispensing equipment. Dispensing systems can also create verification and documentation of all pigment additions to the concrete mix.

Liquid pigment also mixes more readily with the concrete and therefore significantly faster color development and better dispersion of color takes place in the mixer. Liquid color costs more than powdered color, but ultimately it helps produce more consistent colored concrete. The use of liquid color in precast and ready mix has been increasing at an increasing rate over the last five to ten years.

Granular

Granular pigments are basically powder pigments joined together to make small (bb size) balls. They have been used in the construction industry approximately 20 years. Granules can also be added automatically, and since they are dry, they do not require the addition of any extra water to the mix. As stated earlier, this form of color is only available for synthetic iron oxides, and is used mostly in concrete paver plants and some concrete masonry manufacturing facilities.

Specifying

The best way to specify color for a concrete project is to start with color samples from a pigment manufacturer or, for precast applications, use PCI's Color & Texture Guide. In the specification it is particularly helpful to call out the color of cement to be used, the pigment number and name, and the percentage addition of the pigment based on the weight of the cementitious material in the mix.

In general, it is not recommended to use less than 1% pigment addition or more than 5% pigment addition based on cementitious materials. Addition rates below 1% are not recommended because it is difficult to maintain color consistency at this low addition rate. Addition rates over 5% are not recommended for several reasons. Primarily, the high addition causes a higher volume of fines being added to the mix, which may cause a reduction in compressive strength. Additionally, synthetic yellow iron oxide and burnt umber do not pass ASTM C979 above a 7% addition rate.

Quality Control and Production Controls

Color Evaluation & Sampling

It is mandatory to produce a concrete sample when evaluating concrete pigment, evaluating pigment in the liquid, dry or granular state is not acceptable. Samples should be allowed to cure for at least one week before being approved, particularly when using gray cement. It is best to record the pigment number and the lot number with the mix design. Samples should be replaced every two to three years due to possible cement color changes, yellowing of cement over time, pigment lot retention for three years and depletion of aggregates over time.

Finally, when evaluating pigments, it is critical to evaluate the pigment only when mixed into concrete; the same pigment formulation may look different in the dry state from batch to batch due to blending differences. When these pigments are mixed into concrete, however, the resulting concrete pieces will be consistent in color.
Cement
For each element of a project a single type and brand of cement should be used. Switching type or manufacturer of cement during a job will cause color variation. For projects in which color consistency is a factor, white cement is superior to gray cement. White cement is significantly more expensive than gray, but colored concrete made with a white cement base is typically much more uniform in color since white cement is color controlled in the manufacturing process. For this same consistency reason, fly ash and other pozzalonic material should be evaluated carefully and excluded from the specification if there is any question regarding their color consistency throughout the entire project.

When producing colored concrete consistency is the key - from the approved sample through raw material selection to production, curing and finally finishing. Consistent water/cement ratios are also very important. The higher the water/cement ratio, the lighter the concrete will be. The converse is also true. Lower water/cement ratios produce darker concrete.

Finish

The finish of the concrete has a profound impact on the end color and consistency of all concrete pieces. Integral pigments are not normally a good choice for smooth, off the form finishes. Generally, a smooth off the form finish creates color variations at the form face because of differential surface drying of the concrete. In general, integral pigments work best with textured concrete - raked finishes, form liners, retarded, sand blast, or acid etched finishes.