Concrete Colourant II

Carbocolor® is a specialty carbon black designed to meet the colouring challenges of the construction industry. Carbocolor is a unique form of carbon with a large particle size similar to that of black iron oxide. As an elemental amorphous carbon, it is inherently chemically stable. The result under long term weathering conditions is stronger colour retention versus competitive products. In Figure 1, the effects of Carbocolor at various loadings in portland cement samples are observed.

Figure 1. Left to right: Carbocolor loaded at 6%, 4%, 3%, 2%, and a reference blank.

Carbocolor versus Traditional Black Colourants

Carbon blacks made with the furnace or lamp black processes have been used in concrete applications in the past. Their inherently small particle size (<60 nm) results in high tinting strength; however, their weatherability is poor. In addition to their fading tendencies, furnace and lamp blacks are also difficult to incorporate into concrete mixtures causing adverse effects on air entrainment and slump. As a result, most concrete manufacturers have maintained the status quo and continue to use iron oxide for grey or black pigments, or accept the shortfalls of furnace or lamp blacks when aged.

Iron oxides have much lower tint strength than any of the carbon blacks, but have demonstrated higher durability than furnace and lamp blacks in concrete applications. Their chemical instability over the long term is also a trade off as over time they develop the red colour associated with their most stable state. Carbocolor is colour steadfast with its inherent chemical stability. By comparison Carbocolor will not fade or change shade when submitted to UV light, acids, alkalis, or heat.

Carbocolor's Mechanisms of Colour Retention

There are two mechanisms by which fading can occur in coloured concrete:

1. The loss of pigment particles from the concrete specimen
2. The degradation of the pigment

The nature of portland cement renders the use of small particle carbon blacks as pigments impractical. There are several size classifications for pore structure in hydrated cement pastes.[1] The

[1]Mindness, S. and Young, J.F., Concrete. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, pp. 99-101

designations have been divided into two categories, capillary pores and gel pores. Gel pores typically have diameters of less than 10 nm making them insignificant for most grades of carbon black. Capillary pores are subcategorized into large (50-10,000 nm) and medium (10-50 nm) diameter sizes.

The large capillaries are inevitable escape routes for colourants. Carbocolor, with an average particle diameter of approximately 280 nm, a low degree of particle aggregation, and some residual particle agglomeration after mixing, could still be retained in the large capillaries that fall in that size category. A large fraction of furnace black grades such as N550 (56 nm) or N660 (67 nm) would still be able to escape through those capillaries and others with pores sizes much smaller than the vast majority of Carbocolor particles.

Carbocolor has a particle size similar to black iron oxide and as a result a similar amount of either pigment will migrate from a given concrete product. In addition, Carbocolor has a much greater degree of particle aggregation and agglomeration which will increase the effective particle diameter and reduce the amount of material that is able to migrate through the cement pores.

Accelerated Rain Simulation

Tests were performed on two sets of cement roof tiles containing 5% pigment levels of Carbocolor and black iron oxide, specifically BF 330. The tiles were exposed to rain at a rate of 1100 mm (43 inches) annually. The water had a pH of 5.4 to 6.0. The exposed tiles were tested using standard CIELAB methodology which measures the relatives strengths of the light/dark (L*), green/red (a*), and blue/yellow (b*) components. The color difference, reported as ΔE*, is calculated as below:

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

Comparative colour difference data of Carbocolor and iron oxide after exposure shows improved colour retention with Carbocolor as shown in Figure 2.

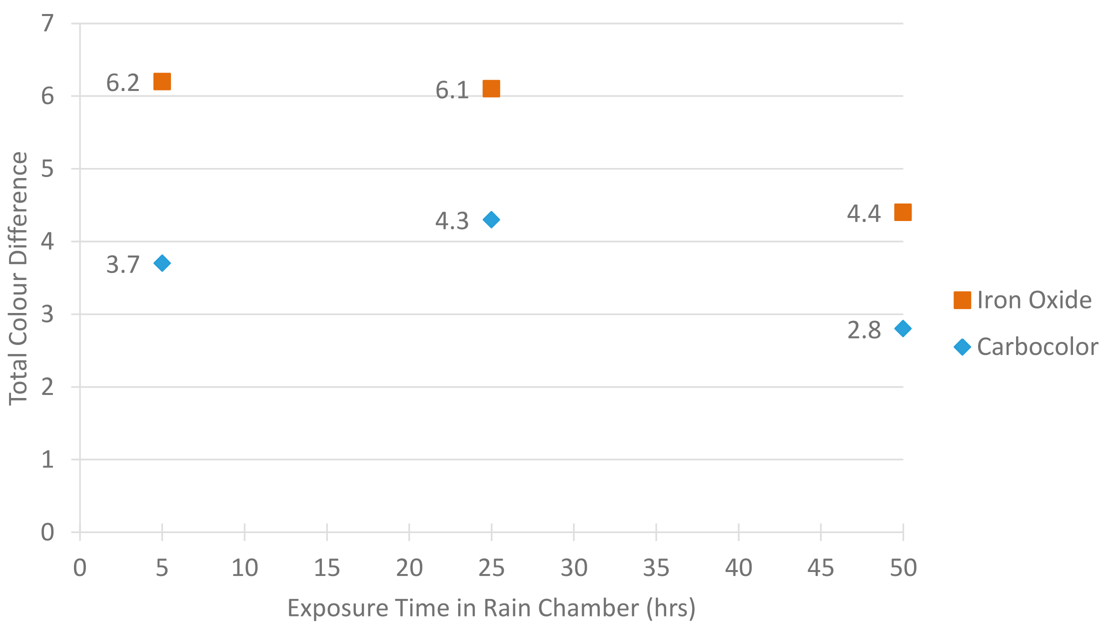

Figure 2. Total colour difference after accelerated rain simulation for Carbocolor and iron oxide. The exposure time of 25 hours is equivalent to 41 years of precipitation in Vancouver, Canada. The Carbocolor had significantly less total color change as compared to the iron oxide sample.

UV Light Stability

Comparative UV light resistance testing of Carbocolor and iron oxide over 500 hours showed the superior UV resistance of Carbocolor. In this case the following ASTM tests were performed:

- ASTM G53 – Practice for Operating Light Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials
- ASTM D2244 – Spectrophotometric Method of Measuring Color Differences in Exposed and Unexposed Specimens. Uses Illuminant D, Hunter Lab scale with specular component

In the Hunter Lab color space, L represents the dark-light component, a represents the green-red component, and b represents the blue-yellow component. It was found that differences in a and b were insignificant; thus the changes in L explained nearly all of the total colour differences (delta E) of the samples. The samples were not subjected to any weathering other than UV radiation.

Figure 3 shows a plot of delta E with respect to the pigment weight percentage. The tests demonstrate that Carbocolor® has superior UV light resistance characteristics in concrete, especially at higher loadings. Note the high degree of fading found in the uncoloured control sample; the fading of concrete alone could play a significant role in the fade resistance of the coloured samples.

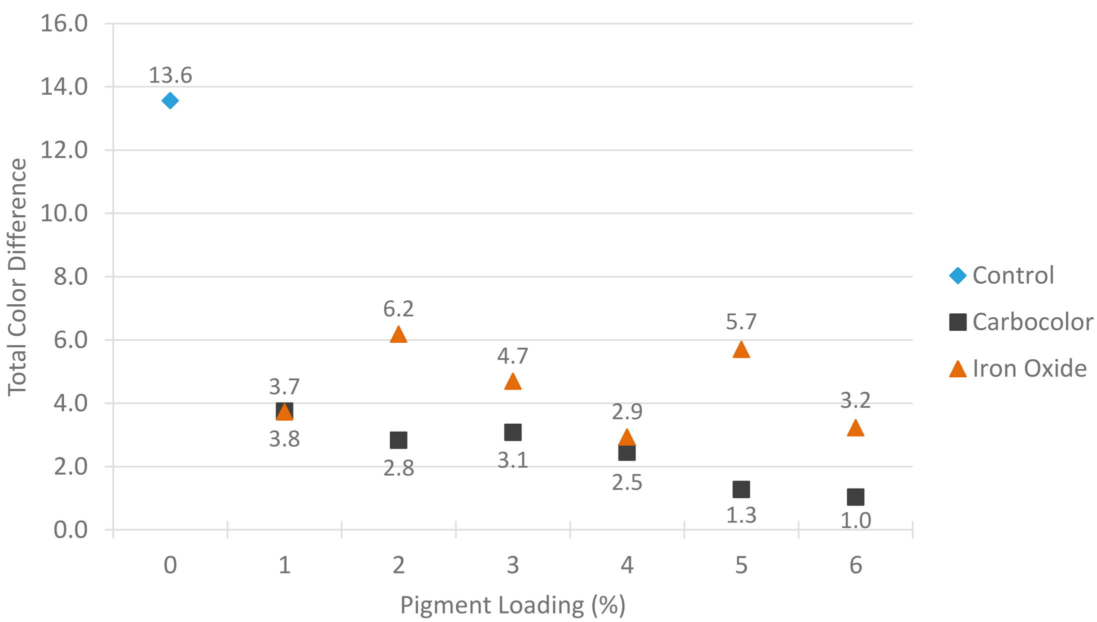

Figure 3. Total colour difference of Carbocolor and iron oxide versus loading after 500 hours of UV light aging. Carbocolor provided superior UV light resistance to the concrete.

Five Years Actual Weathering Stability

Cancarb exposed a concrete curb loaded with 4% Carbocolor for five full years in Medicine Hat, Canada. The environment includes extreme seasonal temperature differences (-40 to +38°C, -40 to +102°F), rapid temperature changes, snow, and, in the location where the curb was placed, weekly exposure to a lawn sprinkler system. In this case the exposed pieces were tested using standard CIELAB methodology.

The dry colour difference, reported as ΔE*, averaged 1.68 in duplicate samples. It is generally accepted that a visual difference can be seen when ΔE* is greater than 1.0. The automotive industry, widely recognized as setting the standard on colour change, considers ΔE* values of less than 3 acceptable on exterior and interior parts after two years of actual or accelerated aging. A ΔE* of 3 is considered to have an observable modest colour change, not a drastic change.

Pigmenting Capability of Carbocolor versus Iron Oxide

Figure 8 contains a photo depicting Carbocolor and 2 grades of iron oxide loaded at 3% in a portland cement mixture. The Carbocolor has a notably bluish tone versus the iron oxide. Further Carbocolor has a darker color as compared to the iron oxide at a similar loading.

Figure 4. Left to right: Carbocolor, iron oxide grade A, iron oxide grade B, and a reference blank. All coloured samples are loaded at 3% pigment.

Note that exact colour replication is difficult and will depend on the settings on your computer monitor, or if printed, the printer. Carbocolor appears darker than iron oxide on the original samples. Of note, maximum colour depth of the iron oxide is attained at 10% loading whereas Carbocolor achieves maximum colour near 6% loading.

The Effect on Cement Physical Properties

In Figures 4 to 6, it can be seen that Carbocolor has no detrimental impact on the compressive strength of concrete even at loadings up to 6%. Further, Carbocolor has minimal detrimental impact on air entrainment, as shown in Figure 7, unlike finer particle size carbon blacks which reduce the amount of air entrained.

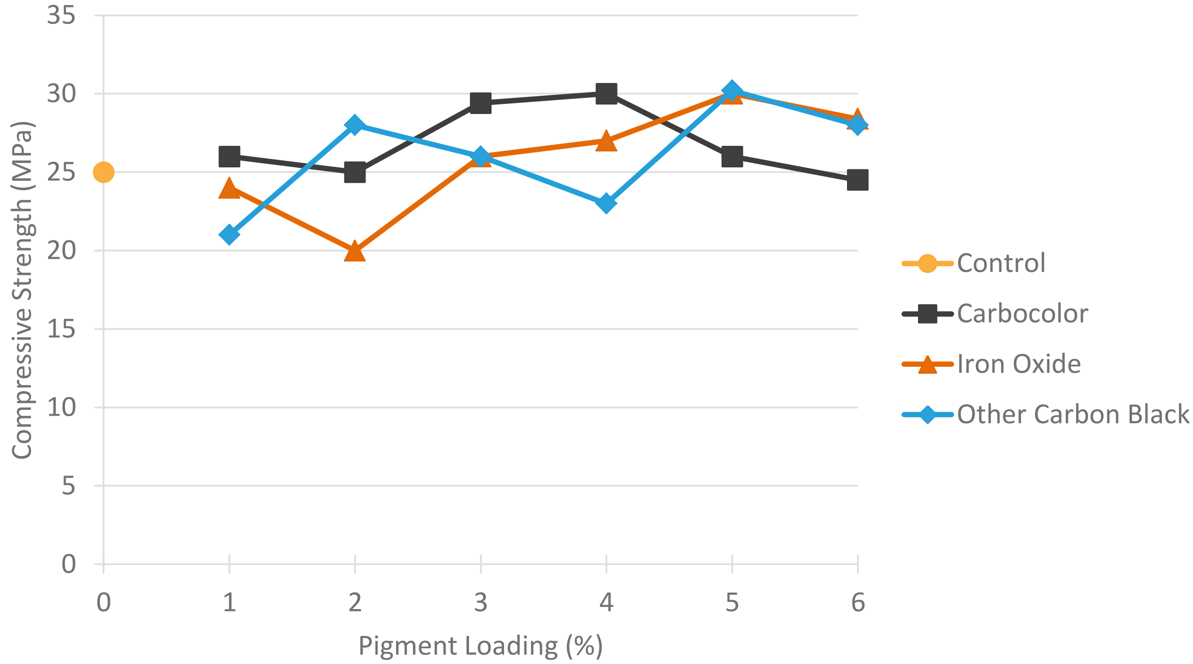

Figure 5. Concrete compressive strength after 7 days for three pigments at various loadings. Samples with Carbocolor had equivalent or higher compressive strength than the control with no pigment.

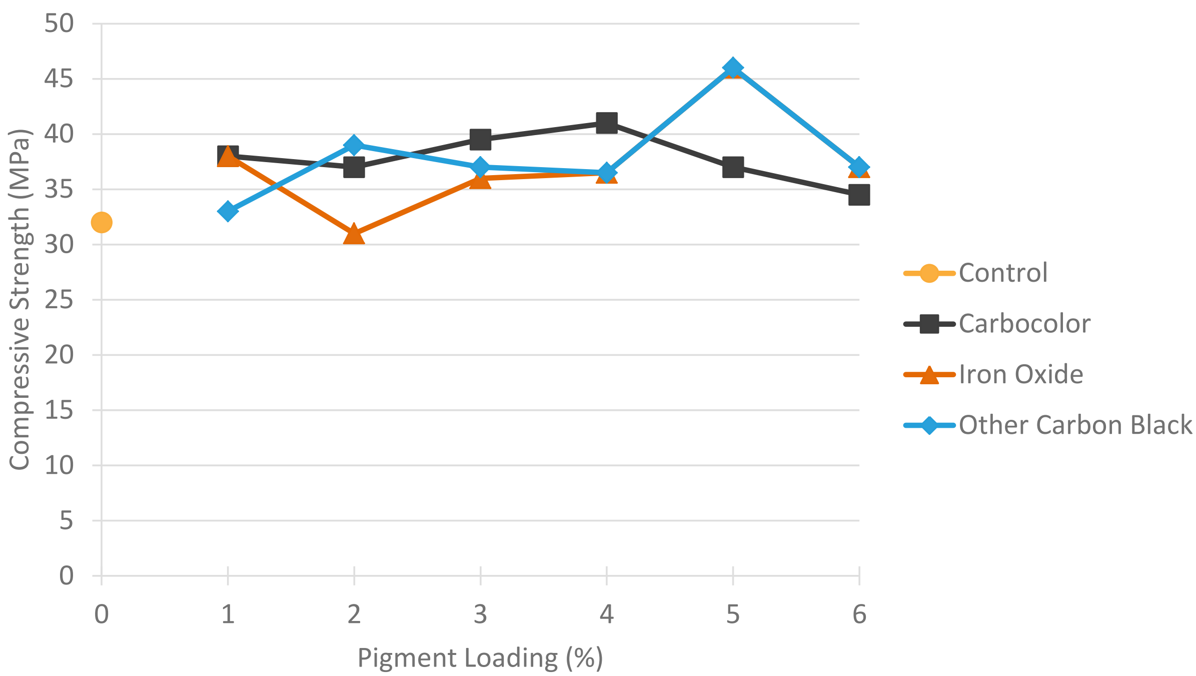

Figure 6. Concrete compressive strength after 28 days for three pigments at various loadings. Samples with Carbocolor had higher compressive strength than the control with no pigment.

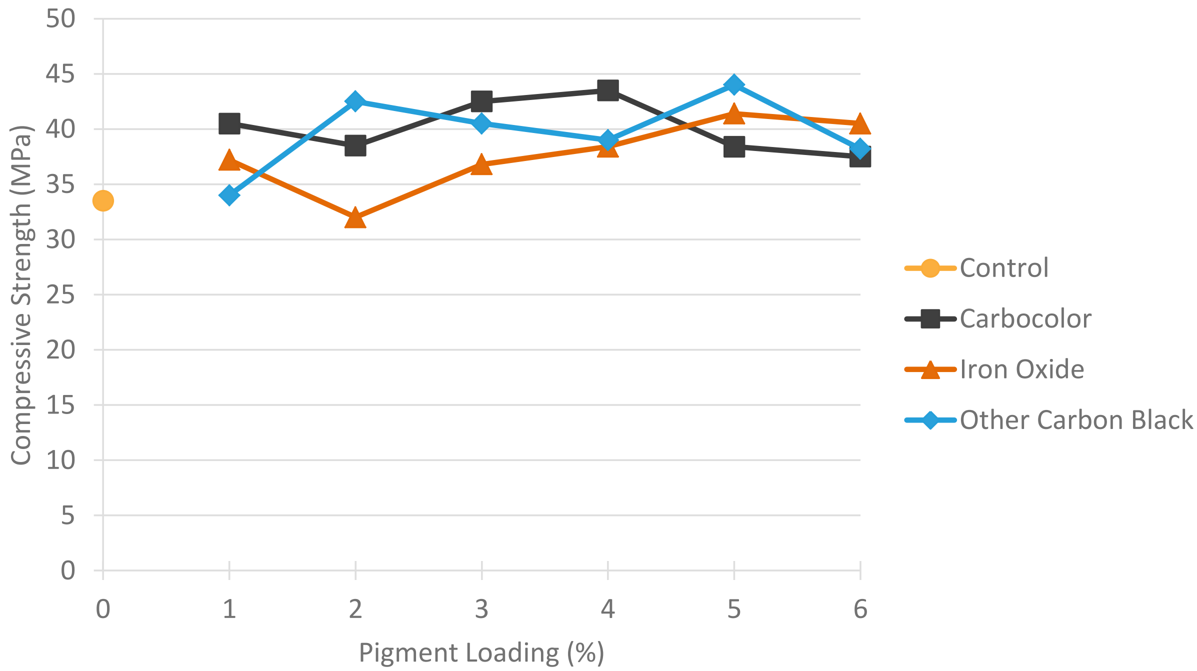

Figure 7. Concrete compressive strength after 40 days for three pigments at various loadings. Samples with Carbocolor had higher compressive strength than the control with no pigment.

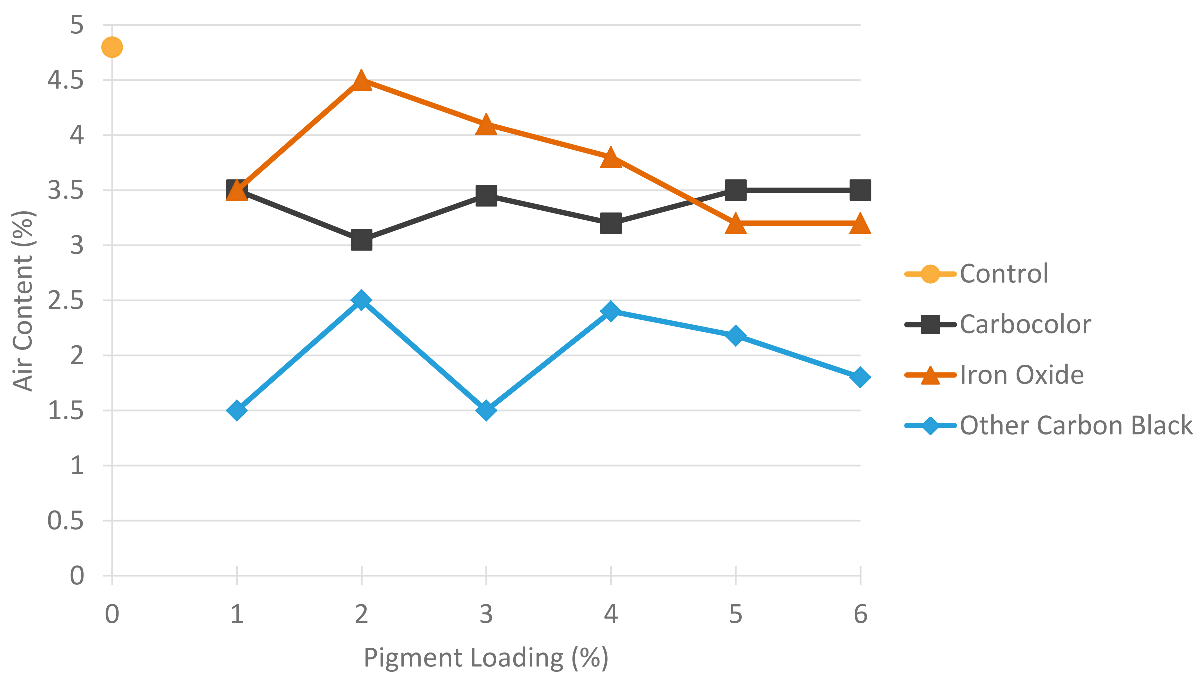

Figure 8. Air content of concrete for three pigments at various loadings. The addition of Carbocolor decreased the amount of entrained air slightly more than iron oxide at loadings between 2% and 4%. At loadings of 5% and 6%, Carbocolor had the highest air entrainment. The other carbon black had the lowest air entrainment across all loadings.