TECHNICAL Bulletin

Subject: Concrete Colourant II

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"CARBOCOLOR®" – AN ENDURING BLACK COLOURANT

Produced at Cancarb's ISO 9001 certified plant in Medicine Hat, Alberta, Canada, Carbocolor® is a specialty 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.

Cancarb Limited is the world's pre-eminent manufacturer of specialty carbon blacks. Cancarb's carbon blacks are produced via the high temperature cracking of natural gas, in the absence of oxygen. The process yields a product with large particle size and very stable surface chemistry. These features are unrivaled by other grades of carbon black, such as furnace or lampblack grades. Traditionally used in the rubber industry, Cancarb has used its experience and expertise to develop Carbocolor®, a product tailored to effectively compete as a stable black colourant in the construction industry.

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

cancarb
1702 Brier Park Cres. N.W. • Medicine Hat, AB, Canada T1C 1T8
Phone 1.403.527.1121 • Fax 1.403.529.6093

Carbocolor® vs. 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 (<0.06 microns) results in high colouring ability 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 lampblacks when aged.

Iron oxides have a 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 ultraviolet light, acids, alkalis or heat.

Carbocolor's® Mechanisms of Colour Retention

There are two mechanisms by which fading can occur in coloured concrete. The loss of a pigment from a concrete specimen will contribute to fading. The degradation of the very pigment itself can also cause fading.

The very nature of Portland cement renders the use of small particle carbon blacks impractical as pigments. Literature* indicates that there are several size classifications for pore structure in hydrated cement pastes. The designations have been divided into two categories: capillary pores and gel pores. Gel pores typically have diameters of less than 0.010µm, making them insignificant for most grades of carbon black. Capillary pores are subcategorized into large (0.05 - 10 µm diameter) and medium (0.010 - 0.050 µm diameter) sizes.

The large capillaries are inevitable escape routes for colourants. Carbocolor®, with a mean particle diameter of approximately 0.280 µm and some residual particle agglomeration after mixing, could still be retained in the "large" capillaries falling in that size category. A large fraction of furnace black grades such as N550 (0.056 µm) or N660 (0.067µm) would still be able to escape through the medium capillaries, at pore sizes much smaller than the vast majority of Carbocolor® particles.

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

*References: Mindess, S. and Young, J. F., *Concrete.* Prentice-Hall, Inc., Englewood Cliffs, New Jersey, pp.99 - 101

Carbocolor® - Evidence of Colour Stability

A.) Accelerated Rain Simulation

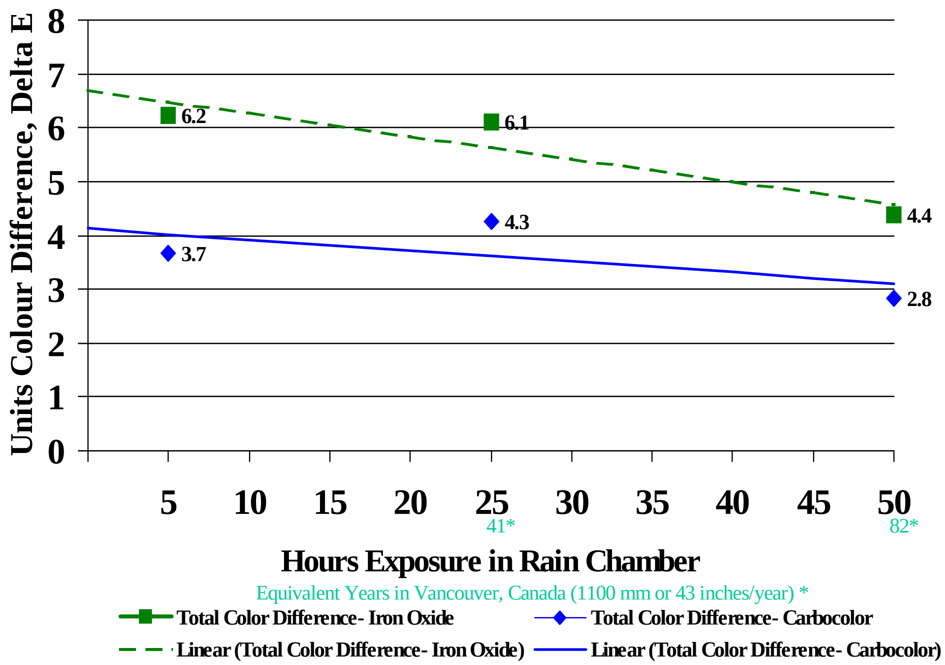
Tests were performed on two sets of cement roof tiles containing 5% colourant levels of Carbocolor® and black iron oxide, specifically BF 330. The tiles were exposed to rain at a rate of 1100 mm (43 inches) annually. The water had a pH at 5.4 to 6.0. The exposed tiles were tested using standard CIELAB methodology which measures the relative strengths of white/black (L), green/red (a) and yellow/blue (b).

The colour difference, reported as Δ E, is calculated as below:

$$\Delta E = (\Delta L^2 + \Delta A^2 + \Delta b^2)^{1/2}$$

Comparative colour difference data of Carbocolor® and iron oxide after exposure shows improved colour retention with Carbocolor® as shown in Figure 1.

Figure 1.
Total Colour Difference
Carbocolor and Iron Oxide
Accelerated Rain Simulation



B.) UV Light Stability

Comparative ultraviolet light resistance testing of Carbocolor® and iron oxide over 500 hours shows the strong UV resistance with 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 Colour Differences in Exposed and Unexposed Specimens. Uses Illuminant D, Hunter Lab scale with specular component.

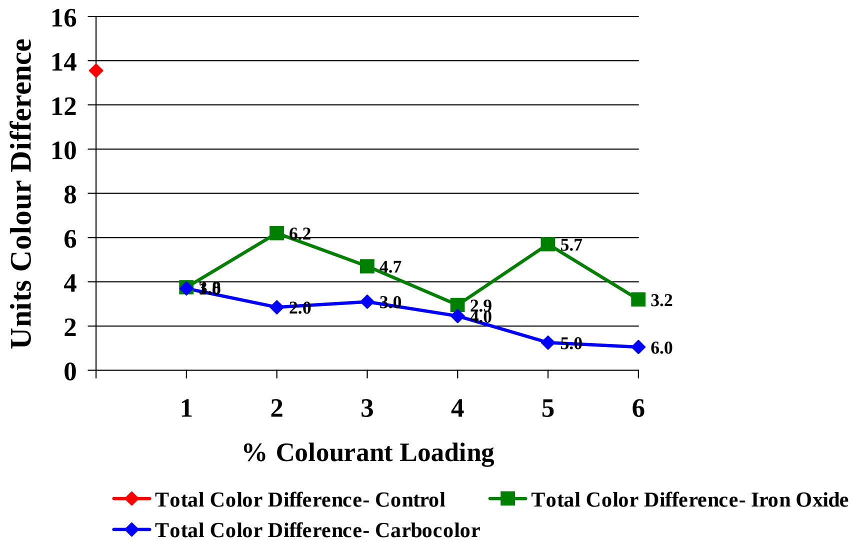
The test categories were:

DL darkness/lightness difference ("+"= lighter, "-"= darker)
Da red/green difference ("+"= more red, "-"= more green)
Db yellow/blue difference ("+"= more yellow, "-"= more green)
DC Total difference in chromaticity (colour without the effects of lightness/darkness)
DE Total colour difference

The data plotted is concerned primarily with DL and DE. The differences between DL and DE for a given sample are minimal, suggesting that the differences in Da, Db and DC have minimal impact on the total colour difference of the samples.

See Figure 2. The tests demonstrate that Carbocolor® has superior ultraviolet 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 2.
Total Colour Difference
Carbocolor and Iron Oxide
500 Hours UV Exposure

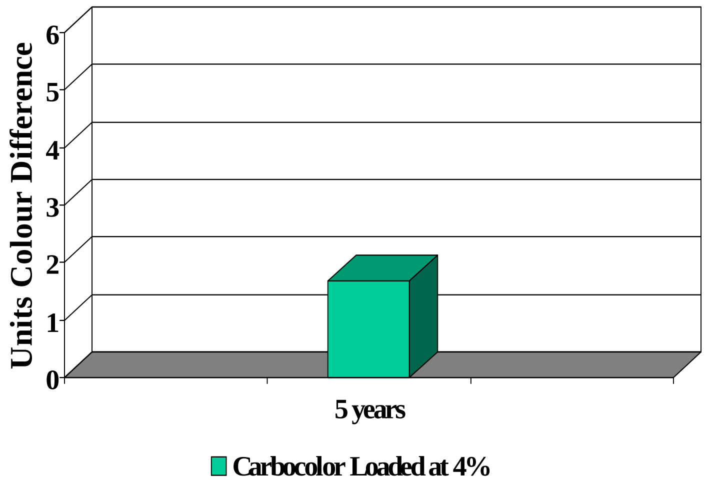


C.) Five Years Actual Weathering Stability

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

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

Figure 3.
Total Colour Difference
Carbocolor
5 Years Actual Weathering



Carbocolor® - The Effect on Cement Physical Properties

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, unlike finer particle size carbon blacks which reduce the amount of air entrained. See figures 4 to 7.

Figure 4.
Concrete Compressive Strengths
for Three Colourants at Various Loadings
7 Day Results

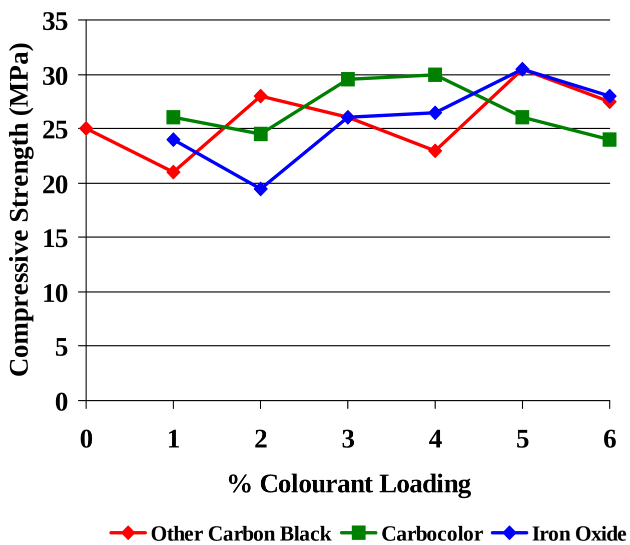


Figure 5.
Concrete Compressive Strengths
for Three Colourants at Various Loadings
28 Day Results

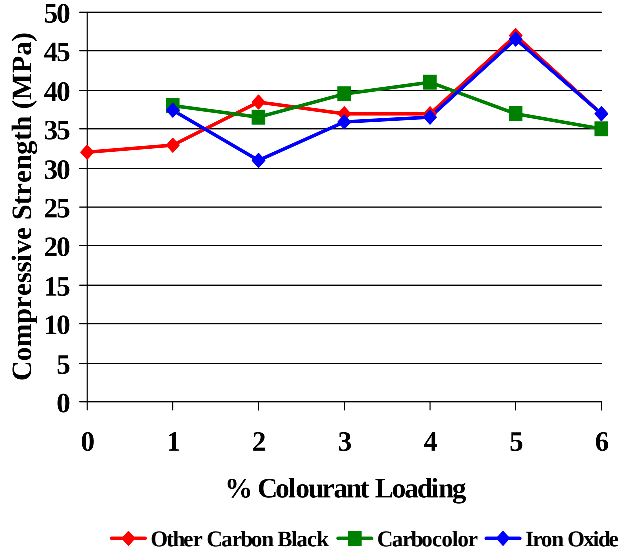


Figure 6.
Concrete Compressive Strengths
for Three Colourants at Various Loadings
40 Day Results

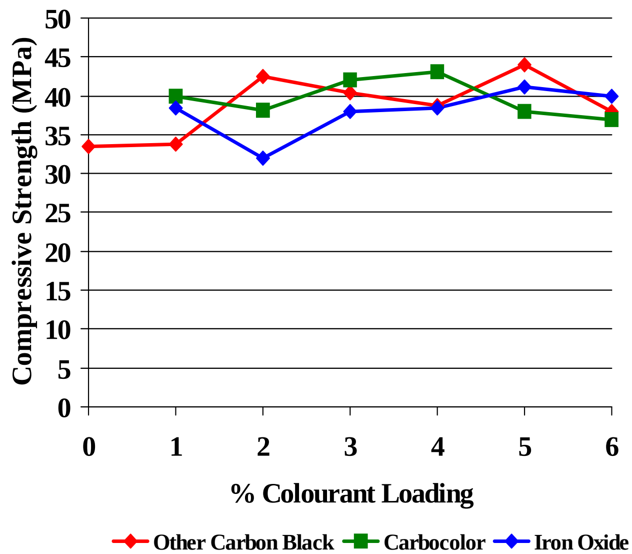
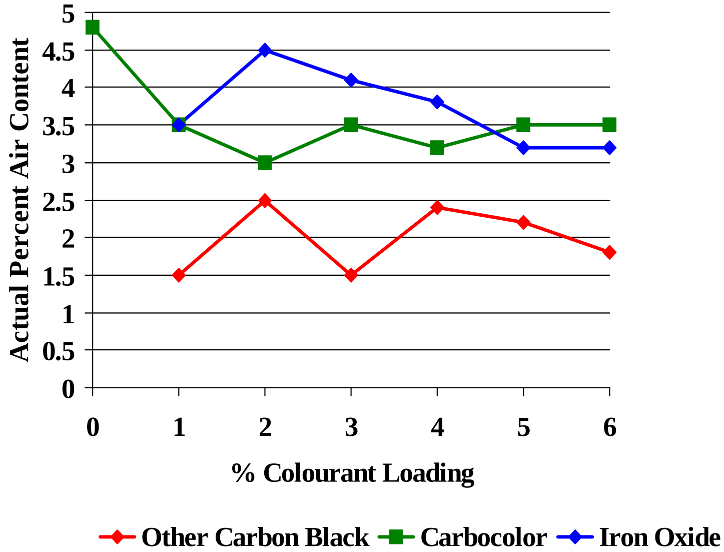


Figure 7.
Actual Air Content in Concrete
for Three Colourants at Various Loadings



Carbocolor® vs. Iron Oxide - Pigmenting Capability

The following photo depicts Carbocolor® and 2 grades of iron oxide loaded at 3% in a portland cement mixture. The Carbocolor® has a notably bluish tone vs. the iron oxide. Further, Carbocolor® has a darker color vs. these products at a similar loading.

From left to right: Carbocolor®, iron oxide grade A, iron oxide grade B and a reference blank. All coloured samples are loaded at 3% colourant.

Note that the 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% and whereas Carbocolor® achieves maximum colour near 6%.

For further information on this and other unique applications of Carbocolor®, contact Cancarb at + (403) 527-1121 or customer_service@cancarb.com.