Deep Purple and Rainbow Indicators

Purpose

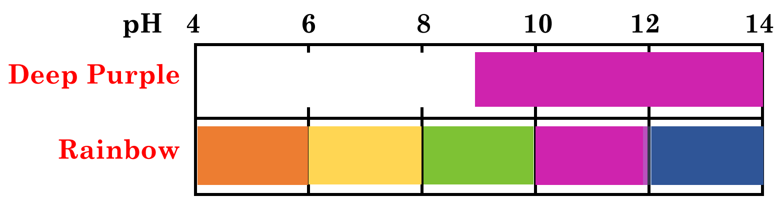
Deep Purple and **Rainbow Indicators** are used to determine the depth of carbonation in samples of field concrete by means of its pH. Carbonation depth can be used for the following purposes:

- To evaluate the cause of corrosion when conducting corrosion surveys
- To estimate service life where penetration of the carbonation front is critical
- To monitor the effectiveness of protective coatings, sealers or procedures for re-alkalization of the cover layer
- To make a rough estimate of concrete strength from the age of concrete and the relative humidity

Principle

The natural alkalinity of cement paste in concrete results in a protective oxide coating on steel reinforcement that prevents the steel from rusting. When carbon dioxide (CO_2) in the air penetrates into concrete, it reacts with the calcium hydroxide ($CaOH_2$) in the cement paste producing calcium carbonate ($CaCO_3$). This reaction is called **carbonation**, and it causes the alkalinity of the paste to decrease, that is, the pH decreases below its normal value of about 13. When the pH drops below 9, the protective oxide coating is destroyed and, in the presence of moisture and oxygen, the steel will corrode. Thus measurement of the depth of carbonation is an essential step for corrosion evaluation of a reinforced concrete structure.

To measure the pH of the cement paste, a freshly broken piece of concrete or a newly cut core is sprayed with the indicator, and allowed to dry. The approximate pH of the paste is indicated by a color index as illustrated below.



Accuracy

The carbonation front or depth of carbonation measured with the **Deep Purple Indicator** represents the traced line where the cement paste has a pH within the range of 8.5 to 9.5 as shown above.

The carbonation front measured with the **Rainbow Indicator** was correlated with the depth of carbonation determined by petrographic thin section analysis for a wide range of concretes with varying slump, with or without calcium chloride or fly-ash, different water-cement ratios, varying degrees of consolidation and different finishing methods:

Campbell, D.H., Sturm, R.D. and Kosmatka, S.H., "Detecting Carbonation," *Concrete Technology Today*, Vol. 12, No. 1, March 1991, Portland Cement Association, USA

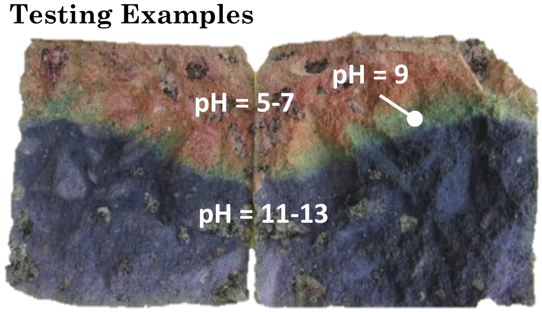
The results show that the depth of carbonation determined from thin section analysis correlated well with the depth where the **Rainbow Indicator** indicated a green color or pH of 9 as shown above.

On normal concrete, the depth of the carbonation front indicated by the Deep Purple Indicator can be determined with an accuracy of ± 10 % to ± 15 %.

One study with several mortar mixes exposed to accelerated carbonation showed that the standard deviation for measurements of depth of carbonation with the Rainbow Indicator is about 0.8 mm:

A. Belda, K. De Weerdt, M.R. Geiker, "Carbonation front characterization with pH colour indicators," 35th Cement and Concrete Science Conference, University of Aberdeen, Scotland (2015)

Testing Examples



The depth of carbonation evaluated by spraying the surfaces of a freshly broken core with the ***Rainbow Indicator****. Depth of carbonation varied from 27 mm to 41 mm.*

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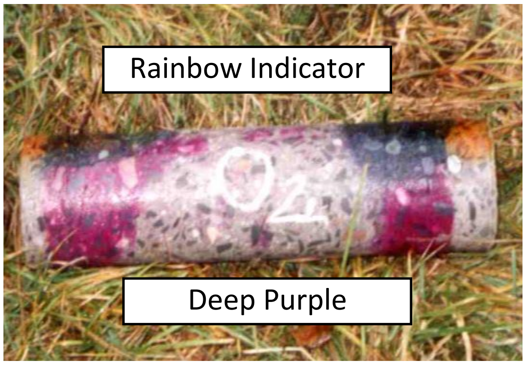
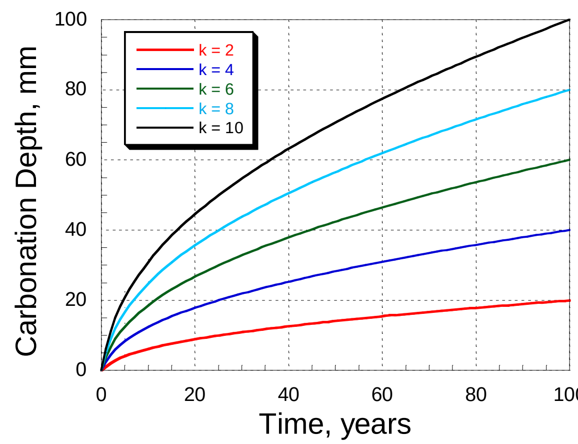


Shown in the photo to the left, the pH profile of a newly cut core was evaluated by the **Rainbow Indicator** (top of core) and by the **Deep Purple Indicator** (bottom of core). The core was drilled through the exterior beam of a bridge. Both indicators show that the depth of carbonation was greater on the right side of the core. The left side of the core was the exterior face of the beam, which was exposed to the weather. The right side of the core is the interior surface of the beam, where the environmental conditions were more favorable for diffusion of carbon dioxide and resulted in greater penetration of the carbonation front.

Carbonation Depth versus Time

The penetration of the carbonation front depends on many factors, such as the penetrability characteristics of the concrete, the in-place moisture content, and the CO_2 concentration in the environment. Penetration is slow in dry and wet concrete, and is greatest when the concrete has an internal relative humidity between 50 and 75 %. For a given concrete and constant exposure conditions, the depth of penetration of the carbonation front d_c, varies approximately with the square root of time.



$$d_c = k\sqrt{t}$$

The constant k depends on the factors mentioned above. The graph shows the depth of carbonation versus time for different values of k. If the depth of carbonation d_{c1} is measured at a time t_1 and it is assumed that conditions in the future will be similar to those in the past, the depth of the carbonation front at a later time t_2 can be approximated as follows:

$$d_{c2} = d_{c1}\sqrt{\frac{t_2}{t_1}}$$

Ordering Numbers

RI-7000 **Deep Purple Indicator**
Set of 4 spray bottles, 80 mL each

RI-8000 **Rainbow Indicator**
Set of 4 spray bottles, 80 mL each