Construction and Building Materials 105 (2016) 176–188

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

Methods for measuring pH in concrete: A review

Ali Behnood, Kim Van Tittelboom, Nele De Belie *

Magnel Laboratory for Concrete Research, Department of Structural Engineering, Faculty of Engineering and Architecture, Ghent University, Technologiepark-Zwijnaarde 904, B-9052 Ghent, Belgium

ARTICLE INFO

Article history:
Received 22 January 2015
Received in revised form 29 October 2015
Accepted 6 December 2015

Keywords:
Concrete
Alkalinity
Expression
Leaching
Electrode
Fibre optic
pH

ABSTRACT

pH is an important parameter to indicate the alkalinity level of concrete. The most severe concrete damages are caused or accompanied by dropping of the alkalinity level and consequently, decrease of the pH value of concrete. Therefore, it is crucial to measure the pH of concrete by an accurate and reliable method. This paper critically reviews the methods that have been developed for measuring the pH of fresh and hardened concrete. These methods are categorized in two broad divisions including destructive and non-destructive methods. The expression, ex-situ and in-situ methods are explained in detail as destructive methods, while the use of embedded potentiometric electrodes (mainly metal/metal oxide electrodes) and fibre optic sensors are evaluated as non-destructive methods. Also, advantages and drawbacks of each method are investigated and they are compared based on different technical and practical aspects. Despite the broad range of used methods for measuring the pH of concrete, there is no standardized test procedure. Because of the important role of pH with regard to durability of concrete structures, it is highly recommended that the required measures are taken to develop a specific standard test method for measuring the pH of concrete with a high level of accuracy, repeatability and reproducibility.

Contents

1. Introduction

In general, pH is one of the most important parameters which has to be measured in many works of analytical chemistry research. Therefore, many researchers have worked to develop different electrochemical and non-electrochemical measurement techniques. Vonau and Guth summarized experimental methods for measuring pH values as shown in Fig. 1 [1]. The

* Corresponding author.
E-mail address: Nele.DeBelie@UGent.be (N. De Belie).

http://dx.doi.org/10.1016/j.conbuildmat.2015.12.032
0950-0618/

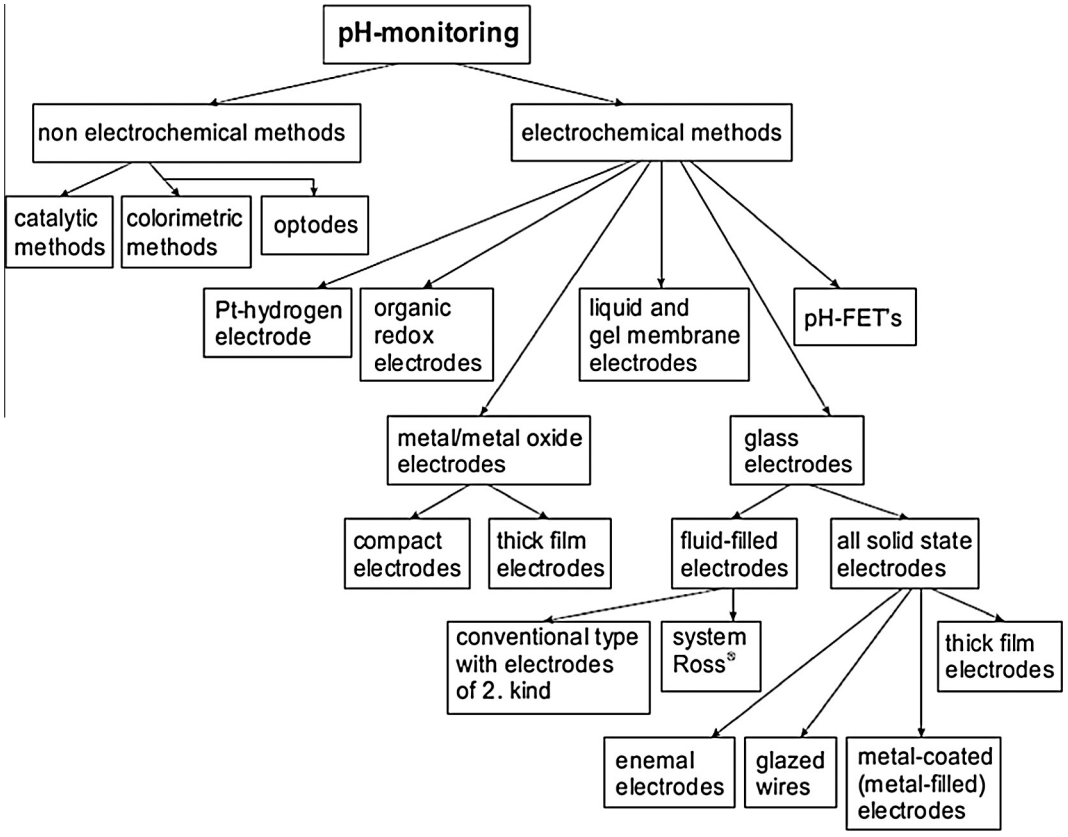

Fig. 1. A summary of experimental methods to measure pH values in analytical chemistry [1].

non-electrochemical methods were introduced earlier so that for example, Arrhenius developed his method based on the catalytic measurements in 1889 [1]. Furthermore, colorimetric methods which were broadly used previously are based on the colour change of an organic acid-system and are currently used in the optodes for measuring pH values [1].

On the other hand, the most crucial deterioration mechanisms of reinforced concrete structures including corrosion, carbonation and acid attack are related to the level of alkalinity of concrete. The pH, which is defined as the negative logarithm of the concentration of active hydrogen ions, shows the level of alkalinity of concrete under different conditions. The pH of ordinary Portland cement concrete is usually between 12.5 and 13 [2], but it can decrease due to deterioration mechanisms such as chloride ingress, carbonation or acid attack [3]. Chloride ingress into concrete can result in a pH reduction due to the formation of hydrochloric acid. Furthermore, the carbonation process, in which calcium hydroxide in concrete is transformed into calcium carbonate, can reduce the pH of concrete to values less than 9 [4]. The initiation of corrosion of embedded rebars in concrete can occur for lower threshold chloride concentrations when the pH of the concrete decreases as shown in Fig. 2 [5]. This process can accelerate destabilization of the protective passivation layer on the rebars and initiate corrosion in reinforced concrete elements [3]. Fig. 2 shows that a pH drop of concrete to values less than 11 in the vicinity of the rebars can result in initiation of active corrosion in the presence of nearly zero ppm of chloride ions [5].

Therefore, it is very important to measure the pH of concrete and many researchers have developed different methods for this purpose in concrete engineering. This paper critically reviews available methods for studying pH of concrete at different stages.

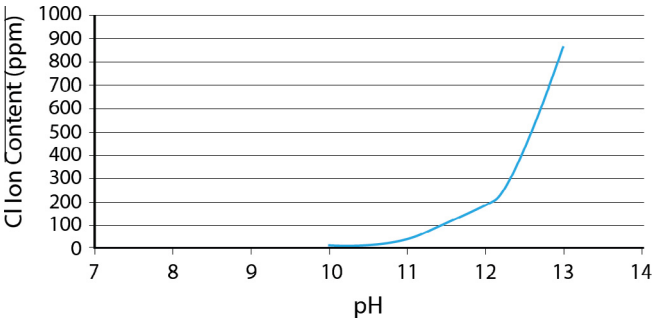

Fig. 2. Relation between the threshold chloride concentration and the pH of concrete for initiation of corrosion [5].

2. pH measurement methods for fresh concrete

Although most research has focused on the pH of hardened concrete, some researchers have evaluated pH variation of fresh concrete within the first hours after mixing which is usually around 13 and more for normal concrete with ordinary Portland cement (OPC) [2,6]. This can imply less importance of pH fluctuations of fresh concrete which has normally more predictable and almost constant behaviour compared to pH variations of the hardened concrete particularly under long-term deteriorations during the service life of the concrete structures. The pH of the fresh concrete can be estimated by direct applying the pH strips into the fresh mixture. However, this method is not reliable enough and might be useful only for rough estimation of the pH value of fresh concrete. Another method consists of directly inserting a low-alkali-error glass pH electrode which is the most common pH sensor on the market. However, this is not recommended due to the fragility