Construction and Building Materials 187 (2018) 984–995

Contents lists available at ScienceDirect

Construction and Building Materials

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

Performance evaluation of concretes having different supplementary cementitious material dosages belonging to different strength ranges

B.S. Dhanya [a,*], Manu Santhanam [b], Ravindra Gettu [b], Radhakrishna G. Pillai [b]

[a] Department of Civil Engineering, RIT, Government Engineering College, Kottayam 686501, India
[b] Department of Civil Engineering, Indian Institute of Technology Madras, Chennai 600036, India

HIGHLIGHTS

- Incorporation of SCMs affect strength and durability properties of concrete.
- *Performance indicators*, combining both strength and durability criteria, are developed.
- Limiting values of *Performance Indicators* are also suggested.
- Many options are available to get different levels of durability within a strength range.
- Within the same strength range, SCM mixes are more durable compared to pure OPC mixes.
- Database generated in this study can act as a guideline for material selection.

ARTICLE INFO

Article history:
Received 2 August 2017
Received in revised form 16 July 2018
Accepted 25 July 2018

Keywords:
Durability
Supplementary cementitious materials (SCMs)
Performance classification
Wenner 4-probe resistivity test
Rapid chloride permeability test
Water sorptivity test
Oxygen permeability index test

ABSTRACT

Production of durable concrete at lower strength levels is always a challenge for concrete technologists. One way to achieve this objective is by the use of Supplementary Cementitious Materials (SCMs). An attempt has been made in this paper to develop indicators called performance indicators, which combine both strength and durability criteria. Limiting values of these indicators are also suggested. Different mixes in the same strength range are classified into different performance classes based on these performance indicators. The durability parameters evaluated here include surface resistivity, charge passed, sorptivity index and oxygen permeability index. The database generated can act as a guideline for material selection and it demonstrates the potential of SCMs to improve durability.

1. Introduction

Concrete is the largest consumed man-made material. According to Richardson [1], the challenge before the engineering community is to produce sustainable concrete by combining different aspects such as strength, cost effectiveness and environment-friendliness. One way to achieve this goal is to make the structures more durable. Durability of concrete structures in a particular service environment depends mainly on three factors – the aggressiveness of the environment, the material used for construction and the construction practices. Control of the first factor is not possible. Thus, the plan for achieving durability in concrete construction should focus on material selection as well as on construction practice [2].

Traditionally, compressive strength is considered as the only crucial parameter to select a particular concrete. However, both research and practical experiences show clearly that strength and durability are not necessarily related [3–5]. Strength depends on the total porosity of the concrete, whereas durability depends on the pore interconnectivity [3].

Achievement of durability in high strength and high performance concrete is not that difficult as the microstructure in these types of concretes is well developed. Producing durable concrete at lower and medium strength levels is still a challenge. There is a distinct need to address durability in such concretes, as these are used for a variety of projects ranging from residential to infrastructure. The goal of achieving durability in low strength grade

* Corresponding author.
E-mail address: dhanyaavinod@gmail.com (B.S. Dhanya).

https://doi.org/10.1016/j.conbuildmat.2018.07.185
0950-0618/

concretes can only be realized by the use of Supplementary Cementitious Materials (SCMs). However, there is lack of clarity on how much is the extent of improvement in each of the durability parameters when SCMs are used. Thus, a combined study of all the durability parameters along with strength in the same concrete is highly essential.

Many researchers have attempted to study the above aspect. Ramezanianpour et al. [6] did a comparative study on the relationship between concrete resistivity, water penetration, charge passed in rapid chloride permeability test (RCPT), and compressive strength. The authors were able to get good correlation between resistivity and water penetration as well as resistivity and charge passed. However, they were not able to achieve any correlation between compressive strength and surface resistivity. The study by Burden [7], on concrete mixtures with different water to binder ratios and fly ash replacement levels, drew the conclusion that fly ash had greater influence on durability parameters than on strength. The tests conducted included compressive strength, RCPT and accelerated carbonation test. The author re-emphasized that strength is not a good indicator of durability. By contrast, in a correlation study between compressive strength and certain durability indices of plain and blended cement concretes, Al-Amoudi et al. [8] obtained good correlation between compressive strength and certain selected durability indices corresponding to chloride permeability and coefficient of chloride diffusion irrespective of the mix design parameters. This observation differs with other available literature. The binders used in the study included Type I cement, silica fume and fly ash. Indeed, most of the literature agrees to the fact that SCMs influence the durability parameters more compared to strength. The reasons for the same are due to the filler effect as well as pozzolanic reaction, which eventually leads to more tortuous pore structure and alterations in the pore solution chemistry [9,10].

Baroghel-Bouny [11] presented a performance based approach to evaluate and predict the durability of reinforced concrete structures. In this approach, the durability indicators (DIs) were classified into two, viz., universal indicators and complementary parameters. The universal indicators are basic physical and chemical properties that are directly related to transport properties and microstructural characteristics such as initial $Ca(OH)_2$ content, porosity, chloride diffusion coefficient, gas/liquid permeability etc. The complementary or optional parameters need to be evaluated many a times because they appear in many predictive models. Examples of such parameters include the surface chloride concentration, chloride-binding capacity etc. Potential durability classes corresponding to each durability indicator, such as very low, low, medium, high and very high were developed, which can be used as a tool for mixture comparison. Based on the above framework, a multi-level modelling concept by combining the durability indicators and physical/chemical models was proposed, which can be applied at four levels of sophistication [12]. The DIs were determined at different ages (28, 90, 120 and 180 days) on saturated concretes along with 28 day characteristic compressive strength values. Even though an overall correlation between chloride diffusion coefficients and 28 day compressive strength was reported, it was shown that mineral additives like fly ash can produce durable concrete at lower strength level, which violates the correlation.

Fig. 1 indicates the implementation of the performance approach based upon durability indicators, as proposed by Baroghel-Bouny [11].

However, this approach seems to be very complicated for practicing engineers as the evaluation of both universal indicators and complementary parameters suggested by the authors require sophisticated laboratory facilities. Further, combining the DIs measured at different ages (28, 90, 120 and 180 days) with 28 day compressive strength seems to be illogical. For engineering purposes, simple qualitative tables are more suitable rather than complicated models on quantification.

The current paper focuses on the influence of SCMs on the durability parameters of concrete belonging to different strength classes. The performance of 38 different concretes with 28 day mean strengths from 20 to 70 MPa was evaluated using compressive strength and four different durability tests. Initially, the mixes having the same strength range were classified based on their performance in durability tests. Later on, performance indicators were developed combining parameters such as strength, durability and mix design aspects.

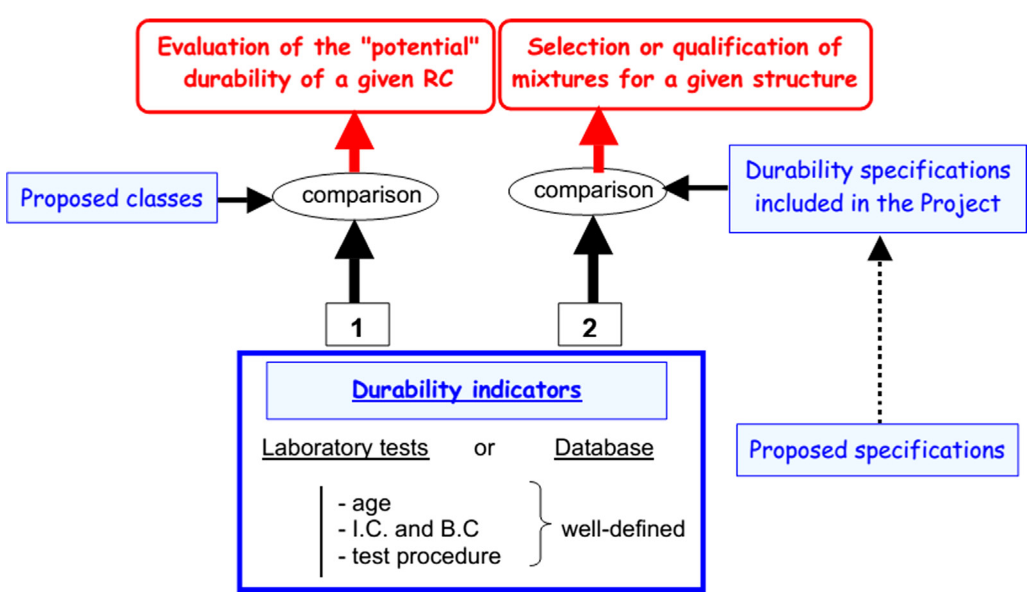

Fig. 1. Implementation of the performance approach based upon durability indicators proposed by Baroghel-Bouny [11].