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The use of Novel Non-destructive Methods for Quality Control and Performance Evaluation of Concrete Structures

Sree Nanukuttan
Queen's University - Belfast

Niall Holmes
Dublin Institute of Technology, niall.holmes@dit.ie

Sudarsan Srininvasan
Queen's University - Belfast

Lulu Basheer
Queen's University - Belfast

Muhammed Basheer
Queen's University - Belfast

See next page for additional authors

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Authors
Sree Nanukuttan, Niall Holmes, Sudarsan Srininvasan, Lulu Basheer, Muhammed Basheer, John McCarter, and Gerry Starrs

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Niall O. Holmes
DIT, niall.holmes@dit.ie

The use of novel Non-Destructive methods for quality control and performance evaluation of concrete structures

Sree Nanukuttan, Niall Holmes, Sudarsan Srinivasan, Lulu Basheer, Muhammed Basheer
*Queen's University, School of Planning, Architecture and Civil Engineering, Belfast, N. Ireland, U.K.; *Ph +44 28 9097 4218; *email: s.nanukuttan@qub.ac.uk*

John McCarter, Gerry Starrs
Heriot Watt University, School of the Built Environment, Edinburgh, Scotland, U.K.

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Abstract: Concrete cover provides the first line of defense against the ingress of many deleterious substances into the concrete. Therefore, a measure of its transport properties is vital in assessing its long term performance in a given exposure condition. In new structures the rate of ingress of the deleterious substances could be monitored using array of electrical sensors that are embedded in the cover concrete. For structures that are currently in service, tests can be performed by removing cores from the structure (lab based tests) or by using tests that can be performed on the surface (in situ tests). Results relating to few of the most commonly used lab based test methods are presented here along with two in situ permeability apparatuses, viz. Autoclam Permeability System (for measuring gas/water permeability and water absorption) and Permit Ion Migration Test (for determining rate of ionic ingress). Data from these test methods are further exploited using numerical models to predict the long term behaviour of structures exposed to chloride environment. The results from a long term study conducted at a marine exposure site presented in this document suggests that a combined approach of testing and modelling can be used to successfully to predict the long term behaviour of concrete structures.The abstract should summarize the contents of the paper and should contain at least 70 and at most 200 words. It should be set in 9-point font size, justified and should have a hanging indent of 2-centimenter. There should be a space before of 12-point and after of 30-point.

1 INTRODUCTION

The durability of reinforced concrete structures depends on their resistance to: (a) corrosion of reinforcement as a result of carbonation, chloride ingress and leaching, (b) freeze-thaw deterioration, (c) crystallization of salts in pores, (d) sulphate attack, (e) acid attack, (f) alkali attack, (g) alkali-silica reaction, (h) cracking in both the pre-hardening and hardened states, (i) fire damage and (j) abrasion (Basheer *et al*., 1996 and BCA 1997). As illustrated in Fig. 1, most of these mechanisms of deterioration are related to the microstructure and transport properties of the concrete cover (Basheer *et al*., 1996). This is due to the fact that environmental penetrations which cause damage to the concrete are influenced by the transport properties of the concrete cover. Therefore, it is desirable that concrete is tested non-destructively at the surface in order to assess the quality at the time of construction and the performance in service. Arising out of these need, the Autoclam Permeability System (Basheer *et al*., 1994) for measuring the sorptivity and the permeability and Permit Ion Migration Test hereafter mentioned as PERMIT (Basheer *et al*., 2005 and Nanukuttan, 2007) for determining the ionic transport of concrete were developed at Queen's University Belfast, UK.

Reinforced concrete structures can be made durable by resorting to appropriate design, selection and use of materials and construction practices. If an extremely high initial quality is achieved, this may lead to a performance history, as shown by curve 1 in Fig. 2. However, for most concretes, the performance history is such that the performance deteriorates gradually with time and not suddenly (and catastrophically) as shown by curve 2, but there is significant deterioration with time, and intermittent maintenance changes the performance level or alters the rate of change of the performance (curve 3). This necessitates the continuous monitoring of the condition of structures on site. That is, the main requirement of a monitoring and testing strategy is to measure the **'state of health'** of the building or the structure **'on completion'**, which can then be checked regularly during its **'life'** by further routine collection of data.

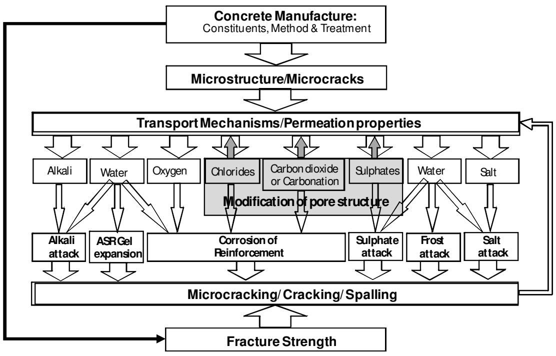

Fig. 1 Dependence of durability of concrete on microstructure and transport mechanisms

Ideally information collected before the extent of the problem becomes severe, i.e. in the initiation period, will be invaluable for the effective maintenance management of civil engineering structures (Fig. 3). The research at Queen's, hence, has considered the use of sensors which can be embedded in new constructions for monitoring the continuous changes of the cover concrete during the initiation period. Details of electrical resistance sensors developed at Heriot-Watt University, Edinburgh (McCarter *et al.*, 1995) and few results are included in this paper.

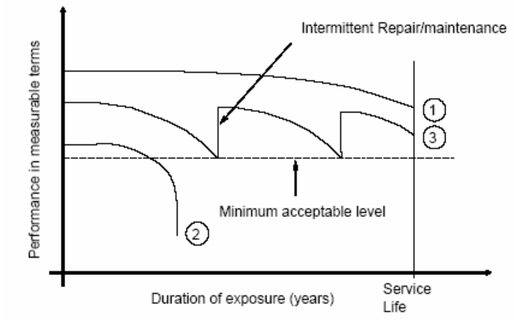

Fig. 2 Service life performance of reinforced concrete structures

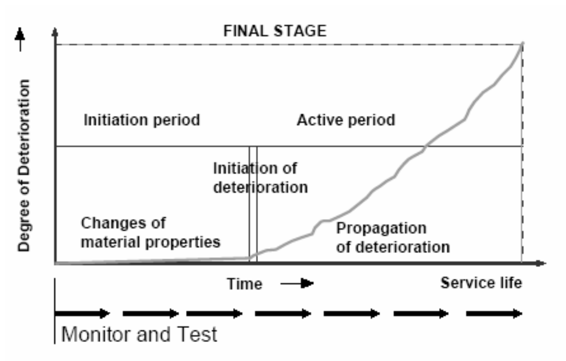

Fig. 3 Need for continuous monitoring of structures

The main objective of this paper is to summarize developments in testing and monitoring concrete for durability and illustrate how progress could be made in developing performance-specifications in terms of results from these test techniques.