Chapter 1
Introduction

H. Beushausen

1.1 Background to the Work of TC 230-PSC

For the design of concrete structures, durability and service life prediction have increasingly gained importance in recent years. This comes as a result of the inadequate durability performance of many reinforced concrete structures built in the past decades, which places enormous strain on construction budgets worldwide. The dominant cause of premature deterioration of concrete structures is reinforcement corrosion related to carbonation or chloride ingress. Traditional durability design approaches are based on prescribed limiting values for selected mix design parameters such as water/binder ratio, compressive strength and cement content. However, prescriptive mix design parameters fail to adequately characterize the concrete's resistance against carbonation or chloride ingress, because they ignore to a large extent the different performance of various binder types and of mineral components added to the cements or to the concrete itself, as well as the type of aggregate, and do not allow to take into account the influences of on-site practice during the construction process. Prescriptive approaches also cannot explicitly account for a rational service life requirement.

Performance approaches, in contrast, are based on the measurement of material properties that can be linked to deterioration mechanisms under the prevalent exposure conditions. The measurement of actual concrete material properties of the as-built structure allows accounting for the combined influences of material composition, construction procedures, and environmental influences and therefore forms a rational basis for durability prediction and service life design. Performance approaches can be applied in different stages and for different purposes, including design, specification, pre-qualification and conformity assessment of the as built

H. Beushausen (✉)
University of Cape Town, Cape Town, South Africa

© RILEM 2016

H. Beushausen and L. Fernandez Luco (eds.), *Performance-Based Specifications and Control of Concrete Durability*,
RILEM State-of-the-Art Reports 18, DOI 10.1007/978-94-017-7309-6_1

structure. Most test methods for the assessment of the structure's resistance against reinforcement corrosion are based on the quantity and quality of the cover concrete.

Transport properties of cementitious materials are key performance parameters for predicting the quality of the cover zone, since deterioration mechanisms such as chloride ingress or carbonation relate to the ease with which a fluid or ion can move through the concrete microstructure. The passage of potentially aggressive species (ions or molecules in the form of liquids and gases) is primarily influenced by the penetrability of the concrete. Penetrability is broadly defined as the degree to which the concrete permits gases, liquids, or ionic species to move through its pore structure. It embraces the concepts of permeation, sorption, diffusion and migration and is quantified in terms of the transport parameters. Various methods for testing concrete penetrability properties of as-built concrete structures have been developed worldwide, some of which have for many years already been successfully used not only for research, but also for durability specifications and quality control.

An important driver for producing performance-based approaches is the increasing development and use of innovative and new concrete types and constituent materials. Prescriptive requirements often fail to resemble the durability characteristics of modern concrete types and hinder innovation and economic design and construction. Further, based on the often premature deterioration of concrete infrastructure built in the past decades, owners of structures are increasingly reluctant to accept black-box construction solutions and are beginning to ask for technical proof that their structure can meet service life requirements. In this respect, one of the advantages of performance-based design specifications is that the quality of the as-built structure can be evaluated and actions can be taken in case of non-conformity, i.e. in case the as-built structure does not meet the specified limiting values for durability characteristics.

Performance-based approaches for concrete structures are not limited to durability characteristics and have for many decades already been successfully applied, for example for mechanical properties. The most widely accepted performance approach for concrete is that for compressive strength, which was developed some time in the early part of the 20th century. Prior to that time, strength was controlled through the specification of limiting w/c ratios, which is similar to the traditional and still widely applied prescriptive design approaches for concrete durability. The implementation of compressive strength as a clearly defined performance criterion enabled not only economic design but also created a very efficient quality control tool for construction quality. The same can be expected from the implementation of performance approaches for concrete durability.

The principle of performance-based design and quality control for concrete durability has been subject to significant worldwide research efforts for more than 25 years and the literature reports on many examples of successful implementation. The work of this TC 230-PSC is largely a follow-up from the work done by RILEM TC 189-NEC (Non-destructive evaluation of the penetrability and thickness of concrete cover), chaired by Roberto Torrent. TC 189-NEC published a State-of-the-Art Report in 2007 [1], concluding that several suitable test methods exist to characterize the penetrability, and hence the durability, of in situ concrete in a statistically significant manner.

In engineering practice, performance approaches are often still used in combination with prescriptive requirements. This is largely because, for most durability test methods, sufficient practical experience still has to be gained before engineers and owners are prepared to fully rely on them. In this respect, the exchange of relevant knowledge and experience between researchers and practitioners worldwide will help to successfully build the foundation for the full implementation of performance-based approaches. This State-of-the-Art Report, produced by RILEM TC 230-PSC (Performance-Based Specifications and Control of Concrete Durability), is intended to assist in such efforts.

Important aspects to consider for development and implementation of performance-based design approaches for durability include service life prediction models, deterioration mechanisms, performance test methods and their application, interpretation and limitations, responsibilities of owners, engineers and contractors, and appropriate actions in case of non-conformance to design specifications. This report addresses these issues and presents practical guidance for the selection and application of suitable test methods, statistical analysis, and interpretation of data.

1.2 Terminology

The authors of the various chapters adopted a standard terminology, as outlined in the following paragraphs. The suggested terminology relates to the specific case of durability of concrete with respect to the resistance against reinforcement corrosion. The mentioned terms may have different/additional meanings for other aspects of material technology. Definitions given in EN-206-1:2000 [2] have been added where relevant.

1.2.1 Compliance Assessment

Compliance assessment refers to the quality control of the as-built structure, with the aim to establish if specified performance criteria have been met. This involves experimental investigations on the structure, or on samples removed from the structure, or on laboratory-cured specimens made from the same concrete batch as the one used in the structure.

1.2.2 Designed Concrete

Concrete for which the required properties and additional characteristics are specified to the producer who is responsible for providing a concrete conforming to the required properties and additional characteristics (EN 206:2013, [2]).

1.2.3 Deterioration Model

A deterioration model allows predicting concrete deterioration over time. In the scope of this publication this commonly links to the analytical or numerical modelling of chloride ingress or carbonation.

1.2.4 Durability Indicators

Durability indicators are measurable material properties that can be used to predict the concrete's resistance against deterioration. Most commonly, these include transport properties or results from performance simulation tests.

1.2.5 Durability Potential

The durability potential of a certain concrete mix composition is established in the laboratory through experimental investigations of durability indicators, which is commonly done under near-ideal conditions for production processes and curing conditions. The as-built concrete structure may not achieve the full durability potential of the concrete, due to the influences of on-site workmanship and environmental conditions.

1.2.6 Initial Test

> Test or series of tests to check before the production starts how a new concrete or concrete family shall be composed in order to meet all the specified requirements in the fresh and hardened states (EN 206:2013, [2]).

1.2.7 Non-destructive Test

A test to quantify a specific concrete material property on an in situ structure without affecting the serviceability of the structure.

1.2.8 Non-invasive Test

Once the testing has been completed, a non-invasive test does not leave any evidence of the testing on the structure (such as holes, surface damage, surface contamination, or surface discolouration).

1.2.9 Performance-Based Design for Durability (General)

Performance-based design for durability involves the assessment of relevant material properties of a specific concrete through experiments, analytical modelling, numerical modelling, or experience in order to predict the concrete's resistance against deterioration for a certain period under certain environmental exposure conditions.

1.2.10 Performance-Based Design for Durability (Specific to This Publication)

In the scope of this publication, performance-based design for durability involves the assessment of relevant concrete properties through experimental investigations in the laboratory as well as on-site.

1.2.11 Performance Criteria

Performance criteria are limiting material parameters or properties that are established in the design process, usually linked to the concrete's resistance against chloride ingress or carbonation. Typical performance criteria in the scope of this publication refer to durability indicators.

1.2.12 Performance Simulation Tests

In the scope of this publication, performance simulation tests encompass the direct measurement of the concrete's resistance against the ingress of chlorides or the progress of carbonation, typically under accelerated conditions, i.e. under the influence of an artificial environment with chloride or carbon dioxide concentrations higher than those usually existent in real exposure conditions.

1.2.13 Prescribed Concrete

> Concrete for which the composition of the concrete and the constituent materials to be used are specified to the producer who is responsible for providing a concrete with the specified composition (EN 206:2013, [2]).

1.2.14 Prescriptive Design for Durability

Prescriptive design for durability involves the specification of limiting values for constituent materials and mix design parameters, typically covering binder type, compressive strength, water/binder ratio, and binder content in relation to the environmental exposure class, cover depth, and required service life. The concrete is assumed to be durable for the specified service life when these prescriptive specifications are met.

1.2.15 Pre-qualification

Pre-qualification refers to the assessment of relevant concrete properties in the design process (prior to construction) in order to establish suitable concrete types and mix compositions for a given environmental exposure and required service life.

1.2.16 Producer

> Person or body producing fresh concrete (EN 206:2013, [2]).

1.2.17 Semi-invasive Test Method

A semi-invasive test method leaves evidence of the testing on the structure (such as core or drill holes, minor surface damage, uncritical surface contamination, or surface discolouration).

1.2.18 Service Life

> The period of time during which the performance of the concrete in the structure will be kept at a level compatible with the fulfilment of the performance requirements of the structure, provided it is properly maintained (EN 206:2013, [2]).

1.2.19 Service Life Model

A model for the prediction of the service life duration of concrete structures, based on deterioration models and limit state criteria such as corrosion initiation or propagation, damage indicators, etc. Service life models may have numerous input parameters such as material properties and mix proportions, durability indicators, environmental conditions, protective measures such as stainless reinforcing steel and concrete surface coatings, corrosion inhibitors, etc.

1.2.20 Specification

> Final compilation of documented technical requirements given to the producer in terms of performance or composition (EN 206:2013, [2]).

1.2.21 Transport Properties

Concrete transport properties relevant to the scope of this publication include permeability, absorption, electrical resistivity, and conductivity, and are mostly used to predict/model the concrete's resistance against the ingress of harmful substances, such as chlorides or carbon dioxide.

1.2.22 User

> Person or body using fresh concrete in the execution of a construction or a component (EN 206:2013, [2]).

1.2.23 Verification

> Confirmation by examination of objective evidence that specified requirements have been fulfilled (EN 206:2013, [2]).

References

1. Torrent R, Fernandez Luco L (editors). Non-destructive evaluation of the penetrability and thickness of the concrete cover. France: State-of-the-Art-Report, RILEM TC 189-NEC, RILEM Publications S.A.R.L.; 2007. 223 pp.
2. EN-206:2013. Concrete: specification, performance, production and conformity. European Standard, CEN; 2013.