Civil Engineering Research Journal
ISSN: 2575-8950

Juniper Publishers
key to the Researchers

Opinion
Volume 9 Issue 4 - January 2020
DOI: 10.19080/CERJ.2020.09.555769

Civil Eng Res J

Transition to Specifying Concrete Durability by Performance

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Submission: December 13, 2019; **Published:** January 03, 2019

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Abstract

It is unrealistic to believe that the transition from the current method of specifying concrete durability can be achieved in a single step. A series of incremental changes are needed to develop confidence and provide time to resolve the outstanding issues mainly related to the performance in a standardized test compared with the performance in the real environment. An opinion on an appropriate first step is given.

Keywords: Concrete; Concrete structures; Durability; Performance-criteria; Specification

Introduction

The European Standards Committees for concrete design, construction and materials have agreed that they should move towards the specification of durability by performance. There are several good reasons why such a development is thought to be essential:

a. On a general move to a "circular economy" approach, the range of types of constituents is increasing with concrete being seen a 'green' outlet for recycled and secondary materials. While this is reasonable, it must not be at the cost of durability.

b. The current experience-based empirical provisions do not always provide the most sustainable solution as they are often over-designed, i.e. the durability performance of reinforced concrete often exceeds the working life of the building it supports.

c. Durability depends on more than the selected cement/binder type and proportions. Other factors that influence durability are aggregate type and fines content (enough to give a closed structure) where these are often not considered.

d. The national provisions in Europe for the same exposure class vary widely [1].

A proposal on how to implement such a system was advanced by the chairmen of the relevant CEN committees. Durability was to be specified by Exposure Resistance Classes (ERC) and performance-criteria in reference test methods are to be specified. In addition, deemed-to-satisfy (ERC/DtS) limiting values and constituents based on performance in the reference test methods were to be provided. The plan was to" phase out" the current system in Europe that is based on national deemed-to-satisfy limiting values and constituents (NAT/DtS), which are based on local experience as giving the intended design service life.

While moving towards the specification of durability by performance was agreed unanimously by the various committees, what was not stated but assumed (at least by the author) that such a system:

a) would have the same relationship in the reference test with reality for all types of constituents.

b) be based on initial testing and conformity testing that can be completed in a reasonably short period.

c) that the cost of testing would be reasonable.

Before expressing an opinion on what is the right approach to develop, the following section is a brief summary of current European experience with performance testing.

Current Experience in Europe with Performance Testing

In most special (major) projects in Europe there is usually some durability performance testing of concrete before the works start. It varies with the project, but chloride resistance, freeze-thaw resistance and temperature rise are common and usually part of the initial testing. The test methods vary as do the performance criteria. Performance testing during production is less common,

but it has been used on a few projects. The European concrete standard, EN206 [2], was drafted for normal structures, but it is also used for special structures via, for example, the specification clause 'Other technical requirements'. The current standard has never been a barrier to having performance criteria added to a specification, but the current activity is to specify durability in performance terms for normal structures permitting conformity to be based on conformity to specified limiting values and constituents (conformity to the ERC/DtS values). There is a strong push to change this to limiting values and constituents defined at national level (NAT/DtS). Currently, except for Switzerland, performance testing for normal structures is not the norm. Some years ago, Switzerland only permitted a very limited range of the types of constituents that had been standardized in Europe. They also had extensive accelerated test data on the concretes they had been using. Using this accelerated test data as the benchmark, they introduced a system for all concretes that included initial and routine performance testing plus limiting values while extending the range of permitted types of constituents. When the Swiss approach was considered as the framework for a European system, there were objections to having to prove the performance of concretes that had already been proven over decades of experience, and at a more fundamental level, there is the desire to base performance on absolute criteria, e.g. a defined end of the design service life, and a minimum reliability based on modelling.

Basis for the system under development in Europe

A complete system requires all the following elements:

A. design working lives of different types of structures- in general these are already defined in the structural codes for the evaluation of mechanical actions.

B. Exposure Classes related to the form of deterioration.

C. concept of minimum cover and nominal cover.

D. the reliability index for the system (beta value) which, as for structural safety, defines the probability of achieving a given level of deterioration at the end of the design working life.

E. what event defines the end of design working life.

F. test methods.

G. criteria for concrete.

H. modelling to assess the impacts of exposure variability and test precision.

I. allowances for uncertainties.

The first four elements of a system are already covered by the Eurocodes [3,4]. The other elements are under discussion. You cannot have a performance-based system without standardized test methods with known precision. The test result when used in a model should give results that reflect reality, and this is not always the case e.g. with current carbonation tests [5]. Solutions are being sought. For practical reasons there is the need to obtain a test result in a reasonably short period and this indicates that accelerated testing is required; however, the relationship between accelerated tests and what is regarded as being the reference methods is not good, e.g. between the chloride migration test and the chloride diffusion test. In Europe there is still not consensus on test methods for certain types of performance, e.g. sulfate resistance. Test methods is still an area where more research is needed. Let me put this into context. When we moved from nominal mixes, e.g. 1:2:4, to specifying by compressive strength, it took many years to resolve all the issues with respect to the compression test much of it at the Cement & Concrete Association in the UK. Now specification by strength is the norm. In a similar way resolving the issues with performance tests will take time; however, if we wait until all the issues with respect to test methods are resolved, progress will never be made with the specification of durability by performance.

In Europe it has already been accepted that for resisting corrosion of reinforcement, the durability will be specified in terms of Exposure Resistance Classes. A new system was required to facilitate the trade-off between minimum cover for durability and concrete quality, but for this purpose a system where durability is specified by performance is not necessary, see for example BS 8500-1[6]. Nevertheless, using the ERCs is a convenience way of specifying the requirements to the concrete producer.

Opinion on the Way to Progress

In the opinion of the author, it is unrealistic to believe that the transition to a full performance-based specification for durability can be achieved in a single step. It will require a series of incremental changes to develop confidence and resolve any problems that may arise. Another factor is that no standard body uses performance-based criteria for durability without back-up limiting values, and even if they did so it is highly likely that the specifier would add their own limiting values on the basis that they tend to include their standard specification clauses. Standardization should not be considered a platform for trying out innovative ideas but a reflection of best current practice. In theory performance criteria should not require back-up limiting values but is there complete confidence in there being no way to design a concrete that will pass the test but not perform adequately in the real environment. Until such confidence is achieved, having back-up limiting values is a prudent precaution.

Only by use will the technical issues be identified and consequently steps are required that use the test procedures, but procedures and criteria are set where the risks of a serious problem are acceptably low.

The author is not keen on the proposal to phase out the current experience-based system as both test methods and modelling

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are simplifications of reality. The current approach to specifying durability is based on experience and engineering judgement with what works in the local environment and, in the author's opinion, this should remain the main method for satisfying the specified ERC; however, in addition performance criteria based on accelerated testing should be introduced into the concrete standard for the following situations:

a. where the concrete is to contain a type of constituent that is outside of local experience.

b. where there is doubt over whether the intended performance will be achieved, e.g. the carbonation or freeze-thaw resistance of a concrete with low Portland clinker content and a high proportion of secondary aggregates.

c. where the binder/fines content is so low it might not give a concrete with a closed structure.

d. to prove that a concrete will still give an adequate performance when the specified limiting values are relaxed.

The performance should be proven by initial testing and conformity of production be based on conformity to the limiting values. This first step might be not going far enough by some and going too far by others, but it will provide a basis where experience and confidence in performance testing can be developed.

Conclusion

The transition from the current approach to specifying concrete durability to a performance-based approach should be achieved in a series of steps. Test methods and modelling are simplifications of reality and criteria based on this approach should not be given a higher status than criteria based on experience in the local environment. While experienced based criteria should remain the main way of satisfying a specified ERC, provision should be made for initial testing using performance-based criteria as there are circumstances where proof of performance is appropriate.

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