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PERFDUB : A FOUR-YEARS RESEARCH PROJECT TO MAKE A PERFORMANCE-BASED APPROACH OPERATIONAL IN FRANCE

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Abstract

Today, the applied code and standards in France and in Europe for structural concrete are based on a prescriptive, means deemed-to-satisfy approach . Requirements related to durability are linked to exposure classes defined in the European concrete standard (EN 206). According to each exposure class, limiting values for composition of concrete are given, which can be different from one country to another depending on its experiences.

The main objective of the National Project PERFDUB is to set up a methodology for justifying durability of concrete (and concrete structures) with a performance-based approach and to make it operational.

To achieve this objective and despite twenty years of research on durability of concrete structures, many obstacles have still to be tackled such as: lack of suitable and practical test methods to measure durability-related properties, identification of performance thresholds resulting in targeted service life, reliability of service life models, various variabilities such as aging, spatial variability and curing effect, and commitments and responsibilities of the various stakeholders.

This methodology is intended to be applied for job sites for which a specific level of quality assurance is provided. The field of research deals with new structures but is also interested in old structures in order to link pathologies where ageing is observed to the type of concrete and its sustainability features.

The present article gives an overview of the technical program of PERFDUB research.

1. INTRODUCTION

In the last two decades, many researches on concrete structure durability and service life modelling have been conducted [1-4]. Despite that many improvements in understanding basic mechanisms have been achieved, the way to apply a Performance Based Approach (PBA) has still not emerged except in few places. Different reasons can explain this situation, among others the very wide diversity of performance tests used worldwide, each country having their own experiences and references.

In France, several durability indicators and performance tests have been developed starting in the 90s. On one hand, durability indicators – defined as measurable material properties that

can be used to predict the concrete’s resistance against deterioration - are an indirect but practical way to estimate the concrete’s performances. On the other hand, performance simulation tests are often more representative (even if they are accelerated) of the real mechanisms occurring in the selected exposures.

Today, the design rules in Europe for structural concrete are based on a deemed-to-satisfy approach described in EN 206. It gives for instance some indications on a minimum cement content, a maximum water to cement ratio to obtain the desired service life, fixed to 50 years.

If service lives beyond these 50 years have to be achieved for some outstanding constructions, or if for sustainability reasons alternative materials such as recycled aggregates have to be used it is necessary today to go beyond this prescriptive approach, Finally, PBA will facilitate innovation.

In order to develop a shared and accepted methodology of a performance-based approach in practice for civil engineering structures, complex buildings or some precast elements, all types of construction sector stakeholders (owners, engineering companies, building and civil engineering companies, public and private laboratories, universities, ready-mix concrete suppliers, materials suppliers) have set up a French National project called PERFDUB (Approche PERFormantielle de la DURabilité des ouvrages en Béton - Performance Based Approach for justifying concrete structures’ durability).

It intends to cover all aspects of concrete structures’ durability ; not only rebar corrosion or freeze-thaw but also chemical attacks.

As underlined in a survey conducted in the framework of European standardization activities, it would be too radical to move from a deemed-to-satisfy approach which is suitable in most of the cases to a full PBA. In the mid term, both methods should coexist.

French National Project Perfdub is a four years research program with 3741 k€ total fundings (coming from the 49 partners (Fig. 1) contribution) ; it has been launched in March 2015.

For this project, only concrete mixes made of constituents with established suitability (according to EN 206) are considered.



Figure 1. Partners of PERFDUB Project

2. PROJET ORGANIZATION

The research program is structured in different themes. The animation of these themes is entrusted to a pair consisting of a representative of the industrial world and an academic representative to ensure a good balance between theoretical and pragmatic approaches.

The corresponding research topics are:

- Theme 1: Test methods
- Theme 2: Definition of eligible performance thresholds
- Theme 3: Concrete mixes evaluation
- Theme 4: Contractual aspects
- Theme 5: Dissemination

Theme 1 aims to assess and develop suitable and practical test methods to measure durability-related properties.

Theme 2 aims to review, clarify, or set threshold values for durability indicators and indicators of structures lifetime based on the analysis of old concretes and predictive models, for each exposure class of EN 206, various coverdepths and for different lifetimes of structures.

Theme 3 has selected concretes compositions (complying or not with EN 206 requirements) that will be evaluated according to the test methods developed in Theme 1 providing a comprehensive database of experimental results allowing to link experiences from prescriptive approaches and the new PBA approach. Themes 4 and 5 are themes that are involved from the start of the project. In particular theme 4 aims to a) set up responsibilities of each concerned parties, b) propose appropriate contractual framework(s) and c) define terms and conditions for both routine control and non-conformities with trials associated tolerances. This way, theme 4 is responsible for verifying that actions within the themes 1, 2 and 3 will be in a position to answer questions about the performance-based approach application.

3. RESEARCH PROGRAM

A. THEME 1: DURABILITY TESTING

Two types of durability tests can be distinguished:

- durability indicators characterizing the properties of concrete in relation to resistance to external aggressions and used as input data for durability models (example: chloride ions diffusion coefficient towards the protection of reinforcement in marine environment);
- accelerated ageing tests (example: accelerated carbonation).

The objective of the national project is to have, for each exposure class defined in the standard EN 206, at least one indicator (or accelerated test results) related to tests that allow to compare and/or to assess the capacity of a proposed concrete mix design to withstand a given degradation.

Test methods which are being studied within PERFDUB are summarized in Table 1. To be legitimate and operational, these tests must have a robust technical repository which makes consensus (procedures, representativeness, repeatability and reproducibility, effect of concrete age) and that could be applied to the vast majority of used concrete at present and in the near future.

They must also be measured at intervals consistent with the constraints of construction, with limited test durations (ideally less than 3 months) and test methods simple enough to be accessible to a large number of laboratories and economically acceptable.

Working proposals for durability tests are therefore in an overall objective to make operational deployment of the performance-based approach throughout all the stages of life of a concrete (specifications, mix design development, production and construction, quality control, and ageing monitoring).

The principle is to rely on work in progress and future work, to make it possible to emerge consensus, deepen the critical points and fill the gaps; and this in close contact with French standardization groups, the national working groups and European and International (CEN, *fib*, RILEM) work.

Table 1 hereunder summarizes test methods which are being studied within PERFDUB:

Table 1: Test methods studied within PERFDUB program

Exposure classes	Reference test	Alternative test
XC	Water porosity Gas permeability Accelerated carbonation (XP P18-458)	Accelerated carbonation (prCEN/TS 12390-12) Torrent permeability Water absorption Capillary absorption test
XS, XD	Non steady state chloride migration test	Steady state chloride migration test Resistivity test
XA acid / pure water	Constant pH leaching test [5]	Leachcrete test [7]
XA sulfates	« Messad » test [6]	SIA 262-1 standard

B. THEME 2: DEFINITION OF ELIGIBLE PERFORMANCE THRESHOLDS

The objective of this working group is to identify eligible performance thresholds for each exposure class of EN 206 and for different service lifetimes and covers.

The action plan is as follows:

- identification of mix design parameters (effective water content, binder content, binder type, aggregates type...) and manufacturing parameters (maturation, cure conditions...) that are mostly influencing the durability of the cement-based materials;
- characterization of “common” concrete mixes in accordance with standard NF EN 206/CN or with French Fascicule 65 (giving rules for civil engineering structures with 100 years service life time);
- use of existing studies on old concrete structures;
- use of Service Life Models

Compliance with a threshold indicates that concrete, in the environmental conditions pre-identified, ensures required durability. For degradation and lifetime, the threshold corresponds to the achievement of a limit state at the end of the predicted life expectancy. A threshold is valid for: a lifetime, an exposure class, an indicator and a corresponding limit state (e.g. corrosion leading to first appearance of cracking). Note also that the performance limit is valid for a given cover.

Determination of threshold values by means of service life modelling is necessary but not sufficient and need to be validated and supplemented by a feedback of the real behavior of structures in their environment. In other words, the aim is not only to predict the service life using performance indicators, but also the identification of threshold values using the observed real service life assessments: environment (exposure classes), date of construction, age and nature of concrete (mix design, condition of the structure). At minimum, the panel should cover old structures (70 to 100 years) and middle age structures (30-50 years) in marine and inland condition, in each age class concretes with CEM I, CEM II and CEM III. A lot of diagnostic results are already available for these structures.

A part of modeling aspects of PERFDUB are addressed in the framework of the ANR Project MODEVIE (Modeling of the durability of concrete structures) running in parallel during the same period of time. The aim of MODEVIE is first to take into account all the different periods of the structure service life in chaining behavior models, from transfers of deleterious species to corrosion and potential mechanical damages, and secondly to define a model adapted to the use of the performance-based approach in the normative context. MODEVIE will also provide a better understanding of parameters favorable to steel reinforcement depassivation (carbonation and chloride ingress) and corrosion propagation. Limit states associated with reinforcement corrosion will be also rationally defined.

Organized into six tasks, the project involves modeling and experiments. The latter takes into account parameters such as concrete casting, aggregates nature and binder type.

MODEVIE will lead to the definition of an “engineer” type model usable by end-users for the calculation of the structure lifetime for a given limit state (corresponding to an acceptable corrosion state). The input parameters will be the concrete mix parameters, environmental conditions and materials data available from standard tests. MODEVIE gathers specialist partners in the fields of ions transfer, corrosion and normative context for the durability of concrete structures, which are all involved in the development of the performance-based approach for concrete structures and of course active partners of PERFDUB project.

C. THEME 3: CONCRETE MIXES SELECTION

The objective of this theme is to define concrete mixes to be studied during the project so as to provide to the various laboratories samples allowing to carry out durability testing and be representative of a wide enough range of concrete mixes in terms of constituent properties (nature of aggregates, porosity of aggregates, type of cement and additions, ...) and constituent proportions. In particular, the characterization of these mixes will support the definition of eligible thresholds and guide the choice of reference concrete in a comparative approach.

A series of 41 concrete mixes has then been defined, intended to be subjected to durability tests defined previously.

The performance-based approach aims to promote sustainable and low environmental impacting concretes and more generally to contribute to the optimization of the concrete mixes, relying on different durability tests. It is therefore necessary to deepen the response to these tests for which there is a lower feedback, for example: with CEM III, CEM V, concrete with various additions, self-compacting concrete (with high paste volume).

It appears necessary to define a methodology that incorporates the difficulties previously discussed by probabilistic approaches. It is necessary in particular to provide answers to questions concerning the procedures for validation of a composition in the laboratory study phase:

- How to integrate the variability of the characteristics of the concrete on the basis of a single batch?
- How to take into account the uncertainty due to experimental procedures?

The answers to these questions are the expected deliverables.

Another activity within this theme will consist to evaluate:

- temporal variability (or age effect) : characterizing regularly (about once a month during 15 months) the same concrete mix design
- spatial variability : evaluating the properties of a concrete coming from the same batch but collected in different places (from a same concrete wall for instance)

The impact of execution and more especially curing will be also another parameter that will be studied.

D. THEME 4: CONTRACTUAL ASPECTS

To deploy the performance-based approach, it is important to define the responsibilities and commitments of the various stakeholders and in particular to clarify the contractual framework for its implementation.

This approach should apply not only to the long lifetimes, but also shorter lifetimes to meet the needs of markets and optimize the cost of works. It must also enable to develop the use of materials with low environmental impact and to correlatively decrease the environmental impacts of the works.

As the main issue of contracting is the quality control of concrete, it comes to precisely define the modalities of control at the various stages of a project: initial test (study), trial mixes stage, production control, maintenance control.

Therefore, the point is to set up the best indicators and a correlation between short-term (28 days) tests and reference tests with longer term (90 days or more) in order to remain within a reasonable qualification time.

E. THEME 5: DISSEMINATION

Deliverables expected of the various themes are as follows:

- definition of the values for repeatability and reproducibility of durability tests that are standardized or in the process of standardization;
- development of additional durability tests dealing with all of the exposure classes of EN 206 standard;
- definition of a methodology and proposal of acceptable levels for durability indicators and performance tests as a function of the exposure classification, of the service lifetime, of types of cement and additions, and of covers (absolute performance-based approach);
- establishment of rules for optimizing the choice of reference concrete (comparative performance-based approach) as a function of exposure classes, of the service lifetime, of types of cement and additions;
- contractual document inputs for application of the performance-based approach;
- definition of rules to ensure the conformity of concrete, which is a key point for the insertion of the performance-based approach in the standards;
- methodology for the requalification of old structures from measurements of aggressive elements (carbonation, chlorides) ingress and durability indicators on cored samples.

Not only final dissemination is considered, but also communication during the course of the project in order to optimize efficiency of the work and be in position to adjust the research program when needed (taking into consideration international experience and on-going research). That's why an International Monitoring Committee has been created to get some feedback. First synthetic results of PERFDUB project will be available in the summer of year 2017.

REFERENCES

- [1] Alexander, M. and Thomas, M., 'Service life prediction and performance testing – current developments and practical applications', *Cement and Concrete Research* 78 (2015) 155-164
- [2] La Durabilité des bétons – Bases scientifiques pour la formulation des bétons durables dans leur environnement, Presses de l'Ecole Nationale des Ponts et Chaussées (2008)
- [3] Concrete design for a given structure service life - Durability management with regard to reinforcement corrosion and alkali-silica reaction - State of the art and Guide for the implementation of a predictive performance approach based upon durability indicators, AFGC, (2007)
- [4] Synthèse des travaux du projet national BHP2000 (1995-2003)
- [5] Francisco, P., Badoz, C., Rougeau, P., 'A performance approach for durability of concrete exposed to acid attacks and aggressive water', *Proceeding Consec 07*
- [6] Messad, S., Carcasses, M., Boutillon, L. and Linger, L., 'Performance approach using accelerated test method for external sulfate attack', *3rd fib International Congress* (2010)

- [7] Moudilou, E., Bellotto, M., Defosse, C., Serclerat, I., Baillif, P., Touray, J.C., 2002, A Dynamic leaching method for the assessment of trace metals released from hydraulic binders, *Waste Management*, 22, 2.