# THE IMPLEMENTATION OF A PERFORMANCE AND PROBABILISTIC BASED DURABILITY CONCEPT IN REVISED EUROPEAN CONCRETE STANDARDS AN UPDATE

Steinar Helland
S Helland Konsult, Oslo Norway

## ABSTRACT

"Performance-based service life design". What is that ?
This phrase includes three terms that need to be clarified to reduce the present problematic communication on these matters within our community:

- "Performance-based",
- "service life" and
- "design".

This presentation will bring you through the process of maturing this concept within fib and ISO the last 20 years and in CEN the last 10 years, all reported through my personal perspective.
In this written paper, the CEN work is reported up to June 2022. The essential works in fib is reported in bulletin no 34 "Service life design of concrete structures" [1] and "fib Model Code for Concrete Structures 2010" [2]. The relevant ISO standards are ISO 13823 "General principles on the design of structures for durability" [3] and ISO 16204 "Durability – Service Life Design of Concrete Structures" [4]. Within CEN there are a number of internal documents from the various working parties involved in the current major revision of EN 1992 "Design of concrete structures" [5], EN 13670 "Execution of concrete structures" [6] and EN 206 "Concrete" [7].

**Keywords:** Durability, performance-based, exposure resistance classes, standards

## BASIS FOR THE CONFUSION

Our community of engineers lack a common language and terminology when discussing durability matters. For many years the definition of "design service life" given in standards has been:

*"Assumed period for which a structure or part of it is to be used for its intended purpose with anticipated maintenance, but without major repair being necessary".* (prEN 1990 [8])

This is a qualitative description not suited for quantitative design.

fib [1] and ISO [4]. have therefore added the concept of reliability-based Limit State design by supplementing the traditional definition with:

> *"The design service life is defined by:*
> - *a definition of the relevant limit states;*
> - *a number of years and;*
> - *a level of reliability for not passing each relevant limit state during this period."*

This is the single most important contribution by fib to get a meaningful discussion within our community. Ensuring a sufficient service life of a structure by provisions in standards is today the responsibility of the various national standardization bodies in Europe and requirements are given in their national application documents to EN 1992 / EN 13670 / EN 206. The 31 CEN member states are in the present version of the standards all obliged to give provisions to ensure a design service life of 50 years based on a maximum water-binder ratio, binder type, cover to the reinforcement and maximum crack width. However, by comparing some of these national provisions, a remarkable big difference in actual performance is observed for the same exposure situation.

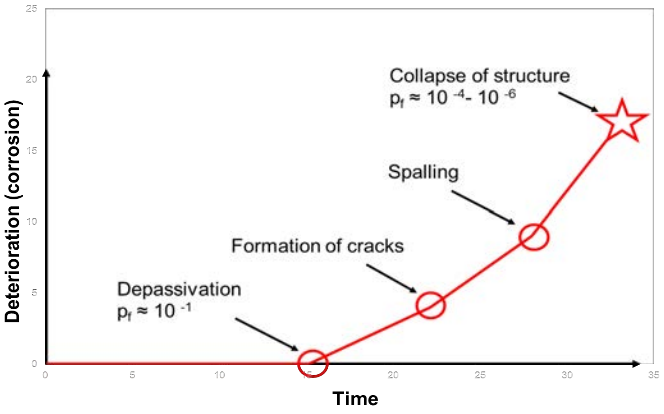

***Fig. 1*** *Possible Limit States and related levels of reliability for reinforced structures subject to corrosion [9]*

*Table 1 – Examples of European durability requirements - From CEN TR 15868 [10].*

| | | |
|---|---|---|
| *Range of XC3 (outdoor, sheltered from rain)* | *UK → CEM I and w/c < 0.55 combined with 25 mm minimum cover for the reinforcement* | *Germany → CEM I and w/c < 0.65 combined with 20 mm minimum cover* |
| *Range of XC4 (outdoor, not sheltered from rain)* | *Netherland → CEM I and w/c < 0.50 combined with 25 mm minimum cover* | *Germany → CEM I and w/c < 0.60 combined with 25 mm minimum cover* |
| *Range of XS2 (submerged in Atlantic sea-water)* | *FR → CEM I and w/c < 0.55 combined with 35 mm minimum cover* | *Norway → CEM I + 6% silica fume, w/b <0,40 combined with 40 mm minimum cover* |

One main political ambition by introducing common European standards was to “reduce hindrance to trade” by harmonizing technical specifications. As might be noticed, we have achieved a common platform, but the differences between the current national provisions have been even clearer when working with the new concept. I have challenged some of my European code-writing colleagues with what they had in mind as “end of design service life”. Most of them had used depassivation of reinforcement as the criteria. One country had used 2 % as an acceptance level. Another 10 % and a third 30 %. One country had used “cracking and spalling” as criteria, but when back-calculating to “depassivation” got an acceptance level of 50 %.

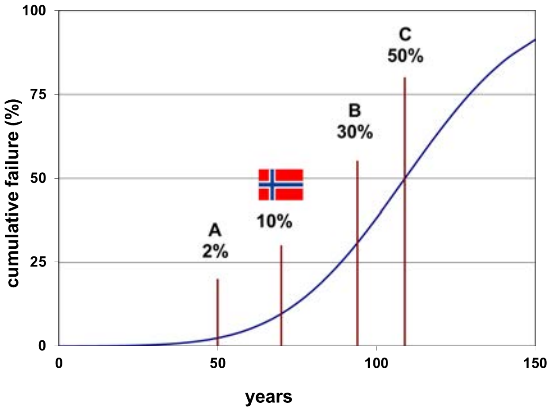

***Fig. 2*** *Time till depassivation of surface reinforcement (example).*
*The Norwegian Standardization body applied a 10 % acceptance level for depassivation as a criterion when determining its durability provisions in 2003, whereas countries A, B and C applied 2, 30 and 50 % respectively [9].*

All these considerations are correct, but if the premises for the durability provisions are not transparent and communicated to the stakeholders, confusion is the result and the different national provisions aimed to ensure the same design service life, are not comparable.

The "Performance of concrete structures" with regard to durability is that it fulfils the design criteria over the design service life of, say 50 years. It is however difficult to link a contract to an inspection 50 years into the future. The contractual obligations for the concrete producer, the constructor and the designer must then be linked to proxy-criteria that can be assessed during the design and construction phase. All such proxies are obviously based on an assumption that they relate to the real in-field and long-term performance. They are then per definition "performance-based".

In the present discussions, often the traditional "deemed-to-satisfy" (DtS) provisions are not regarded to be in this more prestigious "performance-based" category. This confuses our discussion. I really hope that my code-writing colleagues have not settled their DtS provisions randomly, but according to their insight, done their best to let these tabulated provisions reflect the assumed actual performance. If these DtS provisions are given according to fib [1] and ISO [4] documents, they shall:

> *"The specific requirements for design, materials selection and execution for the deemed-to-satisfy method shall be determined in either of two ways:*
>
> > *- on the basis of statistical evaluation of experimental data and field observations according to requirements of Clause 5.4.1;*
> >
> > *- on the basis of calibration to a long-term experience of building tradition."*

As our cement qualities and construction practice vary over time, the second option could be problematic. In Norway, we have however applied the first option when verifying our DtS provisions, both in the revisions in 2003 and in 2014. We then used the Limit State "depassivation" and a 10 % acceptance level of failure when we extrapolated the performance of 2 - 26 year old structures to that of 50 and 100 years [12] [13]. These provisions are therefore performance-based as well as reliability and Limit State based. The same must be true for other DtS requirements in other standards, even if it is not transparent for the reader (and may be not for the authors as well) of these standards what Limit State and reliability these documents reflect.

## MODELLING ACCORDING TO fib/ISO

We all agree that we cannot base our design and construction practice on 50- or 100-years field experience as materials and practice have changed considerably during these years.
As engineers, we then must base our assumptions on extrapolated short- and medium-term field experience. To do such extrapolations, we need time-dependant models, or at least some reasonings. In fib and ISO we have succeeded in giving such models for the ingress of the carbonation front and the ingress of chlorides. For other actions, like freeze-thaw and chemical deterioration, we have not been able to come up with time-dependant models that were sufficiently mature to achieve international consensus.

This fib/ISO methodology and models are the basis for the present CEN work to introduce a more coherent service life design in the next generation of European concrete standards.
The two time-dependant models that have reached international consensus as sufficiently accurate are:

### *Carbonation*

The ingress of the carbonation front might be assumed to obey the following equation:

$$x_c(t) = W \cdot k \cdot \sqrt{t} \tag{1}$$

The details of this traditional "square-root of time" relation are given in [1] [4].

### *Chloride ingress*

The ingress of chlorides in a marine environment may be assumed to obey the following equation:

$$\mathrm{C}(\mathrm{x},\mathrm{t}) = \mathrm{C}_s - (C_s - \mathrm{C}_i) \cdot \left[ \mathrm{erf}\ \left( \frac{x}{2 \cdot \sqrt{\mathrm{D}_{\mathrm{app}}(\mathrm{t}) \cdot \mathrm{t}}} \right) \right] \tag{2}$$

Details of the model/equation are given in [1] [4]. Even if the equation is based on Fick's second law of diffusion, diffusion is only one of many mechanisms that cause the chlorides to penetrate. The equation is then just a convenient equation for curve-fitting of actual field observations. The material parameter is therefore named "apparent", $D_{app}(t)$, and it improves over time according to the relation

$$D_{app}(t) = D_{app}(t_0) \left( \frac{t_0}{t} \right)^{\alpha} \tag{3}$$

The improvement of the apparent diffusion coefficient over time, characterized by the aging factor α, is due to several reasons whereas continued hydration is only one part, but the long-term interaction with the saline solution is the dominant one.

## PRESENT CEN STANDARDS DEALING WITH SERVICE LIFE DESIGN

Today, these provisions are embedded in the hierarchy of regulations and standards as shown in fig.3.

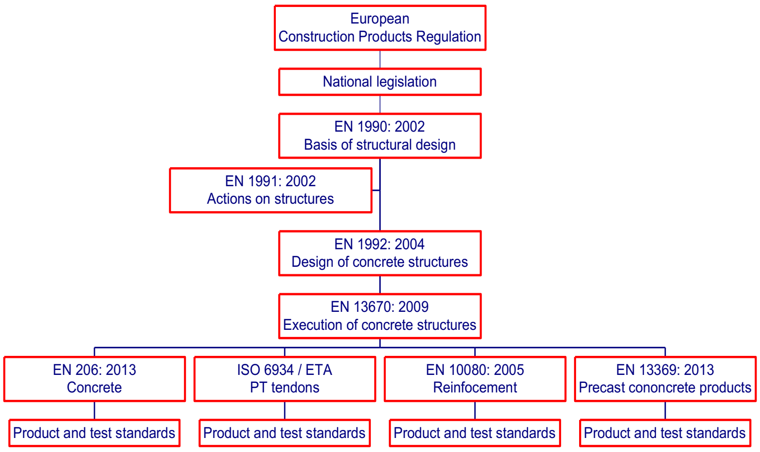

***Fig. 3.*** *Hierarchy of European regulations and standards (main modules)*

The main documents concerning service life design of concrete structures are EN 1992 (Eurocode-2), EN 13670 and EN 206. Since these documents were written by different committees and at different times, they are at present not fully coordinated and the split between them are not fully logic.

According to how CEN interpret the European legislation, matters like durability are under national authority. The common European standards can then only give the structure for the provisions, not the required national level of safety, unless full consensus is reached among all the 31 CEN members. To apply these standards in a country, national application documents are therefore needed. Main elements concerning durability in the coming European standards are:

- EN 1992 --> definition of Exposure Classes (environmental load), definition of Exposure Resistance Classes (ERC, material resistance), minimum cover to the reinforcement, maximum calculated crack widths
- EN 13670 --> General workmanship, Execution Class, Curing Classes, geometrical tolerances for placing of reinforcement
- EN 206 --> consistency in producing concrete. Performance requirements for ERC by testing or alternatively requirements for ERC based on limiting values for composition, mainly based on maximum w/b for different combinations of binders

The three code committees have formed a Joint Chairman Panel (JCP), to coordinate these revisions and to ensure that issues like service life design is dealt with in a coherent manner through the 3 documents. The JCP has also members coming from TC-51 (cement), TC-229 (precast elements)). It has no formal authority but have sketched up the way to handle these matters in a Synthesis Paper that has later been endorsed by all the related committees. The supporting test standards are under the responsibility of a joint group formed by TC-104 and TC-51. The work is undertaken by TC-250/SC2/WG110 for the Eurocode-2 part under the convenorship of Mikael Hallgren /SE and for EN 206 by TC-104/SC1/WG1 under the convenorship of Udo Wiens /DE and Tom Harrison /UK.

## THE NEW CONCEPT UNDER DEVELOPMENT IN CEN

### *Eurocode-2*

The new concept apply Exposure Classes like today. These will be given in Eurocode-2 and are slightly modified compared to current table. Eurocode-2 will also define the performance classes for the concrete material with respect to resistance against deterioration in a similar way as to how Eurocode-2 defines the compressive strength related to characteristic (5 %) value tested under reference conditions.

This is done by Exposure Resistance Classes (ERC). A total of 8 classes for carbonation resistance classes (XRC) and 10 classes for chloride resistance classes (XRDS) are introduced. The required performance is the assumed penetration of the carbonation / chlorides after 50 years under defined reference conditions. The classes are defined in two notes.

> *prEN 1992-1-1, Table 6.3, NOTE 1 The designation of XRC classes for resistance against corrosion induced by carbonation is derived from the carbonation depth [mm] (characteristic value 90 % fractile) assumed to be obtained after 50 years under reference conditions (400 ppm CO2 in a constant 65 %-RH environment and at 20 °C). XRC designation value has the dimension of a carbonation rate [mm/√years].*
>
> *prEN 1992-1-1, Table 6.4, NOTE 1 The designation of XRDS classes for resistance against corrosion induced by chloride ingress is derived from the depth of chlorides penetration [mm] (characteristic value 90 % fractile), corresponding to a reference chlorides concentration (0,6 % by mass of binder (=cement + type II additions)), assumed to be obtained after 50 years on a concrete exposed to one-sided penetration of reference seawater (30 g/l NaCl) at 20 °C.*
> *XRDS designation value has the dimension of a diffusion coefficient [$10^{-13}$ $m^2/s$].*

The main difference from strength is that strength can be assessed at an early age and is supposed to increase only moderate with age, while the durability performance of the structure will normally decrease with age and the material classes must therefore relate to the performance at the end of design service life.

Based on these assumed material characteristics after 50 years, the code committee has applied modelling to adjust for the exposure conditions in the other exposure classes compared to those reference conditions given in the two notes. From this the tables for min cover to the reinforcement for 50- and 100-years design service life are derived. The probabilistic modelling has used a target reliability level (pf) of 7 % ( ß = 1,5). In the modelling we have also included a certain period of active corrosion (till corrosion reach a depth of 50 µm).

Not surprisingly, different experts in the code committee reached different results when they made these modelling despite applying the same fib/ISO models. The main reason was that the different groups based their calculations on different databases. The final tables are then the result of a compromise and is expected to be safe for the great majority of concrete structures in Europe. The considerations behind these tables of min covers will be published in a background paper (the draft has 188 pages).

prEN 1992-1-1: 2021, Table 6.3(NDP)
Minimum concrete cover $c_{\mathrm{min,dur}}$
Carbonation

| ERC | Exposure class (carbonation) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | XC1 | | XC2 | | XC3 | | XC4 | |
| | Design service life (years) | | | | | | | |
| | 50 | 100 | 50 | 100 | 50 | 100 | 50 | 100 |
| XRC 0,5 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| XRC 1 | 10 | 10 | 10 | 10 | 10 | 15 | 10 | 15 |
| XRC 2 | 10 | 15 | 10 | 15 | 15 | 25 | 15 | 25 |
| XRC 3 | 10 | 15 | 15 | 20 | 20 | 30 | 20 | 30 |
| XRC 4 | 10 | 20 | 15 | 25 | 25 | 35 | 25 | 40 |
| XRC 5 | 15 | 25 | 20 | 30 | 25 | 45 | 30 | 45 |
| XRC 6 | 15 | 25 | 25 | 35 | 35 | 55 | 40 | 55 |
| XRC 7 | 15 | 30 | 25 | 40 | 40 | 60 | 45 | 60 |

Like in current Eurocode-2, also the next version will have the tables for min cover as "national determined parameters" (NDP). It is then expected that the national standardization bodies will interpret the exposure classes on a national or regional basis (salinity in the Baltic Sea is less than in Atlantic water, annual mean RH is 65 % in Madrid while 75 – 80 % in Oslo)

prEN 1992-1-1: 2021,Table 6.4(NDP)
minimum concrete cover $c_{\mathrm{min,dur}}$ — Chlorides

| ERC | Exposure class (chlorides) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | XS1 | | XS2 | | XS3 | | XD1 | | XD2 | | XD3 | |
| | Design service life (years) | | | | | | Design service life (years) | | | | | |
| | 50 | 100 | 50 | 100 | 50 | 100 | 50 | 100 | 50 | 100 | 50 | 100 |
| XRDS 0,5 | 20 | 20 | 20 | 30 | 30 | 40 | 20 | 20 | 20 | 30 | 30 | 40 |
| XRDS 1 | 20 | 25 | 25 | 35 | 35 | 45 | 20 | 25 | 25 | 35 | 35 | 45 |
| XRDS 1,5 | 25 | 30 | 30 | 40 | 40 | 50 | 25 | 30 | 30 | 40 | 40 | 50 |
| XRDS 2 | 25 | 30 | 35 | 45 | 45 | 55 | 25 | 30 | 35 | 45 | 45 | 55 |
| XRDS 3 | 30 | 35 | 40 | 50 | 55 | 65 | 30 | 35 | 40 | 50 | 55 | 65 |
| XRDS 4 | 30 | 40 | 50 | 60 | 60 | 80 | 30 | 40 | 50 | 60 | 60 | 80 |
| XRDS 5 | 35 | 45 | 60 | 70 | 70 | — | 35 | 45 | 60 | 70 | 70 | — |
| XRDS 6 | 40 | 50 | 65 | 80 | — | — | 40 | 50 | 65 | 80 | — | — |
| XRDS 8 | 45 | 55 | 75 | — | — | — | 45 | 55 | 75 | — | — | — |
| XRDS 10 | 50 | 65 | 80 | — | — | — | 50 | 65 | 80 | — | — | — |

The various nations are also free to apply a different level of reliability for their provisions than the suggested pf of 7 %.

Like for current Eurocode-2, the coming standard will also only give tables for min cover related to one Consequence Class (CC2 – Normal consequence).

Draft Eurocode-2 was for public European inquiry this winter. It received 4490 comments. 170 of these were related to the new durability concept, but none of these questioned the introduction of the ERC concept, which is quite remarkable having in mind the dramatic difference to current durability provisions. The technical requirements in FprEN 1992-1-1 that will be for formal vote among the member states coming winter will therefore be the same as in the inquiry draft prEN 1992-1-1: 2021

For another well-established (?) topic, shear, the number of comments received was 800 !

The general design assumption in Eurocode-2 is that the concrete material complies with the standard for concrete production, EN 206, and the execution at the construction site comply with the execution standard, EN 13670. The final durability of the structure is then the result of the total set of provisions in these standards and these must then be coordinated to ensure that all effects are considered once and not twice. Eurocode-2 assumes that the execution is according to Execution Class 2 and the quality of the curing is according to Curing Class 2.

The interface between Eurocode-2 and EN 206 is then defined by the two notes to tables 6.3 and 6.4.

### *EN 206 Concrete, specification, performance, production and conformity*

The task of EN 206 is to give the provisions for how to produce the exposure resistance classes that comply with the two notes to Eurocode-2, table 6.3 and 6.4.

The producer will be given two options for verifying compliance with the ERC classes, either by testing the performance or relating to provisions for the limiting values for composition (often denoted as DtS). EN 206 will consider these two options as equivalent, and the producer is free to choose.

The performance of these are given in Eurocode-2 as in-structure performance after 50 years under defined conditions and with a given reliability (characteristic 90 % fractile). No concrete producer will be able, nor willing, to deliver concrete on such specification and condition.

The code committee (TC104/SC1/WG1) has then the task to convert these performances after 50 years to operative requirements that the concrete producer can relate to in a reasonably short period after mixing the concrete. This process involves “back-calculation” from the performance in-structure under the defined conditions at 50 years to related test results on young concrete. For this back-calculation WG1 apply the same fib/ISO models as the Eurocode-2 committee. Since the criteria are given in a statistical way, we also need to consider the expected scatter in-structure performance expressed by a statistical distribution and a standard deviation or co-variance (CoV).

The Eurocode-2 committee expect that the EN 206 provisions will include the scatter due to

1. Variations from concrete plant
2. Variations in testing
3. Variations in compaction on site
4. Variations in curing
5. Variations in ageing under XRC/XRDS conditions

### *EN 206 – Carbonation, Initial Type Testing (ITT)*

The “natural” CEN test method for determining the carbonation rate related to the reference conditions in note to table 6.3, and that can act as input to modelling according to equation (1), is EN 12390-10 (chamber method). This requires 28 days of curing and exposure at 20 ºC and 65% RH with 0,04 % $CO_2$ during 1 year. This is an expensive test; it takes long time and requires an advanced laboratory facility. It can then not be used on a routine basis for verifying the running production. However, it will be used as the reference test for the Initial Type Testing (ITT) where the producer has to verify his mix composition before he is allowed to deliver the concrete to the market.

A minimum of 3 parallel tests according to EN 12390-10 (chamber) is what the code committee feel as reasonable. It will then not be possible to calculate any standard deviation, only a mean value. The ITT compliance criteria will then be related to the mean value and the CoV due to the 5 elements listed above has to be judged by the code committee and used as basis for back-calculating to these ITT criteria. The figure below illustrates the CoV for nominal same concrete in structures exposed to XC4 in different parts of Norway

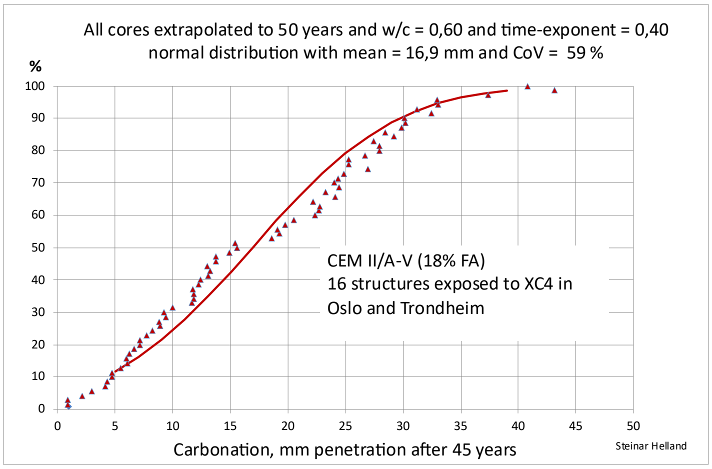

***Fig. 4*** *- Carbonation ingress in 16 Norwegian structures. Assessed after 9 – 16 years exposure and extrapolated to 50 years.*

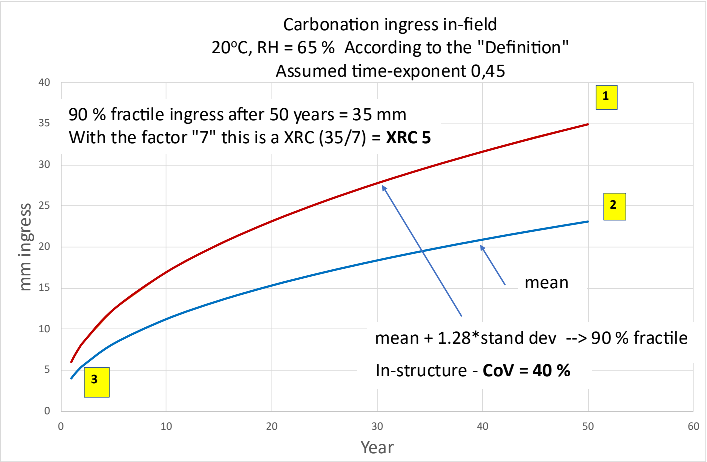

***Fig. 5*** *- Back-calculating carbonation ingress from 50 years to 1 year*

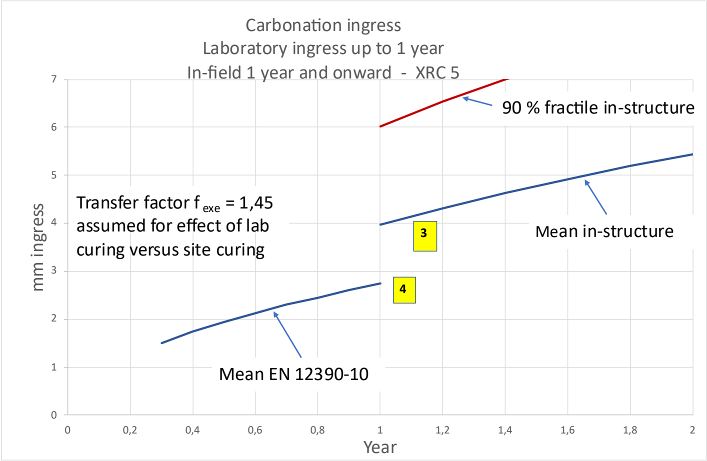

***Fig. 6*** *- Overlap between carbonation depth after 1 year chamber testing and in-structure*

For carbonation, the code committee is converging on a CoV of 40 % as representative for what we experience in real construction under the reference conditions.

The back-calculation will then be as illustrated for XRC 5 by the example in fig 5 and 6.

Point (1) is the 90 % fractile ingress of 35 mm after 50 years for XRC 5 (5 * √50 years = 35)

Point (2) is the assumed mean ingress based on CoV = 40 %

Point (3) is the back-calculated mean ingress to 1 year.

Point (4) is the carbonation ingress in the EN 12390-10 natural chamber test. A transfer factor of 1,45 is used to correlate 28 days water curing in laboratory to Curing Class 2 according to EN 13670.
The ITT criteria for mean carbonation rate according to 1 year chamber test is then 2,8 mm/√years for XRC 5.

While WG1 has converged for the test ITT criteria for XRC, the related limited values for composition (DtS) are still under discussion.

It is however obvious that the key parameter, w/b, will be dependent on the cement or binder type resulting in a lower w/b for blended cements than for a CEM I for the same XRC class.

The table below from one proposal at the committee´s desk illustrate how this differentiation due to binder type could appear in the standard.

| | Maximum mean carb. rate<br>EN 12390-10 | CEM I | CEM II/A | CEM II/B | CEM III/A | CEM III/B |
|---|---|---|---|---|---|---|
| | | max w/b | | | | |
| XRC 5 | 2,8 mm/√years | 0,62 | 0,58 | 0,55 | 0,52 | 0,47 |

The European concrete producers and cement industry have during the last years done an excellent job to reduce the carbon-footprint of their material, mainly by introducing blended binders. If focusing on a “cradle to gate” scenario, as material producers normally do, this differentiation of carbonation performance is not welcomed. Focusing on a “cradle to grave” scenario will however justify this technical differentiation in a sustainability perspective as reduced service life or need for repair will overrule any $CO_2$ gains in the production.

At the other hand, for chloride rich exposures and exposures to aggressive chemicals, the ranking of binders will be opposite. For instance, in the Norwegian standard we have for the last 20 years forbidden the use of unblended CEM I in XS2/XS3/XD2/XD3 exposure.

### *EN 206 - Factory Production Control*

The mix design used during production must be prequalified, either by the ITT testing or by the table for limiting values prequalified by the code committee.

During the production the producer must implement a system for Factory Production Control (FPC), similar to current EN 206, enabling him to ensure that the mix composition verified to comply with the criteria in the ITT phase, or by the code committee, is correctly copied in the running production.

### *EN 206 – chlorides, ITT*

The discussions in the code committee are less mature concerning the ITT criteria for the XRDS classes.

The relevant CEN test standard is EN 12390-11. This is a “natural” test where you expose the concrete for a salt solution with salinity similar to Atlantic water. The exposure length is 90 days after 28 days water curing. The chloride profile is mapped and the apparent diffusion coefficient, $D_{app}$(90 days), is determined. This $D_{app}$(90 days) can then be used as input to the fib/ISO model for predicting chloride ingress.

Like for the carbonation test, this test requires a well-qualified laboratory and the code committee propose a minimum of three parallel tests during the ITT phase enabling the calculation of a mean value.

The back-calculation from the reference 90 % fractile ingress after 50 years under reference conditions will then in principle be the same as for carbonation. When writing this paper (May 17st) we still discuss the CoV for in-structure $D_{app}$(50 year). Extensive Norwegian mapping of $D_{app}(t)$ on long-term exposed marine structures indicate that 70 % could be representative.

Another challenge is the aging factor (see equation (3)). The aging factor is very dependent on the binder type. In general, blended binders have higher and more favourable aging factors than pure CEM I. How to verify the aging factor for the particular concrete mix in question is still under debate.

The CEN committee responsible for test standards (joint TC104/TC51) discuss a possibility to apply EN 12390-11 with different exposure periods ranging from 28 days to 2 years as a basis.

The aging factor will be a key parameter for differentiating the performances of cement and binder combinations with regard to chlorides

***Alternative accelerated test methods***

The two "natural" test procedures, EN 12390 part 10 and 11, are time consuming, expensive and require well-qualified laboratories. There is therefore a strong wish to also offer ITT criteria related to accelerated methods like

- EN 12390-12 that apply 3 % $CO_2$ concentration and exposure period of 70 days
- EN 12390-18 the chloride migration test giving result after 28 days curing

However, none of these can act as direct input to the fib/ISO models and a transfer factor to relate to natural conditions are needed. By reviewing available literature and comparative Round-Robin testing, the code committee conclusion (per May 17th ) is that no such general valid transfer factor can be established.

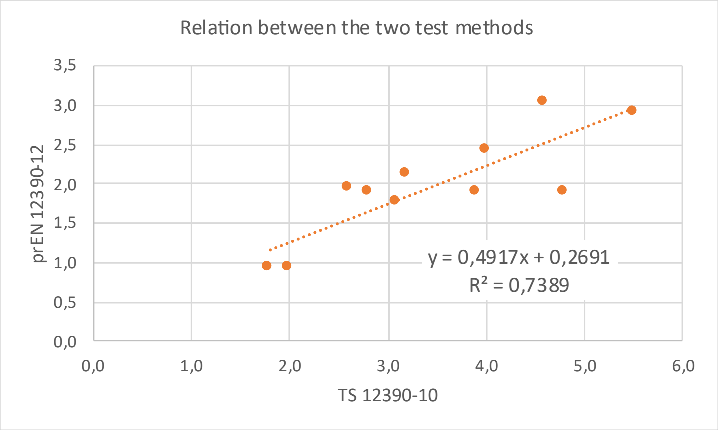

***Fig. 7*** *- The datapoints in the figure represent the mean from each of the 8 participating laboratories in the RR testing [16].*
*The results demonstrate that a considerable scatter must be assumed when applying the accelerated method as a proxy for the "natural" test.*
*Establishing a "safe relationship" would then be very conservative*

We will then probably not be able to give ITT criteria based on accelerated test methods on a European level.

***Resistance Classes – Freeze-thaw (XRF) and chemical deterioration (XRA)***

For these deterioration mechanisms, we do not have any time-dependent model with general international consensus. Designing for a specific service life is then not possible. The option is then to apply the design format denoted "avoidance-of-deterioration" in the fib/ISO terminology. This implies that the deterioration process will not take place. Test methods that might be applied under this concept are in the EU terminology named "Torture Tests" [17]. These tests make the concrete subject to test conditions that are assumed much tougher that what will be experienced in-field. In the case the material stands the test; it will also survive in-field, but with an unknown margin. Traditional freeze-thaw tests are in this category.

CEN does therefore not have any suggestions to introduce more sophisticated concepts in these cases than those traditionally used in current standards. Provisions for XRF and XRA classes will therefore be based on limiting values for mix compositions like today. Some nations will also require freeze-thaw testing, and a few will require testing for chemical resistance according to national test procedures.

### *Implementation of the ERC concept*

One condition expressed by many CEN member states for accepting the new concept have been that an allowance for an extended transition period is granted. Eurocode-2 will then give an option for also applying the current set of provisions for durability for a certain period.

## CEMENT

In current national application documents to EN 206 the majority of CEN Member States consider all cement types to perform equally at the same w/b [10]. This is obviously not technically correct. When working with the new performance-based ERC concept it is evident that different cement or binder combinations reach the same performance level at different w/b levels.

However, we have experienced some resistance from the cement industry to this fact and met arguments like: *Cement differentiation is cement discrimination.*

We have also faced the challenge of giving DtS requirements based on cement type and w/b as the declaration of performance (DoP) for cement produced according to the European cement standard, EN 197, only gives rough information on the composition. The main constituents are also very vague described. With the exception of sulphate resistance, EN 197 generate no information at all for the cement´s potential durability performance in concrete.

This is quite remarkable and makes it very difficult for the concrete standards to formulate rational provisions for durability based on cement types.

One obvious way forward to a more sustainable industry could be that the cement standard declared the cement´s durability potential by testing the cement in reference mixes according to EN 12390 part 10 and 11, in parallel to what they today do for strength testing.

## References:

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