»Views on JWG Durability report 2014

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»Present situation

JWG – Durability Report 2014

well as local expectations and local experience of its performance, however, the different national provisions cannot be explained on a rational basis and within each national provision they do not lead to a consistent resistance.

With the recent developments in methodology for assessing durability it should be time to bring the rules and requirements in our standards one step forward. It is also the experience in standardisation that a greater harmonisation in Europe is requested, for example the Commission is requesting CEN TC250 to consider a reduction in NDPs in the Eurocodes. It would be proactive and wise if we can do this harmonisation under the terms and conditions decided by the concrete community itself, rather than on instructions from others.

The drive to make concrete more sustainable will lead to cements with lower clinker contents and strong pressure to use recycled and secondary materials, which may have a poor shape. All these changes could have an adverse effect on concrete durability and consequently there is a need to have clearly defined performance criteria as an alternative to limiting values or a requirement when certain limits are exceeded.

Proposal for a future system

The basic parameters to consider in a system for practical design of concrete for durability are;

- characterisation of exposure conditions
- characterisation of resistance characteristics of concrete

»Present situation

“ *...the different national provisions cannot be explained on a rational basis...*”

Comment:

As regard the national Danish requirements, this is a wrong statement, because:

1. Provisions against alkali silica reactions is solely based on research data – e.g. the limitations

- on porous flint in fine aggregates
- of equivalent alkali content in concrete with 60 % mortar ≤ 3 kg/m^3 (in all exposure classes except X0 and XC1)

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»Present situation

“ *…the different national provisions cannot be explained on a rational basis…*”

Comment:

As regard the national Danish requirements, this is a wrong statement, because:

2. Requirements for frost resistance is solely based on research data. e.g.
   - Minimum requirements for air content in fresh (≥ 4.5 %) and hardened concrete (≥ 3.5 %)
   - Power’s spacing factor (≤0.20)

»Present situation

" ...the different national provisions cannot be explained on a rational basis..."

Comment:

As regard the national Danish requirements, this is a wrong statement, because:

3. Requirements for carbonation resistance is solely based on a combination of Danish experience and research. This is true for (XC2, XC3, XC4, XA1, XF1)
   - The requirement for w/c ratio ≤ 0,55
   - The requirement for a minimum cover of 20 mm

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»Present situation

“ *...the different national provisions cannot be explained on a rational basis...*”

Comment:

As regard the national Danish requirements, this is a wrong statement, because:

4. Requirements for maximum allowable content of silica fume (≤ 11 % of cement) and fly ash (≤ 33 % of cement) are found to be sound limits by research:
   - To maintain carbonation resistance
   - To maintain passivation of steel in concrete

»Proposal for a future system

Proposal for a future system

The basic parameters to consider in a system for practical design of concrete for durability are;

- characterisation of exposure conditions
- characterisation of resistance characteristics of concrete
- rules for relating resistance to exposure
- requirements for relating minimum concrete cover to exposure intended working life and resistance
- requirements to behaviour under service conditions e.g. cracking etc.

In EN 206 and EN 1992 there is a system for characterisation of exposure conditions; this system should be maintained as a sufficiently differentiated and practical system for use in design. Describing exposure conditions with greater detail is not justified for the time being, while some minor adjustments relating exposure to risk of corrosion could be considered. The major deterioration mechanisms in this classification are associated with carbonation, chlorides and freeze/thaw action, in addition aggressiveness in the ground and in production/service processes in the industry might be relevant exposure conditions to consider. Normally structures and their various structural members will experience combinations of two or more of these.

A system is needed for the characterisation of the resistance of the concrete in reinforced concrete structures to the major deterioration mechanisms related to;

- corrosion of reinforcement i.e. carbonation, chlorides
- deterioration of the concrete i.e. freeze/thaw action, alkali-aggregate reaction and chemical aggressiveness such as sulphate attack

For this purpose it is proposed a system with exposure resistance classes. The definition of a resistance class should be performance based. For implementation in practical daily design deemed to satisfy rules for these classes could be developed, based on experience and calibration with up to date technology and knowledge.

»Proposal for a future system

“ … The definition of a resistance class should be performance based…”

Comment:

- In principle correct, but how can the different environmental interactions be taken into account?
- Shouldn’t the area covered by this standard be divided into a number of environmental zones so that we can really compare the different responses from the concrete?
- What about giving credit for e.g. high performance manufacturing of concrete?

»Proposal for a future system

“ … For implementation in practical daily design deemed to satisfy rules for these classes could be developed…”

Comment:

- Yes, but it will require a lot of systematic data that we do not have yet!

»Proposal for a future system

" … *based on experience* …"

Comment:

- Yes, but who's? – and which?

»Proposal for a future system

“ … *calibration with up to date technology and knowledge…*”

Comment:

- We have a few discrete examples of how this could be done, but again it requires a lot of data that we do not have yet!
- “*Knowledge*”… do you think of “*expert opinions*” as in Duracrete? Please, do not!

»Proposal for a future system

A system is needed for the characterisation of the resistance of the concrete in reinforced concrete structures to the major deterioration mechanisms related to;

- corrosion of reinforcement i.e. carbonation, chlorides
- deterioration of the concrete i.e. freeze/thaw action, alkali-aggregate reaction and chemical aggressiveness such as sulphate attack

For this purpose it is proposed a system with exposure resistance classes. The definition of a resistance class should be performance based. For implementation in practical daily design deemed to satisfy rules for these classes could be developed, based on experience and calibration with up to date technology and knowledge.

Finally rules are needed for relating design working life and exposure conditions to exposure resistance classes and as a result from that determining the minimum concrete cover.

In principle there can be an extremely large number of equally viable solutions. Standardization means however limiting of variants, limiting of variants are also a factor of importance in ensuring quality. This proposal is based on the idea of restricting the number of variants at the design level, this is also in response to the request for simplification where possible and justified. In this system there is room to allow national choices, however as far as requirements is related to technical issues the need for national choices reduces. The national choice could be limited to in which exposure classes the various exposure resistance classes are allowed, alternatively the minimum

»Proposal for a future system

" … Standardization means however limiting of variants …"

Comment:

- It could also mean "…a smart way of sharing and employing knowledge…"
- Why should we limit variants? That would rather be "*normalization*"!
- What good would this do for the society? On the short run? On the long run?

»Proposal for a future system

“ … limiting of variants are also a factor of importance in ensuring quality …”

Comment:

- … or a way to limit creativity!

»Proposal for a future system

“ … restricting the number of variants at the design level …”

Comment:

- Why?

»Proposal for a future system

“ … The national choice could be limited to in which exposure classes the various exposure resistance classes are allowed…”

Comment:

- Why not make common environmental zone definitions?
- That would give a mutual understanding of the climatic action and the response of the concrete!
- … and much easier collection and exchange of existing data across Europe.

»Exposure resistance classes

Exposure resistance classes

plus??

There is a need for exposure resistance classes to cover the environments concrete structures designed according to EN 1992 will normally meet. This will primarily be on the one hand carbonation and chlorides and on the other hand freeze/thaw and chemical aggressiveness. The steps between resistance classes should lead to changes in minimum cover of 5-10mm. Modeling has indicated that only three carbonation resistance classes and three chloride resistance classes are needed. It will be necessary to add at least two freeze-thaw resistance classes and at least one or two sulfate resistance classes. It would be nice to be able to agree a minimum number of classes, on the other hand enough classes are needed to give adequate freedom for national choices, and that consensus can be reached.

It is probably wise to start from the concept of three levels of resistance for both carbonation and chlorides, for freeze/thaw we can probably use two classes with requirements assuming the third class is None/Low and the same can be assumed for chemical aggressiveness, see table 1.

Table 1 Illustration of a system of resistance classes

Corrosion of reinforcement						**Deterioration of concrete**			
Carbonation Resistance Class			**Chloride Resistance Class**			**Freeze/thaw Resistance Class**		**Chemical Aggressiveness Class**	
Low	Medi-um	High	Low	Medi-um	High	Medium	High	Medium	High

»Exposure resistance classes

“ plus??”

Comment:

When some exposures are highlighted now, you might forget other exposures and requirements such as:

- Moist exposure (leaching, ASR)
- Alternating wetting and drying (leaching)
- Shrinkage and creep (in concrete having a high water content)

»Definition of exposure resistance classes

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Definition of exposure resistance classes

The definition of the classes should be performance based, that will allow technology development without a need to amend the classes. The definition should also be related to exposure conditions defined in the system of exposure classes, and with requirements corresponding to realistic requirements while not necessarily being the final requirement(s). This would allow use of experience and observations from practice to calibrate requirements, and to adjust concrete specifications in accordance with observations from real structures under normal service conditions.

Requirement for Carbonation Resistance Classes should be related to long term exposure to Exposure Class XC3 while Chloride Resistance Class should be related to Exposure Class XS2, as these are stable over time and can also be simulated with long term tests in laboratories. XC3 gives conditions where the rate of carbonation is relatively high and conditions where the rate of corrosion is not insignificant. Given that the end of life is defined as carbonation reaching the reinforcement, XC3 exposure produces worse conditions than XC4 with respect to carbonation. The higher relative humidity in concrete exposed to XC4 means that it will carbonate at a rate that is slower than in XC3, but corrode more quickly.

»Definition of exposure resistance classes

" ... This would allow use of experience and observations from practice to calibrate requirements, and to adjust concrete specifications in accordance with observations from real structures under normal service conditions...."

Comment:

Be careful! Observations from practice have much larger deviation and hence we yet need a lot more data. – How would you give the data the weight they deserve?

»Definition of exposure resistance classes

“ … *can also be simulated with long term tests in laboratories….*”

Comment:

Be careful! From where do we know this? E.g. we do not have good experiences with long term chloride exposure tests in the lab!

»Definition of exposure resistance classes

“ … *Given that* ***the end of life*** *is defined as carbonation reaching the reinforcement….*”

Comment:
Observations from practice show that this is *not* the case.

Deep carbonation (at/beyond cover depth) is fairly easy to prevent/counteract, and buildings “can live” long after this point if they are just given a cost effective protective surface coating.

Such a statement would lead to higher costs of buildings!

»Practical application of exposure resistance classes

Practical application of exposure resistance classes

For the exposure resistance classes to be a practical instrument in everyday use the definition of classes should be supplemented with deemed-to-satisfy rules. These deemed-to-satisfy rules should be calibrated using best possible technology available combined with experience and observations. For this purpose the methodologies developed in the Duracrete project, later implemented in the fib Model Code and in ISO 16204, should be employed as accepted best practice at the moment.

The deemed-to-satisfy rules must then be rules applicable not only for CEM I, but for all types of cement and type II additions that are relevant.

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»Practical application of exposure resistance classes

“ … For this purpose the methodologies developed in the Duracrete project, later implemented in the fib Model Code and in ISO 16204, should be employed as accepted best practice at the moment…..”

Comment:

Before this statement a sound argumentation to support it must be given! *Duracrete* is to some extend based on dubious expert opinions (I myself was asked to reply, but I refused!) and mathematically wrong use of the laws of diffusion!

»Durability design in EC2

XD3, XS3	RSD-	-	-

The end of design working life is implicitly defined in EN 1990 as when deterioration is such that major repair becomes necessary. This is not an operational definition for a new design. From a practical point of view the cover requirements shall for new design be related to “start corrosion” as the splitting stresses due to expanding corrosion products is additive to the splitting stresses due to bond etc. utilized in the mechanical design of the structures. From the statistical distribution of cover, carbonation rate or chloride diffusion coefficient as well as aggressiveness of the environment this criterion will not exclude a certain level of corrosion on a limited percentage of the reinforcement. The criterion has also to be modified, or the target reliability, in exposure conditions where the propagation period is very long e.g. X0 and XC1.

When assessing existing structures and their remaining service life, however, the criteria shall be based on assessed/observed performance on a case by case basis, taking due account of the effect of observed deterioration on structural strength and safety etc.

Table 5 is an illustration how EN 206 could give the durability classes and the deemed to satisfy rules, and where the deemed to satisfy rules could be subject to continuous updates based on developments in new materials as well as new developments in technology and knowledge.

»Durability design in EC2

“ … the cover requirements shall for new design be related to “start corrosion”…..”

Comment:

Please observe that the “start of corrosion” can not yet be foreseen with our present knowledge – especially not chloride induced corrosion – we cannot yet define a common test method, cf. RILEM TC-235 CTC!

»Conclusion and recommendation

The basic idea of having a knowledge based set of requirements is sound and can lead to reasonable requirements – Denmark has several examples!

The benefit in specifying performance based requirements in stead of "deemed to satisfy" for the concrete industry and for the society is not obvious.

Some of the presumptions in the report are too general and do not reflect the present state of knowledge throughout Europe.

Combined effects are completely absent in the report – it is not so in real exposure!

It is recommended to proceed the work

Introduction of a system to define environmental actions on concrete in different parts of Europe shall be included.

It is recommended to make the entire system much more transparent

It is recommended to include the "model thinkers" from all over Europe much more actively

»Thanks for your attention!

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