Specifying durability by performance – a preliminary view on the CEN proposals

The European committee for the structural design of concrete structures has declared its interest in introducing service-life design into the next revision of Eurocode 2[1], where publication is anticipated in 2020. These provisions will be based on the *fib Model Code for Service Life Design*[2] and the international Standard ISO 16204[3]. These design procedures need performance input. So besides strength and consistence, the performance specified will be in terms of the resistance of concrete to the various forms of deterioration, such as the rate of carbonation for carbonation-induced corrosion and the chloride diffusion coefficient and ageing factor for chloride-induced corrosion. Tom Harrison of the University of Dundee reports.

Transposing performance requirements to the more traditional way of specifying concrete by limiting values, – minimum cement content, maximum water:cement (w/c) ratio and strength – introduces large variability, which at best is very conservative for some sets of constituents and at worst is unsafe for some sets of constituents. Consequently, a logical way forward is to specify the required performance directly. Once test methods and procedures are in place to achieve this objective, it makes sense from the designer's viewpoint to specify all concrete directly in terms of performance and not by the traditional limiting values.

From another perspective, the concrete sector is under pressure to provide more sustainable concretes but this must not be at the price of insufficient durability. For example, some 'green' concretes have carbonation rates that are significantly higher than concretes used in the past yet they satisfy the current durability specification requirements. If durability were to be specified by performance, the concrete producer could be instructed, or may be given the flexibility, to produce the more sustainable concrete and the client/designer would know that the required durability is being achieved.

A small task group, comprising members from the European design, concrete and precast concrete industries, has been working on these issues and its initial draft proposals were presented earlier this year to its parent committees. A workshop in Brussels was held in October 2014 to try to add more detail to the proposals and BSI nominated two UK experts to attend (the author also attended as a member of this task group).

Concrete resistance classes

At the heart of the proposal is the concept of concrete resistance classes. These classes define the resistance of concrete measured under closely defined standard test conditions together with a margin to account for test uncertainty.

Modelling work undertaken by the Technical University of Munich has shown that three classes for carbonation resistance and three classes of chloride resistance give sensible steps in performance that offer practical differential in concrete cover. It should be noted that implicit to this approach is that the performance determined in the laboratory under these short-term standard conditions is translated into the same comparative long-term durability behaviour. Fundamentally, it would be the producer that would determine by type testing parameters such as w/c ratio, cement content etc, for production and conformity control purposes, rather than the engineer. As with the current specification, special requirements such as low heat, E-value, creep strain would still be special design requirements.

The revised Eurocode 2 will provide guidance on the relationship between intended working life, exposure classes, minimum cover and the concrete resistance classes. As the minimum level of reliability for structures is still a Nationally Determined Parameter (NDP), the choice of the appropriate concrete resistance class will be a NDP, with the hope that most CEN members will opt to select the recommended values given in Eurocode 2.

The appropriate concrete resistance classes will be specified to the producer, together with the compressive strength class and consistence class. The concrete producer may satisfy the specified resistance class by either:

- providing concrete with the proven performance based on type testing leading to a set of limiting values specific to the constituents used and then controlling the production to these limiting values in the normal way
- supplying a concrete based on deemed-to-satisfy limiting values.

In the ideal world, these deemed-to-satisfy limiting values should be determined at the European level but given the range of constituent qualities found across Europe, it may be prudent to leave such limiting values to national provisions. Trying to explain the current national limiting values in a rational and technical way is impossible and there is a serious risk of the whole concept being rejected on the basis that any proposed European limiting values do not coincide with the current national values.

It is sensible to get the performance concept established and running as a first step and for each CEN member to determine which limiting values satisfy the resistance classes. Over time, what does and does not meet the performance criteria will become clear and the limiting values will get adjusted appropriately.

Carbonation resistance classes

Three carbonation resistance classes are being proposed (see Table 1). There is still an on-going debate over what to call these classes. The proposal to call them high, medium and low resistance was not liked as it is difficult to imagine any specifier wanting a concrete with 'low resistance'. Currently the letters 'RC' are being used followed by a number that is the maximum carbonation depth in the standard test. Both the UK and France do not like using 'RC' as these letters are already being used for another purpose.

The test method will be defined in EN 12390-10. At present this Standard is a draft for development called TS 12390-10[4] and it has already been agreed that the carbon dioxide level of the test will be raised from 350 to 400ppm to reflect typical atmospheric conditions. It is also agreed that the carbonation rate will be expressed as mm/√year. The minimum period of exposure to carbon dioxide in the test will be 140 days but longer periods will be permitted. A longer period of exposure tends to give lower or similar rates of carbonation, meaning it is safe to use the 140-day values.

The minimum number of tests has still to be agreed. One proposal is to have at least three tests from different batches if a single concrete is being assessed or at least five tests if a family of concretes is being assessed. Whether the maximum rate of carbonation

Table 1 – Proposed carbonation resistance classes

Carbonation resistance class	Maximum rate of carbonation A), mm/√years	Maximum sample standard deviation B), mm/√years
RC20	1.9 (2.3)	0.7
RC30	3.1 (3.5)	0.9
RC40	4.3 (4.8)	1.1

A) These values include a margin of –1.28σ and the number in brackets includes a margin of –1.28σ/√3.
B) It has to be confirmed by CEN/TC104/SC1 that this is the maximum standard deviation per test (highly likely) and it is not the standard deviation from n tests.

will stay as a single value for simplicity or be a function of √n has still to be discussed and agreed.

The period of validity of these type tests has also still to be discussed and agreed. As a benchmark, Agrément certificates are often valid for five years.

Chloride resistance classes

Again, three classes are being proposed with chloride diffusion being measured at least three times up to two years using the EN 12390-11[5] test procedure and then the extrapolated chloride diffusion at 50 years being the basis for classification (see Figure 1). EN 12390-11 currently has the status of a draft for development, but it has been revised and it is undergoing formal voting as an EN.

The task group has agreed that the test solution will be a defined seawater and that a margin needs to be applied but no proposals have yet been made as to the magnitude of the margin. What is of more concern is the precision of this test and whether it is adequate for classifying in the way proposed. Type testing that takes two years to complete is also not ideal.

Experts and standardisation bodies have been invited to comment on the task group proposals and the author suspects there will be several comments on the proposed approach to chloride classification. For example, it may be more practical to classify on the basis of an initial measured chloride diffusion coefficient and an accepted or measured ageing factor. For the same 'class', a higher ageing factor would be linked with a higher initial diffusion coefficient. This approach means that classification may be completed in months rather than years and it minimises the impact of test precision. Such an approach also has the benefit of avoiding the assumption in the proposed method that ageing will continue throughout the design life, which is an issue being hotly debated between experts.

Freeze–thaw resistance

Freeze–thaw testing is what is described as 'torture testing', which is an extreme test and if the concrete passes, it is highly likely to perform well in practice. The problem with such tests and the normally accepted criterion is that it fails many concretes that have performed well in the UK environment. The scaling test methods (TS 12390-9[6]) and the criteria are under review and it is hoped that before too long acceptable performance criteria for this test will be defined for more moderate climates such as the UK. Freeze–thaw resistance also has to cover resistance to internal damage and at present CEN does not even have a test procedure with the status of 'draft for development'. This has to be something for the future.

Chemical resistance

There is no agreed test method at European level for measuring the sulfate resistance of concrete (or cement). As it is the concrete that needs to resist the aggression, the focus for test development should be on concrete and not cement as many cements may provide adequate sulfate resistance if they are used in the appropriate concrete (see BS 8500-1[7]). Sulfate resistance has to cover both the ettringite and thaumasite forms of sulfate attack. Given the lack of test methods, it is unlikely that the next revision of EN 206[8] will include a performance specification for sulfate resistance.

Conformity and production control

Type testing will lead to limiting values that are specific to a set of constituents from specific sources. While control to comply with limiting values is practised throughout Europe, the introduction of concrete resistance classes will lead to a debate on whether current practices are adequate. There are a number of issues that need to be discussed, validated and agreed, including:

- Is variability from a specific source insignificant?
- Conformity to w/c ratio.
- What tests are needed to prove that the constituents have not changed significantly?
- What are demonstrably similar materials, ie, those that can be used without having to repeat the type testing?

Concluding remarks

The task group and CEN wishes to engage with the wider concrete community in developing these proposals and therefore comments are welcome. It would be appropriate to channel any comments via the BSI Concrete Committee: chairman Chris Clear (Chris.Clear@mineralproducts.org); secretary Mussa Awalah (Mussa.Awaleh@bsigroup.com), with a copy to the author (thomas.harrison.lehon@orange.fr). ●

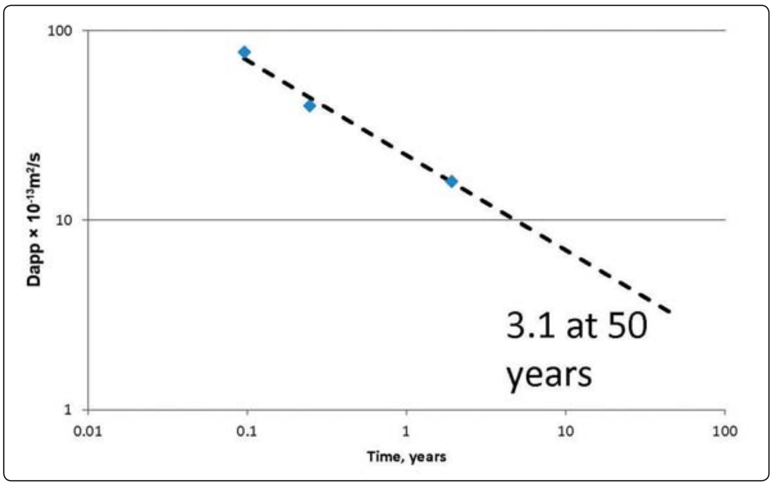

Figure 1: Proposed basis for setting chloride resistance classes.

References

1. BRITISH STANDARDS INSTITUTION, BS EN 1992-1-1. *Eurocode 2: Design of concrete structures. Part 1-1 – General rules and rules for buildings*. BSI, London, 2004.
2. FÉDÉRATION INTERNATIONALE DU BÉTON, *Model Code for Service Life Design. fib* Bulletin 34, Lausanne, Switzerland, 2006.
3. INTERNATIONAL STANDARDS ORGANISATION, ISO 16204. *Durability. Service life design of concrete structures*. ISO, Geneva, Switzerland, 2012.
4. BRITISH STANDARDS INSTITUTION, DD CEN/TS 12390-10. *Testing hardened concrete. Part 10 – Determination of the relative carbonation resistance of concrete*. BSI, London, 2007.
5. BRITISH STANDARDS INSTITUTION, DD CEN/TS 12390-11. *Testing hardened concrete. Part 11 – Determination of the chloride resistance of concrete, undirectional diffusion*. BSI, London, 2010.
6. BRITISH STANDARDS INSTITUTION, DD CEN/TS 12390-9. *Testing hardened concrete. Part 9 – Freeze–thaw resistance – Scaling*. BSI, London, 2006.
7. BRITISH STANDARDS INSTITUTION, BS 8500-1. *Concrete. Complementary British Standard to BS EN 206-1. Part 1 – Method of specifying and guidance for the specifier*. BSI, London, 2006+A1:2012.
8. BRITISH STANDARDS INSTITUTION, BS EN 206. *Concrete. Specification, performance, production and conformity*. BSI, London, 2013.