APLICAREA PROCEDURII DURABILITĂŢII ECHIVALENTE LA CONSTRUCŢII EXISTENTE
THE APPLICATION OF THE EQUIVALENT DURABILITY PROCEDURE TO EXISTING BUILDINGS

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The article presents a proposal with a view to extending the application of the equivalent durability procedure (EDP). It proposes and applies criteria for determining the freeze-thaw of concrete in the context of extending the field of application of the procedure of equivalent durability to existing buildings. The proposed method represents an extending of EDP procedure considering: reducing uncertainties related to the placing of concrete, finishing, curing of concrete and the rate of improving the performance of concrete over time. The application of standardized test methods in Europe also for assessing the freeze-thaw resistance of concrete in existing buildings represent a step forward in increasing concrete durability and prolonged working life of the buildings. The proposed method is similar to the one used in assessing concrete resistance.

Articolul prezintă o propunere de extindere a aplicării principiului / procedurii durabilităţii echivalente (PDE). Se propun şi aplică criterii pentru determinarea rezistenţei la îngheţ - dezgheţ a betonului în contextul extinderii aplicării procedurii de durabilitate echivalentă la construcţii existente. Metoda propusă reprezintă o extindere a aplicării procedurii PDE luând în considerare: reducerea incertitudinilor legate de punerea în operă a betonului, a finisării, tratării betonului şi de gradul de îmbunătăţire în timp a performanţelor betonului. Aplicarea metodelor de încercare standardizate la nivel european şi la evaluarea rezistenţei la îngheţ - dezgheţ a betonului din construcţii existente reprezintă un pas înainte în creşterea durabilităţii betonului şi a duratei de viaţă a construcţiilor. Metoda propusă este similară cu cea utilizată la evaluarea rezistenţelor betonului.

Keywords: *concrete, durability, assessing, performance, existing building*

1. Introduction

This article presents a proposal with a view to extending the application of the equivalent durability procedure (EDP), which represents a step towards addressing sustainability performance of reinforced concrete constructions. This approach is already present as a principle in standard EN 206, 2013 edition [1].

European Committee for Standardization CEN / TC104 / SC1 has developed a proposal presenting the principles of application of EDP [2], which was later published as a final document CEN / TC 104 N1205 [3]. The methods presented in this article are based on certain specifications shown in these documents and they were developed and customized to the level of some applications that dealt with freeze-thaw resistance of concrete.

2.Method

In [2], sustainability specifications for durability equivalent to the procedure are defined, and the uncertainty sources are highlighted (Table 1).

Table 1

Specifications for durability and sources of uncertainty / *Specificaţii pentru durabilitate şi surse de incertitudini*

Method of specifying concrete durability	Sources of uncertainty	Controlling the uncertainty and how it is taken into account
Equivalent durability procedure	i) Variations in the quality of concrete constituents	Controlling the production at the station and attesting the conformity
	ii) Placing, compaction, finishing and curing	In-situ tests prior to releasing into operation of the element / structure (checking)
	iii) The rate of performance improvement with time	Periodical in–situ tests (evaluation)

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The methods presented herein - as proposals/ novelties - refer to paragraphs ii) and iii) and will be detailed in this article.

The EDP method was developed in order to establish the behavior of some concretes prepared with certain materials as components (especially "candidate" cements with additives) compared to concretes prepared with "reference" cements for which the behavior in the same media of exposure is known and considered adequate. In the acceptation of this method, the performance equivalent to sustainability is determined by applying acknowledged testing methods for "candidate" concretes and obtaining some results that can be appreciated by different criteria [4, 5].

The testing methods used refer to the ones acknowledged in Europe [6 - 9].

In this article the authors present their proposal that is applied to the freeze-thaw resistance.

The proposed method represents an extending of EDP procedure considering the following aspects:

- Reducing uncertainties related to the placing of concrete, finishing, curing of concrete and the rate of improving the performance of concrete over time.
- Evaluating the state of the concrete and some specific characteristics depending on the environmental exposure.

The steps to be taken for implementing the method are exemplified for freeze-thaw action:

i. Determining the freeze-thaw resistance based on CEN/TS 12390-9 [6] standard.

ii. Establishing and verifying some appropriate criteria in compliance with exposure classes XF; The following condition must be fulfilled:

$$s_n^{se} < s_n^{s}, \qquad (1)$$

where:

s_n^{se} The mass of the scaled material after *n* freeze-thaw cycles experimentally obtained by applying the standard composition.

s_n^{s} Maximum permissible mass of scaled material, established depending on the exposure class XF.

These two preliminary stages are necessary for selecting the components.

iii. Testing of some compositions designed according to the legislation in force for a specific application/exposure class XF. The scaled material mass will be calculated and it will be verified that:

$$s_n^{se} / s_n^{c} \geq 1 \qquad (2)$$

where:

s_n^{c} represents the mass of scaled material after n freeze-thaw cycles [composition for a particular application].

iv. After placing the concrete, and in any case after 28 days, cores are extracted and - according to the requirements [6] of alternative methods - the mass of material scaled after n cycles (noted $s_n^{c,is}$) is determined.

v. When monitoring over time the performance of the concrete subjected to freeze-thaw and/or evaluating freeze-thaw resistance, cores will be extracted at certain time intervals and different values will be determined for $s_n^{c,is}$.

vi. The criteria for evaluation proposed for cases iv) and v) are:

$$s_n^{c,is} \leq 1.20\ s_n^{c} \qquad (3)$$

When there are no data regarding the value for s_n^{c}, and in any conditions:

$$s_n^{c,is} \leq s_n^{s} \qquad (4)$$

Depending on the age of the concrete and the prescribed lifetime, the samples extracted will be subjected to a number of cycles, not less than 28.

Assessing the freeze-thaw resistance for concretes prepared with existing elements is performed on cylindrical samples, i.e. cores extracted from the concrete. Depending on the type of the element, (including the initial phase), the surface orientation to be assessed is chosen relative to the casting direction.

3. Experimental Research

This chapter presents the results obtained for freeze-thaw resistance for concrete prepared with four types of cements, where the application of the proposed method is exemplified.

The testing method used in this article, weak test is standardized in Europe:

- CEN/TS 12390-9 - Testing hardened concrete - Part 9: Freeze-thaw resistance. Scaling.

3.1 Slab test method

Concrete samples are subjected to freeze-thaw attack in the presence of deionized water, or 3% NaCl solution respectively.

Freeze-thaw resistance is evaluated by measuring the amount of scaled concrete from the exposed surface of the concrete, after 56 freeze-thaw cycles.

When applying the method proposed in the article, the stipulations of point 5.7 of the standard describing alternative applications are also taken into account.

The mass of exfoliated dry material is

determined to constant mass (110 ± 10) ^{0}C. The amount of scaled material is rounded at 0.1g.

$m_{s,n}$= $m_{s,before}$ + ($m_{v+s(+f)}$ – $m_{v(+f)}$) (5)

where:

$m_{s,n}$ represents the mass of the scaled material after *n* freeze-thaw cycles rounded to the nearest 0.1g

$m_{s,before}$ represents the mass of scaled material measured previously;

$m_{v+s(+f)}$ represents the mass of the vessel containing the material exfoliated (by brushing) filtered (from water) and of the filter rounded to the nearest 0,1g;

$m_{v(+f)}$ represents the mass of the empty vessel and of the dried filter rounded to the nearest 0.1g;

The results are expressed by the following relation:

$$s_n = \frac{m_{sn}}{A} \bullet 10^3 \quad (6)$$

s_n represents the mass of the exfoliated material related to the surface, after n freeze-thaw cycles;

$m_{s,n}$ – as per relation (5)

A= total area of the tested surface estimated prior to preparing the testing device.

In this article, s_n is noted s_n^{se}.

The article presents the results regarding the performance of concretes prepared with cements of types C1, C2 and C3 (with different dosages of additives).

3.2 Characteristics of concretes

3.2.1 Caracteristics of hardened concretes

Table 2 shows the synthesis of the results for the class of compression resistance of concrete prepared with the three types of cements for standard compositions [6] and those according to NE 012/1-2007 [10] compared to the requirements in this regulation, as well as the results obtained by applying slab test method where s_n^{se} represents the mass of the scaled material relative to the test surface, after 56 freeze-thaw cycles.

Table 2

Caracteristics for concrete resistance / *Caracteristicile de rezistenţă ale betonului*

Type of cement	Composition	Cement dosage used (kg/m^3)	W/C ratio obtained	Cement dosage (kg/m^3) min.	W/C ratio max.	Resistance obtained (MPa)	Concrete class obtained	Exposure class NE 012/1-2007	Concrete class NE 012/1-2007	s_n^{se} (kg/m^2)
C1	CEN/TS 12390-9	320	0.5	-	-	40	C25/30	-	-	0.09
C2						36	C25/30			0.48
C3						38	C25/30			0.50

Type of cement	Composition	Cement dosage used (kg/m^3)	W/C ratio obtained	Cement dosage (kg/m^3) min.	W/C ratio max.	Resistance obtained (MPa)	Concrete class obtained	Exposure class NE 012/1-2007	Concrete class NE 012/1-2007	s_n^{se} (kg/m^2)
C1	CEN/TS 12390-9	320 Air entrained	0.5	-	-	31	C20/25a	-	-	0.12
C2						29	C20/25a			0.75
C3						30	C20/25a			0.61

Type of cement	Composition	Cement dosage used (kg/m^3)	W/C ratio obtained	Cement dosage (kg/m^3) min.	W/C ratio max.	Resistance obtained (MPa)	Concrete class obtained	Exposure class NE 012/1-2007	Concrete class NE 012/1-2007	s_n^{se} (kg/m^2)
C1	NE 012/1	320	0.5	300	0.55	40	C25/30	XF1	C25/30	0.10
C2		320	0.5			36	C25/30			0.52
C3		320	0.5			38	C25/30			0.61

Table 2 continues on next page

Type of cement	Composition	Cement dosage used (kg/m^3)	W/C ratio obtained	Cement dosage (kg/m^3) min.	W/C ratio max.	Resistance obtained (MPa)	Concrete class obtained	Exposure class NE 012/1-2007	Concrete class NE 012/1-2007	S_n^{se} (kg/m^2)
C1	NE 012/1	360 Air entrained	0.38	300	0.55	51	C35/45a	XF2/XF3	C25/30a	0.14
C2		380 Air entrained	0.35			49	C30/37a			0.40
C3		370 Air entrained	0.36			54	C40/50a			0.41

Type of cement	Composition	Cement dosage used (kg/m^3)	W/C ratio obtained	Cement dosage (kg/m^3) min.	W/C ratio max.	Resistance obtained (MPa)	Concrete class obtained	Exposure class NE 012/1-2007	Concrete class NE 012/1-2007	S_n^{se} (kg/m^2)
C1	NE 012/1	380 Air entrained	0.36	300	0.55	57	C40/50a	XF4	C30/37a	0.18
C2		410 Air entrained	0.34			51	C35/45a			0.29
C3		400 Air entrained	0.34			60	C45/55a			0.40

Table 3

Fulfilling the initial criteria / *Îndeplinirea criteriilor iniţiale*

Exposure		XF1**	XF2**	XF3**	XF4*
Method		Slab test			
Type of cement	C1	X	X	X	X
	C2	X	X	X	X
	C3	X	X	X	X

X = fulfilled criterion
O = unfulfilled criterion
*) criterion existing in international de specialty literature, **) criterion proposed by the authors

Table 4

Aplying the criteria/ A*plicarea criteriilor*

Type of cement	S_n^{se} Composition CEN/TS 12390-9*)	Exposure class NE 012/1	S_n^{c} Composition NE 012/1*)	S_n^{se} / S_n^{c} ≥1	$S_n^{c,is}$ ≤ 1.20* S_n^{c}	$S_n^{c,is}$ ≤ S_n^{s}
C1	0.09*)	XF1/XF3	0.10*)	-	0.12	1.3/1.0
C2	0.48*)		0.52*)	-	0.62	
C3	0.50*)		0.61*)	-	0.73	
C1	0.12**)	XF2	0.14**)	-		1.3
C2	0.75		0.40	1.87	0.5	
C3	0.61		0.41	1.48	0.5	
C1	0.12**)	XF4	0.18**)	-	0.54	1.0
C2	0.75		0.29	2.5	0.35	
C3	0.61		0.40	1.52	0.5	

*) The requirements for the compositions are identical and minimum of the concrete classes were fulfilled using a dosage of 320 kg/m^3, the results for S_n^{se} and S_n^{c} being thus very close for the first three cements (in theory they should be identical, the differences resulting from the precision of the method)
**) Having very low values for this type of cement (which could be considered as a reference) it is not necessary to apply the other criteria.

3.2.2 Assessing criteria for freeze-thaw resistance of concrete

The criteria presented are either proposals of the authors, or practiced in Europe and they are at an experimental research level and/or national regulations with a view to assessing the performance of some cements and studying the possibility of using them in various exposure environments.

Method: ***Slab test***

Proposals, criteria:

- **For class of exposure XF1** (cement dosage 320 kg/m^3, W/C rate = 0.5)

Quantity of scaled material, s_n^s must be less than 1.3 Kg/m^2 after 56 freeze-thaw cycles

- **For class of exposure XF3** (cement dosage 320 kg/m^3, W/C rate = 0.5)

Quantity of scaled material, s_n^s must be less than 1 Kg/m^2 after 56 freeze-thaw cycles

- **For class of exposure XF3** (cement dosage 320 kg/m^3, W/C rate = 0.5, entrained air)

Quantity of exfoliated material, s_n^s must be less than 1.3 Kg/m^2 after 56 freeze-thaw cycles

<u>Existing criterion:</u>

- **For class of exposure XF4** (cement dosage 320 kg/m^3, W/C rate = 0.5, entrained air)

Quantity of scaled material s_n^s must be less than 1 Kg/m^2 after 56 freeze-thaw cycles.

Table 3 presents fulfilling of the first criterion for analyzed cements ($s_n^{se} < s_n^s$)

Table 4 presents the value of the scaled material s_n^{se} and s_n^c, and according with the exposure class XF the admissibility criteria, inclusive for the concrete extracted from the structure.

4. Conclusion

This article proposes and applies criteria for determining the freeze-thaw of concrete in the context of extending applying the procedure of equivalent durability to existing buildings.

The application of standardized test methods in Europe also for assessing the freeze-thaw resistance of concrete in existing buildings represent a step forward to eliminating some uncertainties linked to placing of concrete and concrete performances development over time, bringing the proposed method nearer to the one used in assessing concrete resistance.

Therefore more objective assessments can be made on the concretes prepared with cements with additives, especially when performing on-site trials after 28 days, bearing in mind the specific development over time of the performances of such types of concrete, and also highlighting the (favorable) effect of a prolonged curing.

All of these will lead to optimizing the composition, increasing concrete durability and prolonged working life of the buildings.

REFERENCES

1. ***, EN 206 – Concrete - Specification, performance, production and conformity, 2014
2. ***, CEN TRxxxxx: N 703 CEN/TC104/SC1/TG17 – N 71 DRAFT FOR CEN/TC104/SC1 COMMENT - Principles of the equivalent durability procedure DRAFT FOR CEN/TC104/SC1 COMMENT - CEN/TC104/SC1, 2011
3. ***, CEN TECHNICAL REPORT CEN/TC104/SC1/TG5 “Use of additions” TG5-170 - USE OF K-VALUE CONCEPT, EQUIVALENT CONCRETE PERFORMANCE CONCEPT AND EQUIVALENT PERFORMANCE OF COMBINATIONS CONCEPT, 2011
4. ***, VC12 WG4 - DUTCH GUIDELINE FOR THE EQUIVALENT CONCRETE PERFORMANCE CONCEPT Draft version, 2009
5. ***, NBN B 15-100 Méthodologie pour l’évaluation at l’attestation de l’aptitude a l’emploi de ciment et d’additions de type II destines au béton, 2008
6. ***, European Committee for Standardization, CEN / TS 12390-9 “Testing hardened concrete - Part 9: Freeze-thaw resistance. Scaling”,
7. ***, European Committee for Standardization CEN/TS 12390-10. “Testing hardened concrete. Part 10: Determination of the relative carbonation resistance of concrete”
8. ***, European Committee for Standardization CEN/TS 12390-11. “Testing hardened concrete - Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion”.
9. ***, European Committee for Standardization CEN/TR 15177. “Testing the freeze-thaw resistance of concrete - Internal structural damage”.
10. ***, NE 012 Cod de practică pentru executarea lucrărilor din beton, beton armat şi beton precomprimat, Partea 1, Producerea betonului

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