APLICAREA UNOR METODE DE EVALUARE ASOCIATE PERFORMAȚELOR MATERIALELOR PENTRU STABILIREA DOMENIILOR DE UTILIZARE A BETONULUI

APPLICATION OF SOME EVALUATION METHODS ASSOCIATED WITH THE PERFORMANCE OF MATERIALS TO DETERMINE THE AREAS OF USE OF CONCRETE

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The use of admixtures in the preparation of cement and concrete is already a widespread solution at national and European level. There is often the issue of promoting new compositions with varying percentages and types of additions for certain applications and exposure environments, the main issue being to ensure good behavior over time and to ensure a proper working life. The article presents the applications of performance-related methods used at European level to check the possibility of using new compositions in certain exposure environments. These methods stand for useful tools in completing the water/cement equivalent ratio method,expected to provide similar time behaviors to a reference composition. The article presents the 148frost-thawing resistance of concrete based on the results of experimental research carried out by the authors

Utilizarea adaosurilor la prepararea cimentului și betonului reprezintă deja o soluție larg raspândită pe plan național și european. Se pune deseori problema promovării unor compoziții noi având diverse procente și tipuri de adaosuri pentru anumite aplicații și medii de expunere, principala problemă fiind cea legată de asigurarea unei bune comportări în timp și asigurarea unei durate de viață corespunzătoare. Articolul prezintă aplicații ale unor metode asociate performanțelor utilizate pe plan european pentru verificarea posibilității utilizării unor compoziții noi în anumite medii de expunere. Aceste metode reprezintă instrumente utile, în completarea metodei raportului apă ciment echivalent, presupus a asigura comportări în timp similare cu ale unei compoziții de referință. În articol se prezintă aplicarea unor metode asociate performanței betonului în ceea ce privește rezistența la carbonatare și la îngheț-dezgheț a betonului pe baza rezultatelor unor cercetări experimentale efectuate de autori.

Keywords: *concrete, cement with mineral admixture, compressive strength of concrete, k-value concept, performance methods.*

1. Introduction

Durability is being specified by limiting values (maximum w/c ratio, air content and minimum cement content), limits on the permitted constituents and in some cases additional performance requirements, e.g. compressive strength. These empirical provisions have been based on local experience and the local availability of constituents. They do not have a clear consistent and common understanding of what performance is actually defining what is expected at the “end of design service life”, much of the basis for the observed divergence in criteria lies probably here. One of the practical results of the above is that there is a considerable variation in requirements between the various countries in Europe [1].

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 and poorer performance than the materials we are used to. 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 as a requirement when certain limits are exceeded or new materials are being used [1].

The article presents an analysis of the application of various methods related to concrete performance taking as a case study the results of some experimental research on concrete with cement with addition, CEM II/A-S 42,5R respectively concrete with additions with the same proportions, CEM I 42,5R + 10% slag.

This analysis starts from the application of the prescriptive k-value concept [2] which is based on the comparison of the performances of a concrete prepared with cement «A» with those of a concrete in which part of the cement «A» has been replaced with an addition, i.e. the replacement A / C ratio with equivalent ratio A/C + k x addition.

Type II additions contribute to concrete properties by various mechanisms. Their influence on concrete properties depends on the characteristics of the individual material properties,

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on the age of concrete, on the ambient conditions (temperature, humidity) and various other parameters. To take into account these effects in the concrete mix design, the k-value method uses the relationship between the water/cement ratio and the strength of concrete. The concept was introduced by Iain A. Smith for the first time in 1967 for the design of fly ash concretes with fly ash amount up to 25% [3] and has developed further on [4]. There are many other important researches which treat this subject [5 - 7].

The aim of this work was to examine whether the application of this concept can "cover" in achieving equivalent durability performances. That is why the principles of the equivalent durability procedure has also been applied in different proposals at European level [8] and studied by many researchers.

Harrison presents parameters for specifying carbonation resistance [9] and a proposal for performance criteria for resistance to carbonation-induced corrosion 'The exposure resistance for concrete exposed to carbonation shall be referred to the carbonation depth (characteristic value 90 % fractile), in mm, expected to be obtained after 50 years under reference conditions (400 ppm CO2 in a constant 65 % RH environment and at 20°C) [10]. Helland presents a proposal for assessments of carbonation ingress in-field as a tool to calibrate code requirements [11]. Durability Safety Calibration Proposal for Carbonation is presented by David Izquierdo [12]. Elisabeth Helsing, propose a relation between scaling at the end of service life and at the end of testing, freeze – thaw resistance [13]. A new performance-based approach is described to concrete freeze-thaw quality control by Yu Song, Davin Lange [14]. Performance-based durability testing, design and specification is developed by M.G. Alexander & H. Beushausen [15]. A framework for use of durability indexes in performance based design and specifications for reinforced concrete structures is published by M. G. Alexander Æ Y. Ballim Æ K. Stanish [16]. A current experience with probability-based durability design and performance-based concrete quality control is briefly outlined and discussed by Odd E. Gjørv [17].

2. Experimental researches. Methods and materials

The experimental researches consisted in the determination of the performance of concrete prepared with type CEM II/AS 42,5R cement (10% slag) and of a concrete made of CEM I 42,5R with the addition of 10% slag in terms of compressive strength and carbonation resistance and freeze-thaw resistance.

2.1. The determination of the k-value concept

The first stage of the experimental research consisted in determining the *k*-value concept [4], [19]. Table 1 shows the composition of concrete. The characteristics of the fresh concrete are presented in Table 2 and the characteristics of the hardened concrete in Figures 1 and 2.

Table 1

Compositions of the concrete prepared with CEM I 42,5R / CEM I 42.5R and 10% slag
Compozițiile betoanelor preparate cu CEM I 42,5R / CEM I 42,5R și 10% zgură

Cement / cement+slag dosage (kg/m³) / *Dozaj ciment / cimen+zgură (kg/m³)*	Water (l) / *Apa* (l)	Admixture (l) / *Aditiv* (l)	Aggregate (kg) *Agregate (kg)*	0-4 mm type / *sort 0-4 mm*	4-8 mm type */ sort 4-8 mm*	8-16 mm type / *sort 8-16 mm*
270 / 243+27	171 / 160	2.55	1893	757	379	757
300 / 270+30	159 / 156	2.83	1855	742	371	742
340 / 306+34	154 / 143	3.21	1801	720	360	721
370 / 333+37	158 / 153	3.49	1780	712	356	712
430 / 387+43	167 / 153	4.06	1705	682	341	682

Table 2

The characteristics of fresh concretes prepared with CEM I 42,5R / CEM I 42.5R and 10% slag
Caracteristicile betoanelor proaspete preparate cu CEM I 42,5R / CEM I 42,5R și 10% zgură

Cement / cement+slag dosage (kg/m³) / *Dozaj ciment / ciment+zgura (kg/m³)*	W/C *A/C*	Settlement (mm) / *Tasare (mm)*	Density (kg/m³) / *Densitate (kg/m³)*
270 / 243+27	0.64 / 0.60	150 / 110	2379 / 2398 (noncohesive concrete/*beton necoeziv)*
300 / 270+30	0.54 / 0.53	150 / 135	2405 / 2424 (noncohesive concrete/*beton necoeziv)*
340 / 306+34	0.46 / 0.43	150 / 125	2439 / 2446
370 / 333+37	0.44 / 0.42	150 / 145	2400 / 2414
430 / 387+43	0.40 / 0.37	150 / 105	2433 / 2418

The figures 1 and 2 show the variation of the compressive strength according to the W/C ratio.

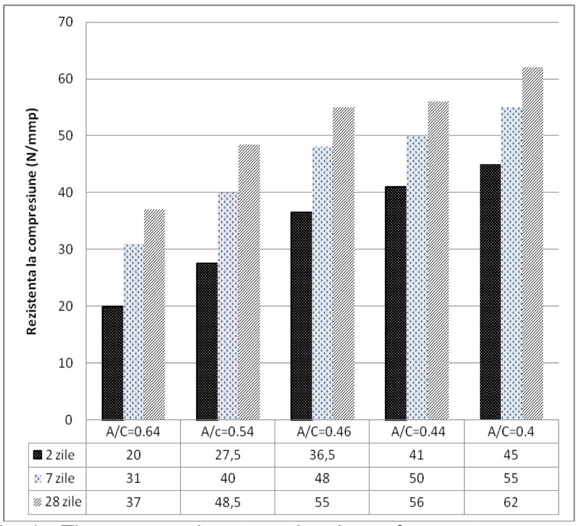

Fig. 1 - The compressive strength values of concretes prepared with CEM I 42.5R / *Valorile rezistentei la compresiune a betoanelor preparate cu CEM I 42,5R.*

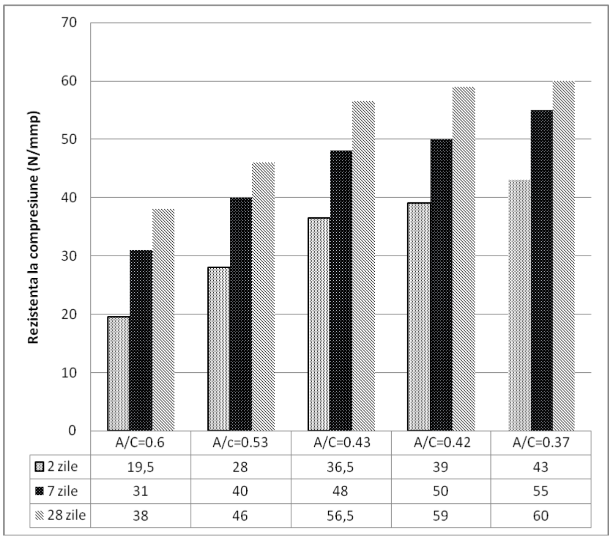

Fig. 2. - The compressive strength values of concretes prepared with CEM I 42.5R and 10% slag / *Valorile rezistenței la compresiune a betoanelor preparate cu CEM I 42,5R și 10% zgură.*

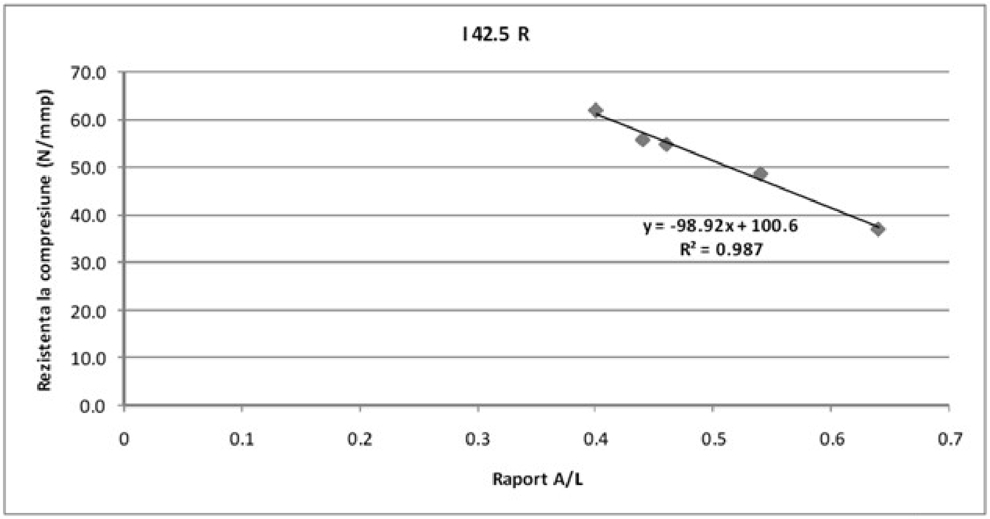

Fig. 3. - The compressive strength values at 28 days of concrete prepared with CEM I 42.5R [19] / *Valorile rezistenței la compresiune la 28 de zile betoanelor preparate cu CEM I 42,5R [19].*

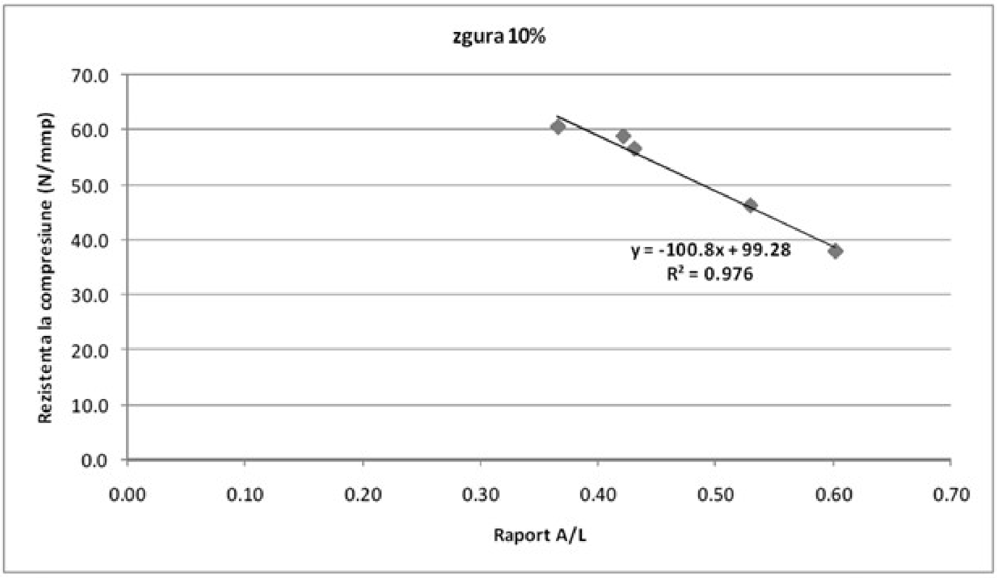

Fig. 4. - The compressive strength values after 28 days of concrete prepared with CEM I 42.5R and 10% slag [19] / *Valorile rezistenței la compresiune la 28 de zile betoanelor preparate cu CEM I 42,5R și 10% zgură [19].*

The diagrams presents in Fig. 3 and 4 [19] were used to determine the coefficients A_0, B_0 for the reference concrete and A_a and B_a respectively for the concrete with addition. The following results were obtained:

$f_0 = 100.6 - 98.92\ \omega_0$

$f_a = 99.28 - 100.8\ \omega_a$ (10% slag)

For the concrete with 10% slag addition, applying the relation (1):

$$k = \frac{(A_a - A_0)(1 + a/c)}{B_a \text{ x } a/c} \text{ x } \frac{1}{\omega_0} + \left[\frac{B_0(1 + a/c)}{B_a} - 1\right] \text{x } \frac{1}{a/c} \quad (1)$$

where:

ω_0 - water / cement ratio of reference concrete without additions;

ω_a - water / cement ratio of cement with additions, $\omega_a = w_a/c_a$;

w_a - water quantity of concrete with additions (kg/m^3);

c_a - the amount of cement in the concrete with additions (kg/m^3);

a/c - addition / cement;

a - the amount of additions (kg/m^3)

f_a, f_0 – the compressive strengths of concrete (N/mm^2);

A_0, A_a, B_0, B_a - coefficients of the linear relation between the A/C ratios and the compressive strength of the concrete for the reference concrete and the concrete with additions.

The result is:

$$k = -0.132/\omega_0 + 0.812 \quad (2)$$

Applying the relation (2) for different water / cement ratios ω_0 = 0.45; 0.5; 0.60, 0.65, a minimum value of the coefficient *k* of approx. 0.5, the k-value concept values varying between 0.52 and 0.62 [19].

2.2. Concrete compositions made with cement CEM II / A-S 42.5R (10% slag) and CEM I 42.5R and 10% slag, coefficient k = 0.5

Concrete mixtures were proposed for two prescribed compressive classes of C 16/20 with an equivalent ratio A/C = 0.65 and C20/25a with an equivalent ratio with an A/C = 0.50, having the compositions and characteristics shown in Tables 3 and 4 for which the strength and durability characteristics have been determined. The determination of the required amount of slag resulted from the choice of a cement dosage (260 kg / m^3 for C16/20 and 330 kg / m^3 for class C20/25a respectively) and considering the coefficient k = 0.5.

Concrete class C 16/20

- Concrete with cement type II / A-S 42,5R (10% slag) was prepared with cement dosage of 260 kg/m^3 and with W/C ratio of 0.65
- Concrete with 10% slag (k = 0.5) was prepared $c_1 + 0.5 \cdot 0.1\ c_1$ = 260 kg/m^3 c_1 = 248 kg/m^3, slag = 25 kg/m^3

Concrete class C 20/25a

- Concrete with cement type II / A-S 42,5R (10% slag) was prepared with cement dosage of 330 kg/m^3 and with A/C ratio of 0.5
- It was prepared concrete with 10% slag (k = 0.5) $c_1 + 0.5 \cdot 0.1\ c_1$ = 330 kg/m^3; c_1 = 314 kg/m^3, slag = 31 kg/m^2

2.2.1. Compositions and characteristics of fresh and hardened concrete

In Table 3 and 4 are presented the compositions and characteristics of C16/20 and C 25/30a concretes. The compressive strength after 28 days is considered appropriate for preliminary tests if the compressive strength values of the concrete obtained are greater than f_{ck} + 6...12 ($f_{cm} \geq f_{ck}$+6...12 according to SR EN 206 [1]), where f_{ck} is the characteristic strength corresponding to the concrete class and for current tests, if the average strength values are greater than f_{ck} + 4 ($f_{cm} \geq f_{ck}$ + 4 according to SR EN 206 [2]).

The results show that the k-concept give a good relationship between the water/cement (water/cement+addition) ratio and the strength of concrete. It is known that the water/cement ratio have a major influence of the strength and durability of concrete, both due to the porosity of concrete. It is known also that if we use the same water/cement ratio but different type of cements,

Table 3

Compositions and characteristics of C16/20 concrete that was prepared with an W/C equivalent ratio to 0.65
Compozițiile și caracteristicile betoanelor de clasa C16/20 preparate cu un raport A/C echivalent de 0,65

Binder type *Tip liant*	Cement + slag dosage (kg/m^3) *Dozaj ciment+ zgură (kg/m^3)*	Water (l) / *Apa (l)*	Super plasticizer admixture (l) *Aditiv super-plastifiant (l)*	Aggre-gate (kg) *Agre-gate* (kg)	0-4 mm type *sort 0-4 mm*	4-8 mm type *sort 4-8 mm*	8-16 mm type *sort 8-16 mm*	Settlement (mm) *Tasare (mm)*	Density (kg/m^3) *Densitate (kg/m^3)*	Compre-ssive strength (N/mm^2) *Rezistența la compre-siune (N/mm^2)*	The concrete class obtained *Clasa de beton obținută*
CEM I+10% slag *CEM I+10% zgură*	248+25	166	2.57	1908	763	382	763	195	2361	26	C16/20
CEM II/ A-S	260+0	166	2.45	1920	768	384	768	200	2338	28	C16/20

Table 4

Compositions and characteristics of C25/30a concrete that was prepared with an W/C equivalent ratio to 0.5
Compozițiile și caracteristicile betoanelor de clasa C20/25a preparate cu un raport A/C echivalent de 0,5

Binder type *Tip liant*	Cement + slag dosage (kg/m^3) *Dozaj ciment+ zgură (kg/m^3)*	Water (l) Apă (l)	Super-plasticizer/ Air-entraining admixture (l) *Aditiv super-plastifiant/ antrenor de aer (l)*	Aggre-gate (kg) *Agre-gate (kg)*	0-4 mm type *sort 0-4 mm*	4-8 mm type *sort 4-8 mm*	8-16 mm type *sort 8-16 mm*	Settle-ment (mm) *Tasare (mm)*	Density (kg/m^3) *Densitate* (kg/m^3)	Air (%) Aer (%)	Compre-ssive strength (N/mm^2) / *Rezisten-ța la compre-siune* (N/mm^2)	The concrete class obtained *Clasa de beton obținută*
CEM I+10% slag / CEM I+10% zgură	314+31	161	3.26/0.69	1856	742	372	742	210	2192	10	31	C20/25a
CEM II/ A-S	330+0	161	3.11/0.66	1870	748	374	748	205	2180	9.2	30	C20/25a

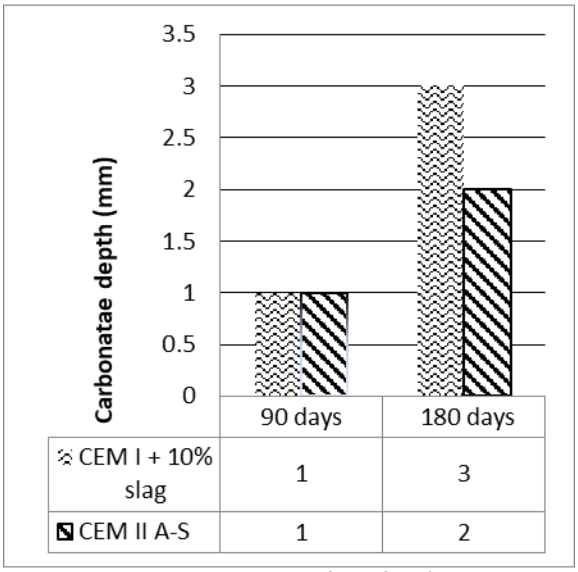

Fig. 5. - The carbonation depths of the C16 / 20 concrete with CEM I and 10% slag and concrete with CEM II / A-S / *Adâncimile de carbonatare ale betoanelor de clasa C16/20 preparate cu CEM I 42,5R și 10% zgură și respectiv beton cu CEM II/A-S.*

we don't obtain the same durability. The problem that we put in this work was, is if we use the same equivalent water/ratio, the same type of cements and percent of addition direct in cement or in concrete (10% slag), we obtain the same durability, and k-concept cover this situation? For answer of this question we made some durability tests (carbonation and frost thaw resistance) and the results were used by applying performance methods proposed in European and national regulation.

2.2.2. Carbonation of concrete

The specimens used to determine the carbonation depth were maintained for 7 days in water and then under standardized laboratory conditions (65% humidity and 20°C temperature) until the test date. The evolution of carbonation was surveyed on specimens kept in the laboratory and examined at different times, 90 and 180 days.

Immediately after splitting, the concrete section was moistened with a 1% phenolphthalein alcohol solution. After applying the indicator solution, the carbonate area retains the initial color of the concrete and the non-carbonated area is red-violet (phenolphthalein changes color to pH <9.2). The depth of the carbonate layer of the concrete was determined according to SR CR 12793 [20].

Figure 5 presents the results for carbonate depth values, expressed to the nearest 0.5 mm, for the compressive strength class C16 / 20.

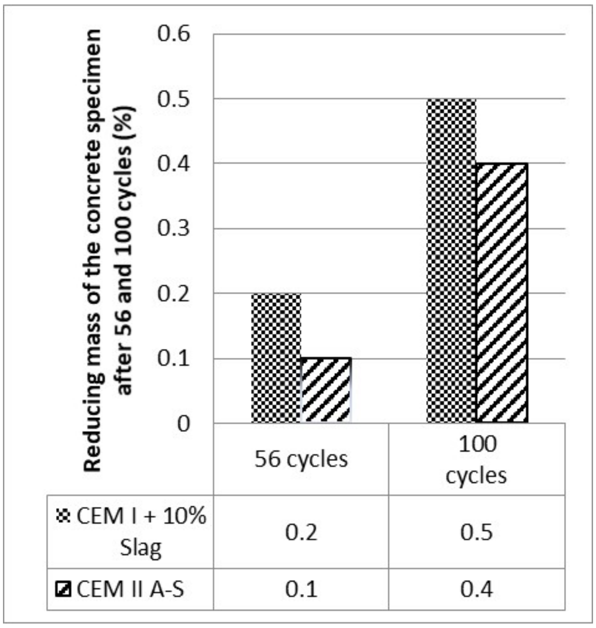

Fig. 6. - Reducing the mass of the C20/25a concrete specimen after 56 and 100 frost-thaw de-icing salt cycles / *Reducerea masei cuburilor din beton de clasa C20/25a după 56 și 100 de cicluri de îngheț-dezgheț cu agenți de dezghețare.*

2.2.3. Frost-thaw resistance

Repeated freezing / thawing behavior of concrete was studied by the "cube test" non-destructive method according to CEN / TS 12390-9 [21]. Figure 6 show the amount of scaling concrete for the prepared concrete at A/C = 0.5 as a percentage by mass to the nearest 0.1 %.

3. Applying performance methods

3.1. Carbonation of concrete

3.1.1. "European"method

Analyzing the aspects of carbonation resistance related to the equivalent durability procedure of the European norm CEN / TC104 / SC1 - N 703 [8], a comparison was made between concrete with cement CEM I + 10% slag considered as candidate concrete and concrete with cement CEM II / AS being the reference concrete (Table 7).

The measured value of the carbonate depth of the candidate concrete must be less than or equal to the reference concrete

$$\pm \frac{1}{\sqrt{2}}\sqrt{\left(([2.33\sigma_R)]^2 - ([2.33\sigma_r)]^2\left(\frac{n-1}{n}\right)\right)} \quad (3)$$

taking into account the mean values at 90 and 180 days for n≥3.

where:

σ_r - the mean standard deviation for candidate concrete was considered;

σ_R - the average standard deviation for reference concrete was considered.

3.1.2. Dutch method

Analyzing the aspects of carbonation resistance related to the equivalent concrete performance concept of the Dutch normative VC12 WG4 [18], a comparison was made between concrete with cement CEM I+10% slag as candidate concrete and concrete with cement CEM II/A-S being as a reference concrete (Table 7).

For each aspect of durability, the assessment was based on the evaluation parameter Tj:

$$T_j = \sqrt{\frac{\left[m_r - \frac{m_t}{1+0.01d_j}\right]}{\frac{s}{\sqrt{n}}}} \quad (4)$$

where: s =

$$\sqrt{\left(\left\{s_r^2 + \frac{s_t^2}{\left(1+0.01\,d_j\right)^2}\right\}\right)} \quad (5)$$

where:

m_r is the average test result of the n samples of the reference concrete;

m_t - the average test result of the n samples of the test concrete;

s_r - the standard deviation of the averages per sample of the reference concrete;

s_t - the standard deviation of the averages per sample of the test concrete;

n - the number of samples;

dj - the limit value of the durability aspect j, as shown in Table 5.

Table 5.

Limit values for " d_j " / *Valori limită pentru " d_j "*

Durability aspect j / *Aspectul durabilitatii j*	Difference d [%] that leads to rejection with a probability of 90% *Diferenta "d" (%) care determina respingerea cu o probabilitate de 90%*
Carbonation *Carbonatare*	+30
Chloride ingress *Penetrare cloruri*	+30
Frost-thaw de-icing salt resistance *Ingheț-dezgheț cu agenți de dezghețare*	+30
Seawater resistance *Rezistența la săruri marine*	+40
Sulphate resistance *Rezistența la atac sulfatic*	+40

For approval T_j should be larger than the limit values shown in Table 6.

Table 6

Limit values for " Tj " / *Valori limită pentru " T_j "*

Number of samples (n) *Numărul de probe (n)*	Limit value T_j *Valoare limită pentru T_j*
3	1.533
4	1.440
5	1.397
6	1.372
7	1.356
8	1.345
9	1.337
10	1.330
11	1.325
12	1.321

For efficacy, Tj > 1.533 when n = 3 and dj = 30.

3.1.3. Synthesis of the obtained results

Table 7 shows the results obtained by applying the two performance methods.

3.2. Frost-thaw resistance

3.2.1. "European" method

Analyzing the aspects of frost-thaw de-icing salt resistance to the equivalent durability procedure of the European norm CEN / TC104 / SC1 - N 703 [8], a comparison was made between concrete with cement CEM I+10% slag as candidate concrete and concrete with cement CEM II/A-S being the reference concrete (Table 8).

3.2.2. Dutch method

Considering the values obtained for reducing the mass of concrete samples after 56 frost-thaw de-icing salt cycles and 100 frost-thaw de-icing salt cycles, the same comparison was made between the concrete with CEM I+10% slag

Table 7

Carbonation performance analysis for concrete C16/20 prepared with CEM I+10% slag taking as reference the concrete prepared with CEM II/A-S [22] / *Analiza performanţelor la carbonatare, pentru betonul de clasa C16/20 preparat cu CEM I+10% zgură luând ca referinţă betonul preparat cu CEM II/A-S [22]*

Normative / *Normativ*	Carbonation of concrete / *Carbonatarea betonului*	
European document CEN/TC104/SC1-N 703 [8] / *Document european* CEN/TC104/SC1-N 703 [8]	Candidate concrete value ≤ reference concrete value / *Valoare beton candidat ≤ valoare beton de referinţă* $\pm \frac{1}{\sqrt{2}}\sqrt{\left(([2.33\sigma_R)]^2 - ([2.33\sigma_r)]^2\left(\frac{n-1}{n}\right)\right)}$ unde n ≥ 3	
	Laboratory conditions / *Condiţii de laborator* 90 days / *90 zile*	m_r = 1.20 (candidate concrete / *beton candidat*); m_R = 0.89 (reference concrete / *beton de referinţă*); σ_r = 0.36; σ_R = 0.18
	Criterion / Criteriu	0 $1.20 \le 0.89 + \frac{1}{\sqrt{2}}\sqrt{\left(([2.33x0.18)]^2 - ([2.33x0.36)]^2\left(\frac{3-1}{3}\right)\right)}$
	Laboratory conditions / *Condiţii de laborator* 180 days / *180 zile*	m_r = 3.13 (candidate concrete / *beton candidat*); m_R = 2.02 (reference concrete / *beton de referinţă*); σ_r = 0.30; σ_R = 0.69
	Criterion / *Criteriu*	0 $3.13 \le 2.02 + \frac{1}{\sqrt{2}}\sqrt{\left(([2.33x0.69)]^2 - ([2.33x0.30)]^2\left(\frac{3-1}{3}\right)\right)}$ =3.07
Dutch normative VC12 WG4 [18] / *Normativ olandez* VC12 WG4 [18]	$T_j = \frac{\left[mr - \frac{mt}{1+0.01xdj}\right]}{s/\sqrt{n}}$, unde $s = \sqrt{sr^2 + \frac{st^2}{(1+0.01dj)^2}}$	
	Laboratory conditions / *Condiţii de laborator* 90 days / *90 zile*	m_r = 1.20 (candidate concrete / *beton candidat*); m_R = 0.89 (reference concrete / *beton de referinţă*); s_t = 0.36; s_r = 0.18; s=0.33; T_j <0
	Criterion / *Criteriu*	0 $T_j = \frac{\left[mr - \frac{mt}{1+0.01xdj}\right]}{\frac{s}{\sqrt{n}}} = \frac{\left[0.89 - \frac{1.20}{1+0.01x30}\right]}{\frac{0.33}{\sqrt{3}}} < 0$
	Laboratory conditions / *Condiţii de laborator* 180 days / 180 zile	m_r = 3.13 (candidate concrete/ *beton candidat*); m_R = 2.02 (reference concrete / *beton de referinţă*); s_t = 0.30; s_r = 0.69; s=0.73; T_j <0
	Criterion / *Criteriu*	0 $T_j = \frac{\left[mr - \frac{mt}{1+0.01xdj}\right]}{\frac{s}{\sqrt{n}}} = \frac{\left[0.89 - \frac{1.20}{1+0.01x30}\right]}{\frac{0.33}{\sqrt{3}}} < 0$

Legend: X is the achieved criterion;
0 - unachieved criterion.

Table 8.

The performance analysis for concrete C20/25a prepared with CEM I+10% slag taking as reference concrete prepared with CEM II/A-S, after 56 and 100 freeze-thaw with de-icing salt cycles [22] / *Analiza performanțelor betonului de clasa C20/25a preparate cu CEM I+10% zgură luând ca referință betonul preparat cu CEM II/A-S, după 56 și 100 cicluri de îngheț-dezgheț cu agenți de dezghețare [22]*

Normative / Normativ	Frost-thaw de-icing salt resistance of concrete / Rezistența la îngheț-dezgheț cu agenți de dezghețare a betonului	
European document CEN/TC104/SC1-N 703 [8] / *Document european CEN/TC104/SC1-N 703 [8]*	Candidate concrete value ≤ reference concrete value / *Valoare beton candidat ≤ valoare beton de referință* $\pm\frac{1}{\sqrt{2}}\sqrt{\left(([2.33\sigma_R)]^2-([2.33\sigma_r)]^2\left(\frac{n-1}{n}\right)\right)}$ unde n ≥ 3	
	56 cycles / *56 cicluri*	m_r = 7.05 (candidate concrete / *beton candidat);* m_R = 5.55 (reference concrete / *beton de referință);*); σ_r = 0.81; σ_R = 0.71
	Criterion / *Criteriu*	0 7.05 ≤ 5.55+ $\frac{1}{\sqrt{2}}\sqrt{\left(([2.33x0.71)]^2-([2.33x0.81)]^2\left(\frac{3-1}{3}\right)\right)}$ = 5.94
	100 cycles / *100 cicluri*	m_r = 27.69 (candidate concrete / beton candidat); m_R = 20.83 (reference concrete / *beton de referință);* σ_r = 5.72; σ_R = 4.05
	Criterion / *Criteriu*	0 27.69 ≤ 20.83 + $\frac{1}{\sqrt{2}}\sqrt{\left(([2.33x4.05)]^2-([2.33x5.72)]^2\left(\frac{3-1}{3}\right)\right)}$
Dutch normative VC12 WG4 [18] / Normativ Olandez VC12 WG4 [18]	Tj = $\frac{\left[mr-\frac{mt}{1+0.01xdj}\right]}{s/\sqrt{n}}$, unde s = $\sqrt{sr^2+\frac{st^2}{(1+0.01dj)^2}}$	
	56 cycles / *56 cicluri*	m_r = 7.05 (candidate concrete / *beton candidat);* m_R = 5.55 (reference concrete / *beton de referință);* s_t = 0.81; s_r = 0.71; s=0.94; T_j = 0.23 < 1.533
	Criterion / *Criteriu*	0 $T_j=\frac{\left[mr-\frac{mt}{1+0.01xdj}\right]}{s/\sqrt{n}}=\frac{\left[5.55-\frac{7.05}{1+0.01x30}\right]}{0.94/\sqrt{3}}$ = 0.23 < 1.533
	100 cycles / *100 cicluri*	m_r = 27.69 (candidate concrete */ beton candidat*); m_R = 20.83 (reference concrete / *beton de referință);* s_t = 5.72; s_r = 4.05; s=5.98; T_j < 0
	Criterion / *Criteriu*	0 $T_j=\frac{\left[mr-\frac{mt}{1+0.01xdj}\right]}{s/\sqrt{n}}=\frac{\left[20.83-\frac{27.69}{1+0.01x30}\right]}{5.98/\sqrt{3}}$ < 0.

Legend: X is the achieved criterion;
0 - unachieved criterion.

considered as candidate concrete and concrete with CEM II/A-S being reference concrete according to the Dutch norm VC12 WG4 [18] (Table 8).

3.2.3. Synthesis of the obtained results

Table 8 shows the results obtained by applying the two performance methods.

4. Conclusions

4.1. Various methods for assessing the durability of concrete, descriptive and performance methods have been applied in the article, according European regulations. Methods have been applied to the case of a concrete with the same slag content but also in the cement and concrete composition respectively.

4.2. The activity index method allows the calculation of an W/C equivalent ratio when using mineral additions in concrete. By applying the method, it was possible to determine the *k*-value concept and based on it, concrete compositions with additions were made.

4.3. In terms of compressive strength, it was similar for the two compositions, these being in the same compressive strength class. Applying performance methods to determine carbonation resistance using composition with cement CEM II/A-S as reference cement, highlights that concrete with the same amount of slag but in concrete does not achieve similar performance. The same conclusions resulted from applying the frost-thaw resistance of concrete.

4.4. In conclusion, it can be stated that prescriptive methods of "deem to satisfy" in general, but also customized to the W/C equivalent ratio concept in the case of use of the mineral additions, should be completed with applying performance methods in order to ensure the same lifetime of concrete constructions.

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