CEMENT CONCRETE MADE FROM ENVIRONMENTALLY FRIENDLY WASTE MATERIALS

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Rezumat. *Reciclarea deșeurilor reprezintă un factor important în conservarea și întreținerea resurselor naturale, contribuind astfel la îngrijirea și îmbunătățirea mediului înconjurător. Lucrarea își propune să demonstreze eficiența utilizării materialelor reciclate (sticlă, cenușă de termocentrală) la prepararea betoanelor de ciment cu urmărirea în comportare prin determinarea caracteristicilor fizico-mecanice și interpretări ale valorilor obținute; precum și utilizarea deșeurilor rezultate din construcții, ca de exemplu: betoane provenite din demolarea fundațiilor, platformelor, structurilor de rezistență a clădirilor sau a altor elemente de beton ca agregate pentru prepararea betoanelor.*

Abstract. *Waste recycling is an important factor in the conservation and maintenance of natural resources, thus contributing to the care and improvement of the environment. The paper aims to demonstrate the efficiency of using recycled materials (glass, thermal plant ash) in the preparation of cement concrete with behavioral monitoring by determining the physical-mechanical characteristics and interpretations of the values obtained; as well as the use of construction waste, such as concrete from the demolition of foundations, platforms, building structures or other concrete elements as aggregates for the preparation of concrete.*

Keywords: Concrete, Recycled materials, Technical assessment document

1. Introduction

The introduction of recycled materials (glass, plastic, textile fibers) in the preparation of cement concrete is not a new approach. Experimental studies have been carried out for more than 20 years and technical assessment have been drawn up for cement concretes in which some of the classic materials (aggregates, cement, filler) are replaced with recycled materials.

Many approved products or studied in the laboratory have been put into practice in construction works, such as:

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- delimitation and compartmentalization of spaces (example: dividing paddocks for aggregate, industrial spaces);
- elements for retaining walls;
- alveolar elements of concrete
- parking platforms, parking spaces, roadways.

Crushed aggregates of granularity class 0/63 mm are obtained after crushing the concrete from the demolition of foundations, platforms, resistance structures of buildings or other concrete elements.

The crushed concrete, having a particle size composition 0/63 mm can be used, depending on the performance characteristics established by the Romanian technical specifications and the specifications of the execution projects, for the following works:

- rehabilitation works and constructions of roads class II-V and streets of category II-IV, as follows: foundation layer, form layer;
- platforms;
- consolidations;
- reinforcements;
- enlargements.

2. Cement concrete type BSP 20, class C 16/20 AND Cement concrete type BSP 30, class C 25/30 prepared with recycled glass aggregates and power plant ash

The component materials used in the preparation of cement concrete type BSP 20 and BSP 30 are:

- Potland Cement, CEM I 42.5 R
- Concrete additive (superplasticizer)
- Addition of power plant ash (20% of the mass of the hydraulic binder)
- Natural sand granularity class 0/4 mm
- 20% Recycled glass aggregates 4/8 mm granularity class
- 40% Recycled glass aggregates granularity class 8/16 mm
- Water

Concrete is prepared in accordance with the requirements of the Technical Regulations for Concrete Constructions and in accordance with SR EN 206 + A2: 2021, NE 012-1: 2007, and the transport and pouring must be carried out in accordance with the specific regulations of each work [1], …, [14].

The manufacture of concrete is carried out by complying with the provisions of the actual regulations, the execution project and the minimum cement content, the

maximum water / cement ratio, aggregate dosages of recycled glass, concrete class, treatment duration after concreting, formwork term (Table 1, according to the European norms NE 012-1: 2007 and NE 012-2: 2010).

2.1. Cement concrete type BSP 20, class C 16/20

Table 1. Comparison of technical characteristics between C16/20 cement concrete and BSP 20 cement concrete, strength class C 16/20

Cement concrete type BSP 20, strength class C 16/20 (concrete cubes 150x150x150 mm, consistency S2, cement type I 42.5R, Dmax 16 mm, cement dosage 310 kg / m3, A / C 0.5, favorable granularity area 3, sand granularity class 0/4 mm, thermal plant ash, recycled glass aggregates granularity class 4/8, 8/16 mm)

No. crt.	***Characteristics***		***Limits imposed NE 012-1***	***Obtained results***		***Testing norms***
				Cement concrete C16/20	***Cement concrete type BSP20***	
COMPRESSION TEST ON CONCRETE						
1	*Apparent density, kg/m^3*		*2000-2600*	*2422*	*2240*	*SR EN 12390-3*
2	*Breaking force, kN*		*-*	*463*	*565*	
3	*Compression strength: - after 33 days, N/mm^2*		*min 20 N/mm^2, at 28 days*	*20,6*	*25,1*	
FROZEN-DEFROST TEST OF CONCRETE (degree of frost G100)						
1	*Rezistenţa la compresiune: - dupa 61 zile, N/mm^2*	*martor*	*min 20 N/mm^2*	*21,0*	*25,1*	*SR 3518*
		G100		*20,3*	*23,8*	
2	*Loss of resistance, % - η 100*		*-*	*3,3*	*5,2*	
Conclusion			*Degree of gelability achieved*			
TESTING THE WATERPROOFNESS OF CONCRETE						
1	*Compression strength: - after 61 days, N/mm^2*	*0.2 time 48h*	*Do not show water leaks on the exfiltration surface*	*No leaks*	*No leaks*	*SR EN 12390-8* *NE 012-2 Annex X*
		0.4 time 24h		*No leaks*	*No leaks*	
		0.8 time 24h		*No leaks*	*No leaks*	
2	*Water penetration depth, mm*		*-*	*50,4*	*49,3*	
Conclusion			*Degree of waterproofing achieved*			

It is possible to observe the improvement of the physico-chemical characteristics for the cement concrete type BSP 20/RSP 20 compared to the classic concrete C16 / 20, as follows (Fig. 1):

- increase in compressive strength by 22,0%
- decrease in bulk density
- decrease of the depth of water penetration

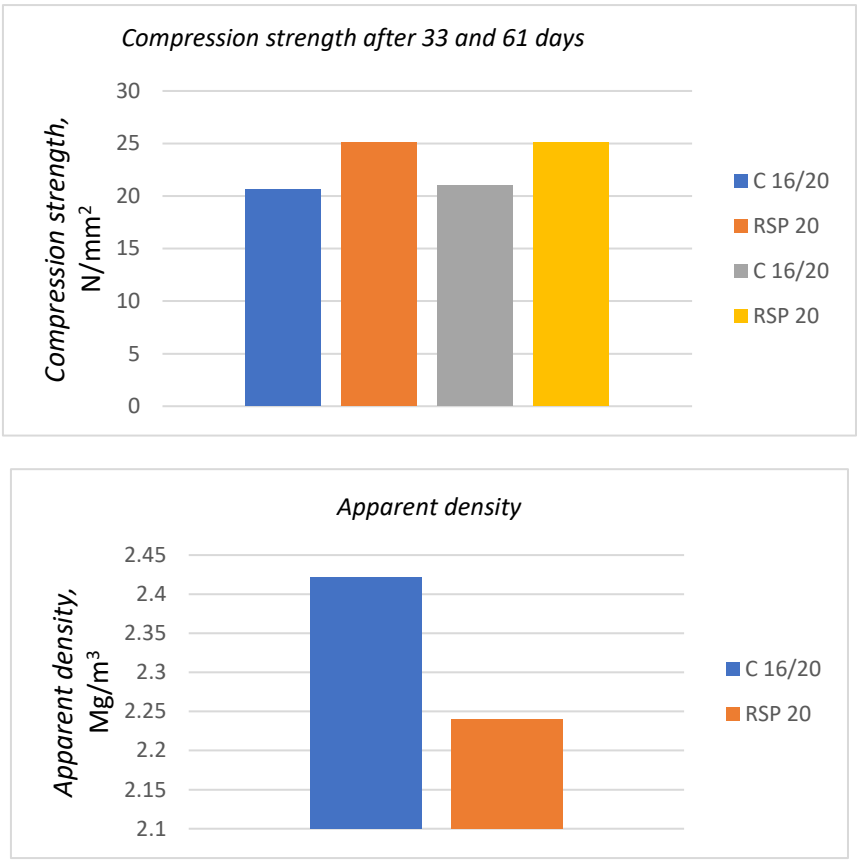

Fig. 1. Compression strength and apparent density of cement concrete type BSP 20 compared to the classic concrete C16 / 20

2.2. BSP 30 cement concrete, class C 25/30

The improvement of the physico-chemical characteristics can be observed for the cement concrete type BSP 30 compared to the classic concrete C25/30, as follows: - increase in compressive strength by 9,2%; - decrease in bulk density; - decrease of the depth of water penetration (Table 2) (Fig. 2).

Table 2. Comparison of technical characteristics between C25/30 cement concrete and BSP 30 type cement concrete, strength class C 25/30

- Cement concrete type BSP 30, strength class C 25/30 (concrete cubes 150x150x150 mm, consistency S2, cement type I 42.5R, Dmax 16 mm, cement dosage 400 kg / m3, A / C 0.47, favorable granularity area 3, sand granularity class 0/4 mm, thermal plant ash, recycled glass aggregates granularity class 4/8, 8/16 mm)

No. crt.	***Characteristics***		***Limits imposed NE 012-1***	***Obtained results***		***Testing norms***
				Cement concrete C25/30	***Cement concrete type BSP 30***	
COMPRESSION TEST ON CONCRETE						
1	*Apparent density, kg/m^3*		*2000-2600*	*2417*	*2230*	*SR EN 12390/3*
2	*Breaking force, kN*		*-*	*736*	*804*	
3	*Compression strength: - after 33 days, N/mm^2*		*min 30 N/mm^2, at the age of 28 days*	*32,7*	*35,7*	
FROZEN-DEFROST TEST OF CONCRETE (degree of frost G100)						
1	*Compression strength: - after 61 days, N/mm^2*	*blank*	*min 30 N/mm^2*	*33,0*	*36,1*	*SR 3518*
		G100		*31,9*	*34,9*	
2	*Loss of resistance, %* - *η 100*		*-*	*3,3*	*3,3*	
Conclusion			*Degree of gelability achieved*			
CONCRETE WATERPROOF TEST						
1	*Step water pressure, N/mm^2*	*0.2 time 48h*	*Do not show water leaks on the exfiltration surface*	*No leaks*	*No leaks*	*SR EN 12390/8*
		0.4 time 24h		*No leaks*	*No leaks*	
		0.8 time 24h		*No leaks*	*No leaks*	*NE 012/2 Annex X*
2	*Water penetration depth, mm*		*-*	*47,2*	*46,3*	
Conclusion			*Degree of waterproofing achieved*			

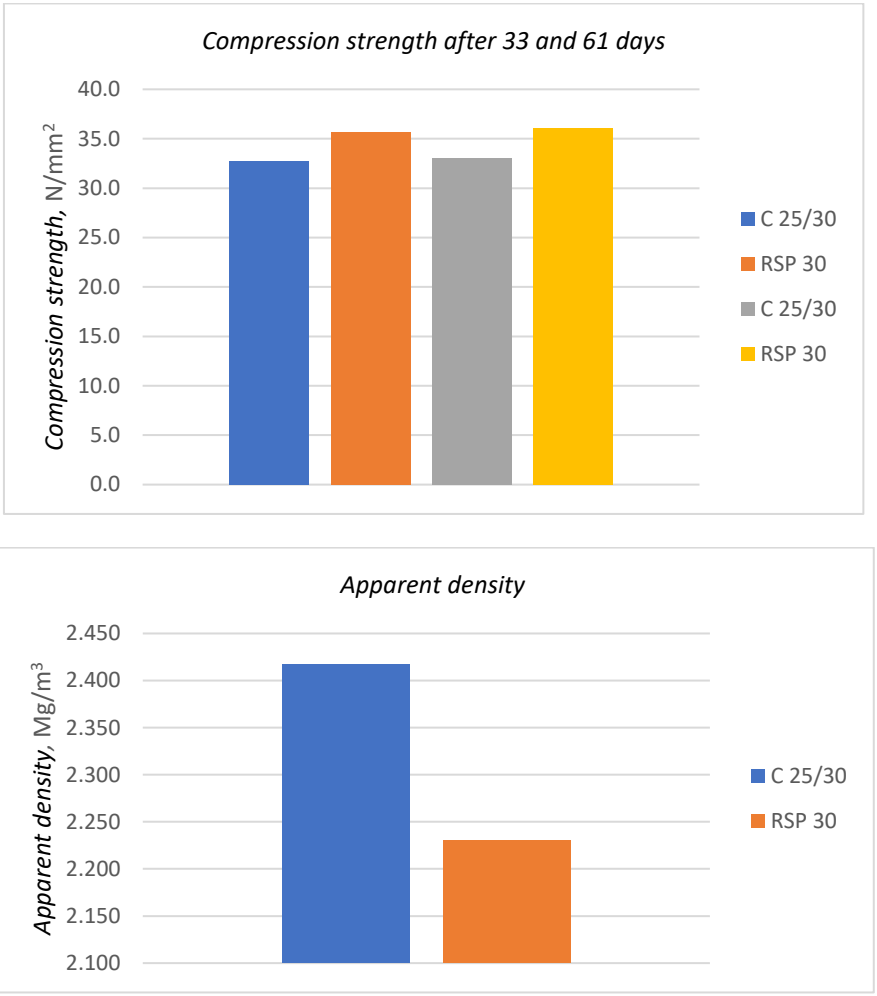

Fig. 2. Compression strength and apparent density of cement concrete type BSP 30/RSP 30 compared to the classic concrete C25/30

3. Crushed concrete

The crushed concrete with a grain size of 0/63 mm is obtained by crushing the concrete waste resulting from demolition with the help of a mobile jaw crusher in the aggregate crushing-sorting station. Physico-mechanical characteristics of gravel aggregates (natural and crushed ballast) with granularity class 0/63 are presented in the Table 3, and other characteristics of crushed concrete are included in the Table 4.

Table 3. Physico-mechanical characteristics of gravel aggregates (natural and crushed ballast) granularity class 0/63

No. crt	Characteristics		Testing method	Medium value Granularity class		Technical conditions according to SR EN 13242+A1:2008	
				0/63 mm natural	0/63 mm crush	0/63 mm natural	0/63 mm crush
1	Granularity,% Passes through the sieve of:	63,0 mm	SR EN 933-1	95,0	94,.0	G_A 85	G_A 85
		40,0 mm		85,0	83,0		
		31,5 mm		79,0	72,0		
		22,4 mm		61,0	57,0		
		16,0 mm		55,0	49,0		
		8,0 mm		36,0	31,0		
		4,0 mm		27,0	20,0		
		2,0 mm		21,0	16,0		
		1,0 mm		18,0	12,0		
		0,63 mm		15,0	9,0		
		0,25 mm		9,0	7,0		
		0,1 mm		4,0	2,0		
		0,063 mm		1,0	1,0		
2	Bulk mass (Mg/m^3)		SR EN 1097-3	1,64	1,63	Declared value	Declared value
3	Real density (Mg/m^3)		SR EN 1097-6	2,57	2,56	Declared value	Declared value
	Water absorption (%)			1,0	1,1		
4	Fine parts content (%)		SR EN 933-1	1,0	1,0	f_3 (max 3)	f_3 (max 3)
5	Flattening coefficient (%)		SR EN 933-3	14,0	13,0	FI_{20} (max 20)	FI_{20} (max 20)
6	Freeze-thaw resistance with magnesium sulphate (%)		SR EN 1367-2	1,5	1,6	MS_{18} (max 18)	MS_{18} (max 18)
7	Los Angeles fragmentation resistance, % (10/14 mm)		SR EN 1097-2	24,0	24,0	LA_{25} (max 25)	LA_{25} (max 25)
8	Wear resistance, % (Micro-Deval) (10/14 mm)		SR EN1097 -1	17,0	17,0	$M_{DE}20$ (max 20)	$M_{DE}20$ (max 20)
9	Shape coefficient, % (8/16 mm)		SR EN 933-4	16,0	15,0	SI_{20} (max 20)	SI_{20} (max 20)

Table 4. Physico-mechanical characteristics of crushed concrete granularity class 0/63 mm

No. crt	**Characteristics**		**Testing method**	**Determined values**	**Technical conditions according to SR EN 13242+A1:2008**
1	Granularity, % Passes through the sieve of:	90 mm	SR EN 933-1	100,0	G_A 75
		63 mm		91,0	
		50 mm		64,0	
		40 mm		48,0	
		31,5 mm		43,0	
		22,4 mm		40,0	
		16 mm		33,0	
		8 mm		28,0	
		4 mm		18,7	
		2 mm		14,8	
		1 mm		10,9	
		0,63 mm		8,5	
		0,25 mm		3,1	
		0,1 mm		1,8	
		0,063 mm		1,2	
2	Bulk mass (Mg/m^3)		SR EN 1097-3	1,61	Determined values
3	Real density (Mg/m^3)		SR EN 1097-6	2,50	Determined values
	Water absorption (%)			2,8	
4	Fine parts content (%)		SR EN 933-1	1,2	f_3 (max 3)
5	Flattening coefficient (%)		SR EN 933-3	10,0	FI_{20}(max 20)
6	Freeze-thaw resistance (%)		SR EN 1367-2	2,0	MS_{18} (max 18)
7	Los Angeles fragmentation resistance, % (10/14 mm)		SR EN 1097-2	39,0	LA_{40} (max 40)
8	Wear resistance (Micro-Deval), % (10/14 mm)		SR EN1097-1	31,0	$M_{DE}30$ (max 30)
9	Shape coefficient (%) (8/16 mm)		SR EN 933-4	12,0	SI_{20} (max 20)

It is noted that the performance of aggregates from crushed concrete is within the reference standard for the use of aggregates in road works, but has high values for crushing strength and wear resistance compared to natural aggregates from gravel. This is due to the concrete cement remaining on the aggregate granule.

4. Conclusions

Cement concretes BSP 20 and BSP 30, prepared with recycled glass aggregates granularity class 4/8, 8/16 mm (by replacing part of the dosage of aggregates granularity class 4/8, 8/16 mm) and thermal plant ash (with the role of annihilating alkali-silica reactions), but presents high values for crushing strength and wear resistance to natural aggregates than conventional concrete.

The use of these concretes in various construction works, such as plain concrete or reinforced concrete, ensures a higher durability and a better operating behavior than conventional cement concretes.

The crushed concrete, granularity class 0/63 mm, has resistance and stability over time, as there is no risk that the product will undergo transformations during storage, physical or chemical transformations that could lead to changes in the physical-mechanical characteristics.

Presents physical-mechanical properties in order to obtain road structures with high load-bearing capacity.

The use of crushed concrete as recyclable material represents a good ecological impact, by reducing the areas occupied by this unused material and by protecting depleted natural resources.

By using recycled materials, greenhouse gas emissions and other emissions decrease, and by replacing conventional materials with recycled materials, the need for stone extraction or the production of new materials decreases.

R E F E R E N C E S

[1] Law no. 10/1995 -*Quality of constructions*, republished since 2016

[2] NE 012-1: 2007 *Code of practice for the execution of concrete, reinforced concrete and prestressed concrete works*

[3] NE 012-2: 2010 *Normative for the production of concrete and the execution of concrete, reinforced concrete and prestressed concrete works. Part 2: Execution of concrete works*

[4] SR EN 206 + A2: 2021 *Concrete. Specification, performance, production and conformity*

[5] SR EN 12390-3: 2009 *Concrete reinforcement test. Part 3: Compressive strength of specimens*

[6] SR EN 12390-8: 2019 *Concrete reinforcement test. Part 8: Depth of water penetration under pressure*

[7] SR 3518: 2008 *Tests on concrete. Determination of frost-thaw resistance by measuring the variation of the compressive strength and / or the relatively dynamic modulus of elasticity*

[8] SR EN 933/1: 2012 *Tests to determine the geometrical characteristics of aggregates. Part 1: Determination of granularity. Granulometric analysis by sieving*

[9] SR EN 933/3: 2012 *Tests for determining the geometric characteristics of aggregates. Part 3: Determination of granule shape. Flattening coefficient*

[10] SR EN 933/4: 2008 *Tests to determine the geometrical characteristics of aggregates. Part 4: Determination of particle shape. Shape coefficient*

[11] SR EN 1097-3: 2002 *Tests to determine the mechanical and physical properties of aggregates*. Part 3: Methods for the determination of bulk density and intergranular porosity

[12] SR EN 1097-6: 2013 *Tests to determine the mechanical and physical characteristics of aggregates.* Part 6: Determination of density and water absorption of granules

[13] SR EN 1097-1: 2011 *Tests for determining the mechanical and physical characteristics of aggregates.* Part 1: Determination of wear resistance (micro-Deval)

[14] SR EN 1097-2: 2020 *Tests to determine the mechanical and physical properties of aggregates*. Part 2: Methods for determining the breaking strength.