ECO-INNOVATIVE TECHNOLOGY FOR THE USE OF RECYCLED GLASS WASTE IN CONSTRUCTION WORKS

Monica COSTEI[1], Nicoleta IONESCU[2],
Cătălin DIMA[3], Nicoleta-Mariana ENE[4]

Rezumat. *Scopul principal al acestei lucrări este de a sublinia posibilitatea utilizării materialului granular obținut din sticla reciclată în lucrările de construcții. Prin utilizarea materialului granular reciclat din sticlă, va rezulta un impact ecologic pozitiv, deoarece va reduce suprafețele ocupate de materiale neutilizate și va proteja resursele rare. Pentru a defini conceptul de „material de sticlă reciclat" și pentru a confirma caracteristicile fizico-mecanice pentru utilizare în lucrări de construcții, au fost efectuate cercetări și determinări de laborator. Acest domeniu de cercetare este actual datorită dezvoltării diverselor tehnologii de recuperare și reciclare a materialelor și necesității de a proteja mediul.*

Abstract. *The main aim of this paper is to emphasize the possibility of utilizing the granular material obtained by recycled glass in construction works. By using the glass recycled granular material, a positive ecological impact will be shown as it will reduce the surfaces occupied by these unused materials as well as it will protect scarce resources. To define the concept of "recycled glass material" and to confirm the physical-mechanical characteristics for use in construction works, research and laboratory determinations were performed. This research domain is current due to the development of various materials recovery and recycling technologies and the need to protect the environment.*

Keywords: glass waste, recycled material, recovery technology, environmental protection

1. Introduction

According to the requirements of the European Directive DC2008 / 98 / CE, which regulates the waste regime, their producers must recycle and capitalize on them, by using the best available techniques, with minimal effects on environmental factors and human health [16]. In the framework directive DC2008 / 98 / CE on waste, recycling occupies the main place in the hierarchy of processes, being located before storage and incineration. Glass being an inert material, in landfills it becomes indestructible in a natural way; therefore, it is extremely harmful to the environment (Fig. 1).

[1] Engineer, Transport Research Institute - INCERTRANS SA, Bucharest, Romania (monica.marinca@incertrans.ro).
[2] Engineer, Transport Research Institute - INCERTRANS, Bucharest, Romania (nicoleta.ionescu@incertrans.ro).
[3] Senior Researcher III - INCERTRANS S.A, catalin.dima@incertrans.ro.
[4] Drd. Eng. - INCERTRANS S.A, nicoleta.ene@incertrans.ro, Faculty of Civil Engineering, University, UTCB- Bucharest.

Fig. 1. Glass in landfills besides other recycled materials

Glass, besides other recycled materials such as cardboard, paper, and plastic, is the most utilized packaging in homes. It is 100% natural, made from quartz sand, limestone, and soda ash, is durable, inert, and biologically inactive. Glass is not biodegradable, meaning once is thrown at the landfill, it stays there as it has no decomposition properties

The paper started from the idea of the need to study the possibilities of using these glass waste in new recycling technologies and their compatibility with the other components of the elements used for construction.

The granular material, obtained from the recycling of glass waste is a non-ferrous material having a composition and properties that allow their use in the technique of road constructions processed in sorts, partially replacing the classic natural aggregates.

The granular material is a product obtained from the line for sorting and recycling glass waste, respectively from the vibrating screen (dimensional separation).

The sort of granular material is obtained from the crushing - sorting - washing installation following the crushing and sorting of the glass waste, coming from the sorting centers. After crushing, glass granules are obtained that look like shards of glass, without sharp edges, which do not cut to different sizes. Following the sorting stage and depending on the endowments of each installation, the following sorts of granular material can be obtained (Fig. 2):

- granularity class 0/8 mm;
- granularity class 4/8 mm;
- granular material mixture 8/16 mm.

class 0/8 class 4/8 class 8/16

Fig. 2. Sorts of granular glass material

For the recycling of glass waste, the installation can be equipped with the following equipments:

- food bunker;
- vibration dispenser bunker extrication;
- transfer band;
- manual sorting band;
- magnetic separator with tape;
- vibration transfer dispenser;
- conveyor belt with feed mill squeegees;
- roller mill;
- mill food conveyor belt;
- vibrating sieve (dimensional separation).

Following the research study and performing laboratory tests, the granular material obtained from glass waste can be used as follows:

- ***Granularity class 0/8 mm*** in mixture with ballast for filling works pits, filling, slopes, roofing works or other landscaping works, according to the requirements of the specifications and the project execution.
- ***Granularity classes 4/8 and 8/16 mm*** used for the preparation of asphalt mixtures applied to the execution of road and street construction works, technical class II-V, respectively II-IV as follows:

  - connecting layer, according to SR EN 13108-1 [2], due to the lower volume of gaps, especially in the case of roads and streets with medium traffic
  - base layer, according to SR EN 13108-1.
- For the manufacture of cement concretes, according to the Code of Practice for the production of indicative concrete CP 012-1: 2007 for road bridge structures.

Laboratory tests were performed both on the granular material and on the asphalt mixtures and cement concrete prepared with it [13].

Following laboratory tests we can say that the results were within the technical rules in force. The obtained results confirm the possibility of their use in construction works.

The study of laboratory research went through several stages to demonstrate the performance of its use in construction works:

Table 1) Determinations of leachability

Nr crt	**Indicator**	**U.M.**	**Determined values according to SR EN 12457-Part 2 Test report 2144 / 23.11.2019**	**Maximum allowed value (mg / kg s.u.)**		
				Inert	**Non hazardous**	**Hazardous**
1	Cd	mg/kg s.u	<0,05	0,04	1	5
2	Co	mg/kg s.u	<0,05	-	-	-
3	Cr	mg/kg s.u	<0,5	0,5	10	70
4	Cu	mg/kg s.u	1,897	2	50	100
5	Ni	mg/kg s.u	0,361	0,4	10	40
6	Pb	mg/kg s.u	<0,05	0,5	10	50
7	Zn	mg/kg s.u	2,69	4	50	200
8	chloride	mg/kg s.u	628	800	15000	25000
9	sulphates	mg/kg s.u	836	1000	20000	50000
11	CCO-Cr/DOC	mg/kg s.u	402	500	800	1000
11	TDS	mg/kg s.u	987	4000	60000	10000

The results of the determinations for leachability in relation to the allowed values according to SR EN 12457-Part 2 [15] are presented in the Table 1.

The analysis of the quality of the leachate from the waste resulting from the sorting and recycling line of glass waste, respectively from the vibrating sieve and the comparison of the quality indicators determined with the limit values highlighted the fact that the quality indicators can be stored in inert waste landfills.

Table 2) Tests on granular material 0/8 mm

Nr. crt	**Determined characteristics**		**Test method**	**UM**	**Medium Value**	**Technical conditions cf. SR EN 13242+ A1: 2008**
1	Granulosity Screenings by:	16,0 mm	SR EN 933/1	%	100,0	G_A85
		8,0 mm			93,7	
		4,0 mm			71,6	
		2,0 mm			70,5	
		1,0 mm			23,3	
		0,63 mm			10,1	
		0,25 mm			2,2	
		0,1 mm			0,9	
		0,063 mm			0,5	
2	Bulk meal		SR EN 1097/3	Mg/m^3	1,23	Declared value
3	Real density		SR EN 1097/6	Mg/m^3	2,38	Declared value
4	Water absorption		SR EN 1097/6	%	0,45	WA_{24} 1 (max 1)
5	Content of fine parts		SR EN 933/1	%	0,5	f_3 (max 3)

The standard tests on granular material 0/8 mm, 4/8 mm and 8/16 mm were presented in the Tables 2, Table 3 and Table 4 respectively.

From the analysis of the granular glass material sort 0-8 mm it was found that the values obtained of the technical characteristics were within the limits imposed for the classic natural aggregates by SR EN 13242 + A1: 2008 [14].

From the analysis of the granular glass material sort 4-8 and sort 8-16 it was found that the values obtained of the technical characteristics were also within the limits imposed by the same international standard for the classic natural aggregates.

Table 3) Tests were performed on granular material 4/8 mm

Determined characteristics		**Test method**	**UM**	**Medium Value**	**Technical conditions cf. SR EN 13242+ A1: 2008**
Granulosity Screenings by:	8,0 mm	SR EN 933/1	%	97,5	G_A85
	4,0 mm			10,8	
	2,0 mm			9,1	
	1,0 mm			7,6	
	0,5 mm			5,6	
	0,25 mm			3,8	
	0,1 mm			2,1	
	0,063 mm			0,8	
Shape coefficient		SR EN 933/1	%	17	Sl_{25}
Content of fine parts		SR EN 933/1	%	0,8	$F_{1,5}$

Table 4) Tests were performed on granular material 8/16 mm

Determined characteristics		**Test method**	**UM**	**Medium Value**	**Technical conditions cf. SR EN 13242+ A1: 2008**
Granulosity Screenings by:	16,0 mm	SR EN 933/1	%	94,8	$G_A90/10$
	12,5 mm			59,0	
	8,0 mm			12,8	
	4,0 mm			7,0	
	2,0 mm			2,0	
	1,0 mm			1,3	
	0,1 mm			0,7	
	0,063 mm			0,4	
Shape coefficient		SR EN 933/1	%	18	Sl_{25}
Content of fine parts		SR EN 933/1	%	0,4	$F_{0,5}$

To determine the ***capacity of the concrete mix asphalt cement and aggregates prepared with recycled glass*** , a series of laboratory tests on specimens prepared in the laboratory have been conducted. Dosages were developed for asphalt and cement concrete mixtures in order to establish the proportions between the materials that make them up, so as to finally obtain the physical-mechanical characteristics specific to the type of mixture / concrete. Establishing and applying the correct dosages depending on the type of asphalt or concrete mixture designed and the real characteristics of the materials that make up their composition led to the demonstration of the performance of recycled glass aggregates. Tests were performed that demonstrated the performance of using recycled glass aggregates in the following construction materials [4], [5], [6]:

- prepared asphalt mixture type BA 31.5 base 50/70 (AB 31.5) (Table 5)
- asphalt mixture type BA 20 leg 50/70 (BAD 20) (Table 6)
- cement concrete type C25 / 30(Table 7).

Table 5) Physico-mechanical characteristics and composition of asphalt mixtures type BA 31.5 base 50/70 (AB 31.5) prepared with glass waste

Nr. crt	**Determined characteristics**	**Test rule**	**Limits imposed**		**Results obtained**
			Normativ AND ind 605:2014	**SR EN 13108-1**	
1. Physico-chemical determinations on Marshall specimens:					
1.1	Apparent density, kg / m3	SR EN 12697/6	-	-	2287
1.2	Stability at 600C (S), kN	SR EN 12697/34	6,5...13,0	Smin5,0 Smax15,0	9,3
1.3	Flow index (I), mm	SR EN 12697/34	1,5…4,0	F1,5-F4,0	3,0
1.4	Water absorption,%	Normativ AND ind 605:2016	1,5…6,0	-	3
1.5	Water sensitivity,%	SR EN 12697/12	60...90	ITSR80	85,8
2. Composition of the asphalt mixture:					
2.1	Bitumen content,%	SR EN 12697/1	Min. 4	TLmin4,0	4
2.2	Particle size curve:				

	Passes through 31.5 mm sieve, %	SR EN 12697/2 SR EN 933-1	90…100	90...100	99,02
	Passes through 20 mm sieve, %		80…99	-	93,72
	Passes through 16 mm sieve, %		74…97	-	79,5
	Passes through 8 mm sieve, %		52…85	-	58,29
	Passes through 4 mm sieve, %		37…66	-	37,07
	Passes through 2 mm sieve, %		22…50	10...50	26,99
	Passes through 1 mm sieve, %		14…39	-	17,91
	Passes through a 0.125 mm sieve, %		3...12	-	10,49
	Passes through a 0.063 mm sieve, %		2...7	0...11	5,92

Table 6) Dynamic characteristics for asphalt mixture type BA 20 leg 50/70 (BAD 20) prepared with glass waste

Nr. crt.	**Determined characteristics**	**Test rule**	**Limits imposed**		**Results obtained**
			Normativ ind 605:2014	**SR EN 13108-1**	
1.	Resistance to permanent deformations (dynamic creep): - deformation at 400C, 200 kPa and 10000 pulses, µm / m - deformation speed at 400C, 200 kPa and 10000 pulses, µm / m / cycle	SR EN 12697/25	max. 20000 max. 2,0	- -	17172 0,7
2.	Rigidity module at 20^0C, MPa	SR EN 12697/26	min. 6000	Smin5500	7339,5

According to the results obtained and presented in the Tables 5, 6 and 7, the following were demonstrated [7], [8], [9]:

- The physical-mechanical characteristics of the mixtures prepared with glass waste complied with the requirements of SR EN 13108-1 [2] and Normativ AND ind 605 [3].
- The physical-mechanical characteristics of the cement concrete prepared with glass waste were within the limits imposed by CP 012-1: 2007 [1].

Table 7) Characteristics of C25 / 30 cement concrete prepared with glass waste [10], [11], [12]

Nr. crt.	Determined characteristics	Test rule	Limits imposed CP 012-1:2007	Obtained Results
1	Apparent density, kg/m^3	SR EN 12390-7	min. 2300	2347
2	Compression strength at 28 days,kg/m^3	SR EN 12390-3	min. 30	34
3	Freeze-thaw resistance	SR 3518	max. 25	5,3
4	Depth of water penetration (P8 / 10), mm	SR EN 12390-8	-	63

Conclusions

This paper was developed taking into account the current situation at a national level, in terms of the need for solutions for recovery and recycling of glass from collection centers. By recycling and use, the reduction of the surfaces occupied by these unused materials is considered.

Following the favorable results obtained from laboratory tests, it has been shown that the granular material from recycled glass allows its use in construction techniques, partially replacing the classic natural aggregates.

By using granular material from recycled glass in construction works, it can be stated that it contributes to the depollution of the environment, by incorporating as much recycled waste as possible.

From the processing of glass waste through the technology of crushing, sorting, dimensional separation, the granularity class obtained can be used as an aggregate in road works and civil constructions, thus replacing a part of the depleted natural raw material.

R E F E R E N C E S

[1] CP 012-1:2007: Monitoring of the concrete compliance

[2] SR EN 13108-1:2016: Bituminous mixtures. Material specifications. Asphalt Concrete

[3] Normative AND ind 605: 2016: Technical regulation "Normative regarding hot-run asphalt mixtures. Technical conditions for design, preparation and commissioning of asphalt mixtures"

[4] SR EN 933-1:2002/A1:2006: Determination of the granulosity. Granulometric analysis by sieving

[5] SR EN 1097-3:2002: Determination of the bulk volumetric weight and inter-granular porosity

[6] SR EN 1097-6:2013 Determination of the actual weight and absorption coefficient of the water

[7] SR EN 12697-1:2006: Bituminous mixtures .Content of binders

[8] SR EN 12697-2:2016: Bituminous mixtures .Volume of voids

[9] SR EN 12697-6:2020: Bituminous mixtures. Determination of the apparent volumetric weight of the specimens

[10] SR EN 12390-3:2019: Testing hardened concrete - Part 3. Compressive strength of cubic specimens and prisma heads

[11] SR EN 12390-7:2019: Testing hardened concrete - Part 7:Concrete density

[12] EN 12390-8:2019 - Testing hardened concrete - Part 8: Depth of penetration of water under pressure

[13] SR 3518:2009: Testing hardened concrete. Concrete Tests. Determination of Freeze-Thaw Resistance

[14] SR EN 13242 + A1: 2008: Aggregates of unbound or hydraulically bound materials for use in civil engineering and road construction

[15] SR EN 12457-Part 2 Characterisation of waste - Leaching - Compliance test for leaching of granular waste materials and sludges - Part 2: One stage batch test at a liquid to solid ratio of 10 l/kg for materials with particle size below 4 mm (without or with size reduction)

[16] DC 2008 / 98 / CE - Waste framework directive. https://eur-lex.europa.eu/legal-content/RO/TXT/PDF/?uri=CELEX:02008L0098-20150731&from=EN. Accesat 31.05.2021.