PERFORMANCE OF PRECAST CEMENT CONCRETE ELEMENTS WITH RECYCLED MATERIALS AND INDUSTRIAL WASTE

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Rezumat. *Lucrarea abordează necesitatea utilizării pe plan național și internațional a produselor reciclate în în construcții, prin înlocuirea materiei prime cu produse reciclate, cum ar fi: zgură de oțelărie (ca agregat artificial) și a materialelor reciclate (sticlă, cauciuc, material textile, hârtie, carton). Lucrarea își propune să arate utilizarea zgurii de oțelărie și a materialelor reciclate: sticlă, cauciuc, materiale textile, lemn, hârtie, carton la obținerea elementelor prefabricate utilizate în construcții. Valorificarea deșeurilor prin fabricarea elementelor prefabricate relevă două aspecte: primul este legat de partea economică (aceste produse au costuri mai mici în comparație cu cele clasice), iar cel de al doilea aspect este efectul benefic asupra mediului înconjurător, prin imobilizarea unor materiale posibil poluante.*

Abstract. *The paper addresses the need for the national and international use of recycled products in construction, by replacing the raw material with recycled products, such as: steel slag (as artificial aggregate) and recycled materials (glass, rubber, textile material, paper, cardboard). The work aims to show the use of steel slag and recycled materials: glass, rubber, textile materials, wood, paper, cardboard to obtain prefabricated elements used in construction. The recovery of waste through the manufacture of prefabricated elements reveals two aspects: the first is related to the economic side (these products have lower costs compared to the classic ones), and the second aspect is the beneficial effect on the environment, by immobilizing some possibly polluting materials.*

Keywords: concrete, slag, recycled glass, rubber

1. Introduction

The works in which the products are used are designed, executed and demolished so that the use of natural resources is sustainable and ensure in particular the following:
- a) after demolition, the materials and products that make up the building elements can be recycled; precast concrete elements with glass, paper/cardboard,

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wood, rubber and recyclable textiles and can be reused by dismantling and assembly in another location;

- b) the durability of the products is min. 20 years;

- c) the raw materials used in the manufacture of component products of concrete prefabs with artificial aggregates and the addition of recycled materials are compatible with the environment.

Concrete prefabs with artificial aggregates and the addition of recycled materials are composed of a concrete that utilizes waste glass, paper/cardboard, wood, rubber and textiles, as well as artificial aggregates (steel slag), thus replacing natural resources of mineral aggregates**.**

Artificial aggregates (steel slag) from the slag dump company SILCOTUB SA, Călărași county

Steel slag is an ideal recyclable waste for use in civil engineering and road construction.

The slag used must contain a ratio of oxide components (SiO_2; Al_2O_3; CaO; MgO) close to classic mineral aggregates and close to those of Portland cement.

Name of the test	Values obtained	Limits conf OM 95:2005	Test method
pH, units of pH	12,29	-	SR EN ISO 10523
Humidity, %	31,15	-	SR ISO 11466
Total dissolved substances, mg/kg	9950	60000	SR EN ISO 27888
Sulfates, mg/kg	13,87	20000	SR EN ISO 27888
Chloride, mg/kg	148,9	15000	SR ISO 9257
Copper, mg/kg	<0,42	50	SR ISO 8288
Plumb, mg/kg	<4,02	10	SR ISO 8288
Nickel, mg/kg	<1,08	10	SR ISO 8288
Zinc, mg/kg	<0,57	50	SR ISO 8288
Chromium, mg/kg	<6,45	10	SR ISO 8288
Manganese, mg/kg	<1,21	-	SR ISO 8662-2
Iron, mg/kg	<2	-	SR 13315

Recycled glass

Recycled glass brought to the recycling center is sorted by color. After that, they are broken, ground and any impurities are removed.

Crushed glass is passed through a sieve, similar to natural aggregates, and is separated into classes of granularity.

Recycled rubber granules from used tires
Rubber granules are obtained from a process of grinding used tires. After finishing the shredding, they go through screening, they are cleaned very well with water and special chemicals

2. Manufacturing process

The manufacture of prefabricated concrete elements with artificial aggregates and the addition of recycled materials is carried out, in accordance with internal production norms, under conditions that ensure the reproducibility of the performances corresponding to the intended field of use.

For the manufacture of prefabricated concrete elements, it is necessary that the indoor air temperature in the production hall be in the range +5oC-30oC.

The technical procedure for the execution of prefabricated concrete elements with artificial aggregates and the addition of recycled materials includes the following stages:

- a) preparation of cement-based concrete; artificial aggregates, glass granules, paper/cardboard shreds, wood granules, rubber granules, textile shreds and plasticizer/water reducing additive (when necessary) which includes:

- dosing of raw materials (aggregates, cement, water, recycled materials, additives) is carried out according to the cement concrete recipe

- the percentages of recycled materials that can be used in the preparation of cement concrete are:

- 30% glass aggregates

- 20% recycled paper shred

-20-40% shredded recycled cardboard

- 20-45% recycled wood chips

-20-50% recycled rubber granules

- 20% shredded recycled textile materials

- starting the batching plant - starting mixing

- putting the components into the mixer, in the following order: steel mill slag aggregates (granularity classes 0/4 and 0/63 mm), recycled glass 0/63 mm/recycled paper shreds/recycled wood shreds/recycled rubber granules / shredded recycled textile materials, cement (minimum resistance class 42.5R), 1/3 of the mixing water, the plasticizer additive with the rest of the water, continue mixing for approx. Ten minutes;

- b) preparing the patterns (cleaning, greasing the surfaces of the patterns/formwork);

- c) pouring and compacting the concrete:

- d) stripping the concrete elements after hardening;

- e) as appropriate, protecting and sprinkling with water the cast concrete elements;

- f) marking the elements and transporting them to the warehouse.

Implementation

Precast concrete with artificial aggregates and the addition of recycled materials are put into operation without difficulty, in normal precision works, by personnel qualified in such works, subject to compliance with the provisions and execution details of the projects, the technical instructions related to the field and in - a work of normal precision, by personnel qualified in such works, in compliance with the provisions and execution details of the projects, the technical instructions related to the field and according to the instructions provided by the manufacturer.

The commissioning of prefabricated concrete elements with glass includes the following work stages:

a) Execution of the embankment:

- establishing property boundaries and marking all important points with stakes;

- drawing elevations on a vertical and horizontal plane and the execution of excavations in accordance with the specifications;

- compaction of the foundation land;

- laying a minimum 20 cm thick layer of ballast and compacting it;

- laying a layer of broken stone or stabilized ballast in a thickness of min. 15 cm and its compaction;

- laying the sand layer and compacting it.

b) Installation of pavers, curbs and bolts

The curbs are mounted before the introduction of the last layer of sand, after compaction has taken place beforehand.

The elevations of the curbs will be transmitted using the theodolite.

Curbs are mounted on a concrete foundation of approximately 10x15cm and 10x20cm for road curbs.

Later, it straddles the side to take over the efforts from the platform.

The panels are installed after finishing the installation of the curbs, the layer of sand with a grain size of 0/4 mm is laid, combined with aggregates with a grain size class of 8/16 mm, laid in a thickness of 6 cm.

Pavers are laid starting from a 90 degree corner or a straight line to avoid cutting them as much as possible.

The panels are placed side by side on the sand layer, keeping track of their alignment, and gently hit with a rubber mallet.

Cutting the pavers at the edges is done with the diamond disc flex.

After laying the first pavers, check the inclination of the plane with the boloboc to ensure correct drainage.

The construction of the vaults begins after the construction of the foundation sole and the waterproofing between the foundation and the masonry.

Draw the direction and position of elevations or walls, the position of door openings. The concrete is poured into the bolts with a pump or by hand and vibrated with a vibrator.

To avoid moving the bolts from their position, concreting will be done after placing a maximum of three rows of bolts. At each row, the alignment of the bolts will be checked both with the thread for constructions in the horizontal plane and in the vertical plane with the plumb line.

At the end, the wall is plastered with mortar for exterior or interior plastering.

c) Installation of lego-type blocks/lego-type concrete masonry elements

- aligning with tight joints the concrete preforms from the first row of dry masonry, as the case may be, on the surface of the foundation plinth or on the surface of the paddock platform, if the platform is made in thick slab solution.

- the blocks related to the next row are applied directly over the lower row, interlaced, by inserting the gaps of the cavities of the upper row into the protrusions in the form of the pyramid trunk of the lower row, assembled previously (lego system).

3. Obtained results:

Table 1- Physico-mechanical characteristics of cement concrete class C20/25 prepared with artificial aggregates and recycled materials (exposure class XC2)

Cement concrete prepared with:	***The determined characteristic***	***Performance levels reference obtained***		***Test method***
artificial aggregates cement the water additives	*Density, kg/ m³*	*Min.2200*	*2211*	*SR EN 12390-7*
	Compressive strength at 28 days, N/mm²	*Min. 25*	*31,1*	*SR EN 12390-3*
	Grade of gel, G50 *Compressive strength after 25 freeze-thaw cycles, N/mm²*	*Max.25*	*25,2* *18,8*	*SR 3518*
	Water absorption, %	*Max.10*	*3,9*	*SR EN 13369*
artificial aggregates cement shredding of textile materials the water additives	*Density, kg/ m³*	*Min.2200*	*2212,5*	*SR EN 12390-7*
	Compressive strength at 28 days, N/mm²	*Min. 25*	*32,3*	*SR EN 12390-3*
	Grade of gel, G50 *Compressive strength after 25 freeze-thaw cycles, N/mm²*	*Max.25*	*28,0* *14,6*	*SR 3518*
	Water absorption, %	*Max.10*	*3,4*	*SR EN 13369*
artificial aggregates cement wood chips the water additives	*Density, kg/ m³*	*Min.2200*	*2218*	*SR EN 12390-7*
	Compressive strength at 28 days, N/mm²	*Min. 25*	*32,0*	*SR EN 12390-3*
	Grade of gel, G50 *Compressive strength after 25 freeze-thaw cycles, N/mm²*	*Max.25*	*14,8*	*SR 3518*
	Water absorption, %	*Max.10*	*3,5*	*SR EN 13369*

Table 2- Physico-mechanical characteristics of cement concrete class C25/30 prepared with artificial aggregates and recycled materials (exposure class XC4, XM2, XF3)

Cement concrete prepared with:	***The determined characteristic***	***Performance levels reference obtained***	***Test method***
artificial aggregates cement the water additives	*Density, kg/ m³*	*Min.2200 2388*	*SR EN 12390-7*
	Compressive strength at 28 days, N/mm²	*Min. 30 36,2*	*SR EN 12390-3*
	Grade of gel, G50 *Compressive strength after 25 freeze-thaw cycles, N/mm²*	*31,8* *Max.25 17,6*	*SR 3518*
	Water absorption, %	*Max.10 4,4*	*SR EN 13369*
artificial aggregates rubber granules cement the water additives	*Density, kg/ m³*	*Min.2200 2275*	*SR EN 12390-7*
	Compressive strength at 28 days, N/mm²	*Min. 30 36,5*	*SR EN 12390-3*
	Grade of gel, G50 *Compressive strength after 25 freeze-thaw cycles, N/mm²*	*31,3* *Max.25 15,8*	*SR 3518*
	Water absorption, %	*Max.10 5,0*	*SR EN 13369*
artificial aggregates paper and cardboard shreds cement the water additives	*Density, kg/ m³*	*Min.2200 2320*	*SR EN 12390-7*
	Compressive strength at 28 days, N/mm²	*Min. 30 36,0*	*SR EN 12390-3*
	Grade of gel, G50 *Compressive strength after 25 freeze-thaw cycles, N/mm²*	*31,0* *Max.25 16,2*	*SR 3518*
	Water absorption, %	*Max.10 4,3*	*SR EN 13369*

artificial aggregates glass aggregates cement the water additives	*Density, kg/ m^3*	*Min.2200*	*2225*	*SR EN 12390-7*
	Compressive strength at 28 days, N/mm^2	*Min. 30*	*36,4*	*SR EN 12390-3*
	Grade of gel, G50		*31,2*	*SR 3518*
	Compressive strength after 25 freeze-thaw cycles, N/mm^2	*Max.25*	*15,8*	
	Water absorption, %	*Max.10*	*4,7*	*SR EN 13369*

Table 3- The compressive strength determined on cores taken from prefabricated concrete elements prepared with artificial aggregates and recycled materials

Prefabricated element	***Compression strength, N/mm^2***		***Test method***
	Value obtained	***Value imposed by NE012-1:2022***	
Pavers 200x200x60 mm	*29*	*Min. 25*	*SR EN 12390-3*
	30		
	30		
Edging 500x100x150 mm	*28*	*Min. 25*	
	29		
	29		
Lego block 1800x600x600 mm	*34,6*	*Min. 30*	
	36.2		
	35,6		
Bricks 400x200x190 mm	*26*	*Min. 25*	
	26,2		
	26,2		

4. Conclusions

Concrete prefabs prepared with steel slag aggregates and recycled materials: glass, rubber, textile materials, wood, paper, cardboard presented appropriate performances, falling within the resistance class for which they were designed.

The use of recyclable materials, which are a potential source of environmental pollution, is met more and more often in the construction industry.

At the same time, by replacing some components of the concrete with materials found in the list of potential pollutants, an effect of reducing the greenhouse effect can be found, by reducing the amount of carbon dioxide, which through the classic technology of obtaining the components often negatively influences the CO_2 footprint.

Fig. 1. Image of the basement construction in the village of Călărașii Vechi, Valea Trestica street, no. 3, within the Cuza Vodă administrative-territorial unit, Călărași county where these prefabricated elements were used

R E F E R E N C E S

[1] SR EN 206+A2:2021 Concrete. Specification, performance, production and compliance
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[3] SR-EN 12620+A1:2008 Aggregates for concrete
[4] SR EN 13369:2018 Common rules for precast concrete products
[5] SR EN 12390-7:2019 Tests on hardened concrete. Part 7: Density of hardened concrete
[6] SR EN 12390-3:2019 Test on hardened concrete. Part 3: Compressive strength of specimens
[7] SR 3518:2009 Tests on concrete. Determining the freeze-thaw resistance by measuring the variation of the compressive strength and/or the relative dynamic modulus of elasticity