Concrete Pavers with Addition of Recycled Glass

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Abstract. To save the environment we need to recycle. In order to save natural resources we must recycle glass products. These recycled glass products are crushed and the necessary sorts are created, namely 0/4 mm and 4/8 mm, which we can partially replace from the aggregates of ballast or quarry needed to make concrete pavers. A study has been made on the mechanical strength of the pavers. The study consisted of making concrete paving stones, as well as making recipes with crushed and sorted recycled glass. The same tests were carried out to verify the products.

In this paper we will present in parallel both the results on classic pavers and the results on recycled glass pavers, the so-called "firefly" concrete. The tests show that recycled materials can be used successfully but in well-defined proportions. These quantities of recycled materials are determined by physical and mechanical testing of the finished product.

Keywords: recycled glass · pavers · concrete

1 Introduction

The Romanian market is suffering from a shortage of raw materials, especially aggregates. To protect the environment we need to recycle. That is why it is necessary to introduce recycled aggregates and in particular crushed glass aggregates into concrete recipes.

In the manufacture of pavers, tested materials must be used whose suitability for use is validated.

These products can be of different sizes depending on the use and the beneficiary. The conditions to be met for concrete pavers are defined by classes which are associated with marking notations. Pavers can be produced from the same concrete or from different concretes for the top and base layers. If pavers are produced with a finishing layer, they must have a minimum thickness of 4 mm above the surface declared by the manufacturer. Isolated aggregate particles penetrating through the finishing layer should be ignored. The finishing layer shall be an integral part of the pavement.

Pavers may be produced with functional and/or decorative profiles. The surface of a paver may be textured, secondary treated or chemically treated, these finishes or treatments must be described and declared by the manufacturer.

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Table 1. Admitted deviations

Pavement thickness mm	Length mm	Width mm	Thickness mm
< 100	± 2	± 2	± 3
≥ 100	± 3	± 3	± 4

Table 2. Maximum differences

Standard	Marking	Maximum difference mm
1	J	5
2	K	3

Table 3. Deviations of flatness and curvature

Caliber length mm	Maximum connectivity mm	Maximum concavity mm
300	1.5	1.0
400	2.0	1.5

The checks to be carried out are:

– Shape and dimensions;
– Physical and mechanical characteristics;
– Visual appearance.

2 Shape and Dimensions

The relevant production dimensions are measured in two/four different places for each size and the actual size obtained is recorded, rounded to the nearest whole number of millimeters.

The production dimensions must be established by the manufacturer.

Measure the relevant production dimensions in two different places / 4 places for each dimension and record the actual size obtained, rounded to the nearest whole number of millimeters [3].

The manufacturing dimensions must be determined by the manufacturer (Table 1).

When the diagonal lengths of the rectangular pavers are indicated in the Table 2 [3].

When the maximum size of the pavers is greater than 300 mm, the deviations from the flatness must be applied to the upper side which is expected to be flat [3] (Table 3).

Table 4. Water absorption

Standard	Marking	Water absorption % of mass
1	A	No measured performance
2	B	≤ 6 as an average

Table 5. Freeze–thaw resistance

Standard	Marking	Mass lost after freeze–thaw test kg/m^2
3	D	≤ 1 as an average no individual value > 1.5

3 Physical and Mechanical Characteristics

The pavers must comply with the following conditions at the time they are declared fit for use by the manufacturer [3].

3.1 Resistance to Climatic Factors

Resistance to climatic factors shall be determined by test methods for freeze–thaw resistance, as well as water absorption.

After conditioning the test tube to (20 ± 5) °C, it is soaked in water to constant mass and then oven dried to constant mass. The mass loss is expressed as a percentage of the mass of the dried test tube.

Recommendations for the weather resistance class required to ensure the durability of the flooring for the intended use for which the product is marketed can be determined at national level [3] (Table 4).

The specimen is preconditioned and then subjected to 28 freeze–thaw cycles while the surface is coated with a 3% NaCl solution. The material that comes off is collected and weighed and the result is expressed in kilograms per square meter. The test tube must incorporate an area greater than 7500 mm^2 but less than 25,000 mm^2.

If there are specified conditions, such as frequent surface contact with deicing salts under freezing conditions, the conditions in the Table 5 may be met [3].

3.2 Tensile Strength by Splitting

The testing machine shall have a scale accuracy of ± 3% over the anticipated test range for the test and must be capable of increasing the load at the specified speeds. The testing machine shall be equipped with a device consisting of two rigid supports whose contact surface has a radius of (75 ± 5) mm.

Table 6. Abrasion strength classes

Standard	Marking	Conditions	
		Wide disc wear test	Böhme test
1	F	No measured performance	No measured performance
2	H	$\leq$ 23 mm	$\leq$ 20,000 mm^3/5000 mm^2
3	I	$\leq$ 20 mm	$\leq$ 18,000 mm^3/5000 mm^2

The two supports shall be held in the same vertical plane with a tolerance of $\pm$ 1 mm at the ends of the bars. The upper bars need to be rotated about their transverse axes.

The characteristic tensile strength by T-splitting shall be less than 3.6 MPa. No individual result shall be less than 2.9 MPa, nor have a breaking load less than 250 N/mm of splitting length [3].

3.3 Wear Resistance

Wear resistance is determined by the wide disc wear test or alternatively by the Böhme test.

Square plates or cubes of 7 cm width are placed on the Böhme abrasive disc on the test track on which a standard abrasive is sprinkled, the disc being rotated and the test tubes subject to an abrasive load of (294 $\pm$ 3) N for 16 cycles. Abrasive wear is determined as mass loss in the test tube volume [3] (Table 6).

3.4 Slip / Skid Resistance

A concrete paver has adequate slip/slip resistance provided its entire top surface is not ground and/or polished to produce a very smooth surface.

Measurement of USRV on a test tube shall be carried out using test equipment incorporating a friction pendulum to assess the friction properties of the test tube surface. The friction pendulum test equipment incorporates a slider placed on an ordinary rubber spring attached to the end of the pendulum. When the pendulum swings, the force between the slider and the test surface is measured by reducing the length of the swing using a graduated scale [3].

4 Visual Aspect

4.1 Aspect

The top faces of concrete pavers must not show defects such as cracks or peeling.

The two-layer pavers must not present delamination (separation) between the layers [3].

Table 7. Test results on pavers

No	Characteristic	Unit	Value of concrete pavers	Value of concrete pavers with added recycled glass
1	Shape	–	Rhombus shape	Rhombus shape
2	Dimensions	mm	300 × 300x50	300 × 300x50
3	Tensile strength by splitting	MPa	3.7	3.6
4	Loading weight	N/mm	340	330
5	Wear resistance	$mm^3/5000m^2$	9100	9100
6	Slip / skid resistance	–	70	65
7	Water absorption	%	4.6	4.5
8	Loss of frost-thaw resistance	kg/m^2	0.738	0.733

4.2 Texture

For pavers produced with a special textured surface, the texture must be described by the manufacturer. After examination it shall be determined that there are no significant differences in texture compared to the samples provided by the manufacturer and approved [3].

Variations in texture consistency of pavers may be caused by unavoidable variations in raw material characteristics and hardening variations and are not considered significant [3].

4.3 Color

The colors may be applied, at the choice of the manufacturer, on a surface course or on the entire body of the pavers. Conformity shall be established if there is no significant difference in color in any sample supplied by the manufacturer and approved by the purchaser. Variations in the consistent color of the blocks may be caused by unavoidable variations in shade and properties of the raw materials through variations in weight and are not considered significant [3].

5 Comparative Tests

In the same patterns and form concrete pavers and concrete pavers with ground glass were made. In the concrete recipe of the pavers, part of the aggregates were replaced with recycled aggregates sort of 0/4 mm and 4/8 mm. The amount of cement was not changed (Table 7).

6 Conclusions

The tests show that the pavers with added recycled glass meet the requirements of the product standard.

The tests show that if we obtain an optimal recipe, we can produce compliant products. Recycled glass can be used as an additive in the composition of concrete without changing the qualities of the product.

The checks have shown that it is possible to replace part of the mineral, natural ballast and/or quarry aggregates with recycled glass aggregates. Therefore, the environment can be saved by disposing the glass waste.

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