UNIVERSITY OF NIS
FACULTY OF CIVIL ENGINEERING AND ARCHITECTURE

in cooperation with
UNIVERSITY OF NOVI SAD
FACULTY OF TECHNICAL SCIENCES
DEPARTMENT OF CIVIL ENGINEERING AND GEODESY

UNIVERZITET U NIŠU
GRAĐEVINSKO-ARHITEKTONSKI FAKULTET

u saradnji sa
FAKULTETOM TEHNIČKIH NAUKA U NOVOM SADU
DEPARTMAN ZA GRAĐEVINARSTVO I GEODEZIJU

PhIDAC 2019 PhIDAC

V INTERNATIONAL SYMPOSIUM
FOR STUDENTS OF DOCTORAL STUDIES IN THE FIELDS OF CIVIL ENGINEERING,
ARCHITECTURE AND ENVIRONMENTAL
PROTECTION

V MEĐUNARODNI SIMPOZIJUM
STUDENATA DOKTORSKIH STUDIJA IZ OBLASTI GRAĐEVINARSTVA,
ARHITEKTURE I ZAŠTITE ŽIVOTNE SREDINE

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EDITORAL NOTE:

The Faculty of Civil engineering and Architecture of University of Nis organizes the Fifth International Symposium of Doctoral Studies' Students in the fields of Civil Engineering, Architecture and Environmental Protection "PhIDAC 2019".

The first Symposium of the Doctoral Studies' Students "PhIDAC 2009", held in September 2009 in Nis, confirmed the expectations of Prof. Slavisa Trajkovic and Professor emeritus Radomir Folic, the founders of this symposium, that the two-day meetings of the students of Doctoral studies and their professors would be of invaluable use both for young researchers and their tutors. Namely, a great number of published and presented papers, as well as open discussion on the quality of paper, directions in further researches and relationships between doctoral students and tutors demonstrated that the Symposium fulfilled the expectations of the participants and that the organization of new meetings should be continued.

At the Second Symposium "PhIDAC 2010" held in Novi Sad, the symposium programme was expanded, i.e. the field of environmental protection was also introduced as the third thematic field with the expectation that this multidisciplinary area should be more closely introduced to young researches in the fields of civil engineering and architecture.

The organizers of the Third Symposium "PhIDAC 2011", also held in Novi Sad, decided that the symposium should be international and thus they opened new possibilities for affirmation and development of young researches from Serbia, as well as of their colleagues from the Balkans.

There were 66 papers dealing with topics in the fields of civil engineering, architecture and environment protection that were submitted for the fourth international symposium of students of doctoral studies "PhIDAC 2012". The papers covered a wide range of scientific topics. All the papers were reviewed. On the basis of the reviews, it was concluded that the young researchers provided a significant contribution to the development of scientific thinking.

Members of the international scientific committee actively participated in the preparation of the symposium and reviewing of the papers. For this symposium too, the proceedings including papers in English and Serbian were included, which provides better and more productive communication and exchange of experience with the colleagues from abroad.

We would like to thank all the authors and co-authors of the papers and their mentors, and it is our wish that the young researchers would continue their successful careers and persist in realization of the goals they have set.

Nis, October 2019 Editors

THE CONTENT:

SESSION CIVIL ENGINEERING AND ENVIRONMENTAL PROTECTION / OBLAST GRAĐEVINARSTVO I ZAŠTITA ŽIVOTNE SREDINE

RADOVI NA SRPSKOM JEZIKU / PAPERS IN SERBIAN LANGUAGE

OBLAST ARHITEKTURA / SESSION ARCHITECTURE

OBLAST GRAĐEVINARSTVO I ZAŠTITA ŽIVOTNE SREDINE / SESSION CIVIL ENGINEERING AND ENVIRONMENTAL PROTECTION

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PRACTICAL USE OF WASTE CRT GLASS FOR MAKING OF CONCRETE PREFABRICATED PRODUCTS

Abstract: The complex recycling process and problematic chemical composition of cathode ray tube glass to a great extent limit the range of its use for making of new product. In this sense, numerous tests have been conducted, with a goal of finding solution for this environmental problem. One of possible solutions is the use of CRT glass for making of various kinds of concrete prefabricates. The paper presents the results of testing of physical and mechanical properties of paving blocks and flags, according to the standards SRPS EN 1338 and SRPS EN 1339. For the reference samples, the material used for making of a wearing surface is quartz sand, while for other products is used a combination of quartz sand and ground cathode ray tube glass. Also, various properties of self compacting concrete (SCC) have been examined, where the CRT glass had a role of powdery mineral admixture. SCC made in this way, with satisfactory physical – mechanical characteristics was used for making of concrete curbs.

Key words: CRT glass, precast concrete, SCC concrete, paving blocks, paving flags, ecology

1. CATHODE RAY TUBE QUANTITIES IN SERBIA AND EUROPE

There are several recycling centers in Serbia, dealing with collection and processing of CRT glass. The recycling centers collecting most glass on a yearly base are: "Jugo – Impex E.E.R." d.o.o. from Niš, "SET reciklaža" from Belgrade, "Božić i sinovi" from Pančevo and "Eko Metal" from Vrdnik. Table 1 shows the amounts of glass collected by the mentioned companies in several recent years.

Table1- Quantities of collected glass in Serbia

Company	Collected qunatity by years [kg]		
	2014	2015	2016
Jugo – Impex E.E.R.	1.287.194	1.892.388	2.218.175
Božić i sinovi	315.750	522.936	728.955
EKO metal	180.627	90.046	132.995
SET Reciklaža	~ 9.061.000 (for three years)		

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The technology of dismantling of CRT screens to constituents is entirely up to date with the state-of-the-art technology used in more developed countries of the world. The Jugo – Impex company recycles the CRT screens using the *Hot Band Technology*. About two thirds of collected glass contains no lead, while one third contains lead. The “Božić i sinovi” company dismantles CRT screens using the *Diamond Saw Method*. This equipment facilitates dismantling CRT screens having 14 to 32 inch diagonals. The plant capacity is 60 to 100 pieces in 60 minutes. The “Božić i sinovi” company disposes the panel glass of the screens on the landfill or stores with it other operators, while the neck glass is handed over to the operators having permission for export of this kind of waste material. According to the data obtained by the Society of Recyclers of Serbia, the "SET Reciklaža" company is among the largest collectors of CRT glass in Serbia. This company, in the period from 2014 to 2017 collected 6091 tons of CRT glass, while in first six months of 2018, it collected 930 tons of CRT glass. Based on the values presented in Table 1 it can be concluded that the quantity of collected glass increases in Serbia every year.

The trend of accumulation of waste CRT glass – follows the trend of increase of this kind of waste in Europe and the world. Computer monitors and TV sets with cathode ray tubes have not been sold in Europe since 2011. However, these devices are still present in the households, and it is estimated that the landfills in Europe annually receive between 50.000 tons and 150.000 tons of obsolete CRT screens [4].

Nulife Glass Ltd and Sweep Kuusakoski Ltd are currently the leading factories in Europe, extracting lead from CRT glass. Both factories are located in Great Britain. Lead is extracted from the glass in the ovens using appropriate chemicals. These companies state that the ovens they use are unique in the world, because the process of extraction of toxic lead is performed in a safe and environment-friendly manner [10-11].

In Sweden, the entire recycling process of CRT screens is performed inside the country. It is estimated that 90-95% of collected TV sets and computers are recycled and used for production of new commodities or used as a source of energy. Stena Recycling is the leading company in Sweden for recycling of CRT and LCD monitors. The collected devices are manually separated to integral components which are then sorted to: metal, plastic, electric parts (e.g. *transformer*) and electronic parts (e.g. *printedcircuit boards*) etc.[12].

In France, there are around 100 companies dealing with processing and recycling of electronic waste. In 2011, in these companies, around 100 thousand tons of screen glass. Eco – systemes, Ecologic and ERP are three largest recycling centers which improved the process of collection and recycling of CRT glass in France and provided that the level of screen processing is in compliance with the European directive 2012/19/EU, i.e. that 65% is recycled [3].

The Spanish company LIFE ClayGlassand and U.S. company Camarcho Recycling worked on a joint project in order to find a suitable solution to use the collected CRT glass. Their solution is using CRT glass in ceramic industry for tile production [1]. Moreover, both panel and neck glass (containing lead) can be used. The mentioned companies received support from the *U.S. Environmental Protection Agency and European Commission*. The USA exported to Spain around 67 thousand tons of CRT glass in 2015, to be used in tile production [2].

2. USE OF CRT GLASS IN PRODUCTION OF NEW PRODUCTS

Regarding the problematic chemical composition of cathode ray tube glass (CRT), which constitutes the greatest portion of any screen, transport and storing of such waste must meet special conditions. The recycling process of cathode ray tube glass is very important in environmental terms. An additional problem in that process is the fact that no one produces new CRT devices any longer, so the closed recycling loop, comprising production of new CRT devices from the old ones, is no longer an option. Therefore, only an open-loop recycling remained as a potential when planning usage of old cathode ray tube screens. In the last ten years, a large number of scientists studied usage of waste glass for production of new products such as: ceramic tiles, artificial marble, glass jewelry, cement mortar, etc. A part of researchers concentrated on usage of glass in production of concrete and concrete prefabricates. Further, a short review of the past research of using glass in the field of concrete technology – production of prefabricated concrete elements is provided [5].

The research of Eshmaiel Ganjian et al [7] included various recycled materials and verified potential for their implementation in production of concrete blocks. Among others, the paper included usage of the following recycled materials: ground-granulated blast furnace slag (GGBS), cement by-pass dust (BPD), recycled plasterboard gypsum (PG), basic oxygen slag (BOS), run - off station ash (ROSA), recycled crushed glass (RCG) etc. In the first research phase, there were 9 concrete mixes with various dosages of recycled materials which served as replacement for a share of cement. Split tensile strength test, at the age of 14 and 28 days, demonstrated that only the batch with the combination OPC7,0/GGBS6,3/BPD0,8 (the numbers in the designation are percentages of share of recycled materials) met the required split tensile strength of 3,6 MPa minimum according to the EN 1338 standard. In the second phase of the research, a part of natural aggregate was substituted with recycled materials (bottom ash, recycled concrete, recycled glass). The used recycled aggregates had the maximum grain size of 4 mm and 6 mm, which was achieved by grounding in the laboratory. In table 2 were presented the results of the reference batch and the batch where aggregate was replaced by the recycled glass. The batch with the addition of glass aggregate, as well as the reference batch itself, did not have the satisfactory split tensile strength. On the other hand slip/skid resistance is excellent, while no loss of the sample mass was recorded after the conducted testing of freezing/thaw and de-icing salt action. The batch with the addition of RCG had higher water absorption than the permissible which is provided for in the EN 1338 standard.

Table2 – The testing results of experimental blocks according to the SRPS EN 1338 standard [7]

Concrete	Density [kg/m^3]	Slip/skid resistance [BPN]	Water absorption[%]	Freeze/thaw resistance [kg/m^2]	Split tensile strength [MPa]
Factory control mix	2383	100	5,4	< 1,0	3,2
Mix with 4 mm RCG	2284	105	7,5	/	2,2

Miao Liu [9] in his paper used white and green glass container glass cullet as replacement for portions of both cement and fine aggregate in SCC. The glass admixture resulted in an increase of water/powder ratio and in decrease of required quantity of superplasticizer. The presence of glass was not reflected on the passing ability (L-box test), but it caused reduction of mechanical characteristics of concrete. The final conclusion of the study is that SCC with good physical-mechanical properties can be made if cement and fine aggregate are replaced with recycled glass in the quantity of up to 10%.

Mafalda Matos Ana et al [10] substituted 50% of limestone filler with recycled glass and monitored its effects on mechanical properties and durability of SCC made in this way. It was established that recycled glass increases concrete resistance to penetration of chlorides, reduces water absorption and has mechanical characteristics similar to the reference batch where filler was not substituted by recycled glass.

3. EXPERIMENTAL RESEARCH

3.1. Materials used in the experiment

For the making of concrete blocks and flags was used cement CRH CEM I 42,5R which meets all the quality criteria stipulated by the SRPS EN 197-1:2013 standard. The base layer of concrete was made using crushed limestone aggregate, of 0/4 mm and 4/8 mm fraction, from the quarry “Dolac”–“Trace Srbija” A.D. Niš. The finished layer – visible layer was made using the quartz sand “Jugokaolin – branch Srbokvarc”– Rgotina, of particle size distribution 0,25-1,2 mm. The glass for experimental research was granted to the Laboratory of building materials by the company “Jugo – Impex E.E.R.” d.o.o. Niš.

For making of SCC three fractions of river aggregate were used (0/4 mm, 4/8 mm and 8/16 mm) originating from the South Morava river screening plant “Šilo Prom” d.o.o. Belotinac which conforms to all the quality standards prescribed by SRPS EN 206-1:2011 and EN 12620:2010 standards. Also, pure Portland cement CEM I 42,5R manufactured by “CRH” Novi Popovac was used. Sika Viscocrete 5380 was used as the chemical admixtures in the mixture as superplasticizer. As in the case of production of concrete blocks, CRT glass from the previously mentioned recycling center were used. Cathode glass was milled in the Laboratory of buildings material, using, for this purpose, specially constructed laboratory mill (figure 1). For the purpose of making of experimental blocks, the glass was milled to the fraction

0,25-1,0mm. Regarding that when making SCC concrete, the glass had a role of a powder mineral admixture is milled so that it completely passes through the sieve opening of 0,125 mm.

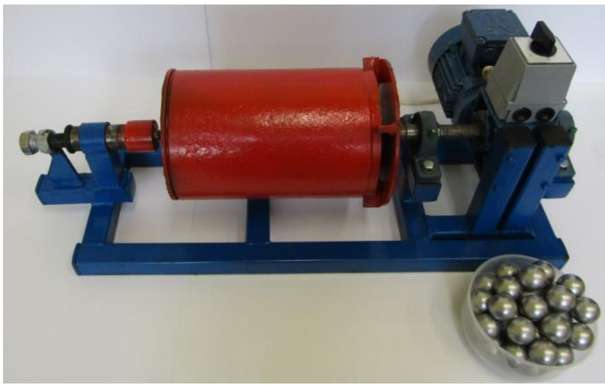

Figure 1- Appearance of a laboratory mill

3.2. Concrete mixture composition

3.2.1 Concrete mixes for making of blocks and flags

In the paper are presented two concrete mixes whose composition is presented in table 3. In the reference batch (E) the finish layer of concrete blocks and flags is made with 100% of quartz, while in the other mix, (WG) 50% of quartz was replaced with the CRT glass of the 0,25/1,00 mm fraction.

Table 3 – Composition of experimental concrete mixtures (for 0,25 m^3)[5]

Concrete	Layer of a block/tile	Aggregate 0/4 mm	Aggregate 4/8 mm	Cement	Quartz 0,25/1,00 mm	CRT	Black color	w/b ratio
		kg	kg	kg	kg	kg	kg	
E	Base	280,0	220,0	95,0	-	-	-	0,32
	Finish	-	-	-	37,0	-	1,10	
WG	Base	280,0	220,0	95,0	-	18,5	-	0,32
	Finish	-	-	-	18,5	-	1,10	

3.2.1 Concrete mixes for making of curbs

Concrete mixture composition is presented in table 1. The self-compacting concrete was made with: 400 kg cement, 1616 kg of the river aggregate with three fractions and 156 kg of recycled CRT glass, having fineness of 0,125 mm which served as a powder mineral admixture. Water/cement ratio was 0,45. The cathode ray tube glass had a share of 5,5% in volume of 1 m^3 of concrete.

Table 4: Composition of experimental SCC concrete mixtures [6]

Type of material	Aggreg. 0/4 mm	Aggreg. 4/8 mm	Aggreg. 8/16 mm	Filer (CRT)	Cement	Water	Admix.
Volume percentage in 1 m^3 [%]	29,62	11,58	20,11	5,5	12,70	18,15	0,45
Specific density [kg/m^3]	2620	2650	2650	2840	3150	1000	1100
Mass 1 m^3 [kg]	776	307	533	156	400	181,5	4,95

4. TEST RESULTS

4.1. Concrete paving blocks and flags

Two sorts of concrete blocks were made, having dimensions 210 x 115 mm and 300 x 165 mm. Also, four sorts of concrete flags were made, having the following widths: 390 x 165 mm, 480 x 165 mm, 540 x 115 mm and 630 x 115 mm. The finish – visible layer of all samples was in average 8 mm thick, across the entire surface of the samples. All the elements had a thickness of 80 mm. The following tests were performed on the mentioned products: shape and dimensions (SRPS EN 1338, annex C), resistance to freeze/thaw and de-icing salts (SRPS EN 1338, annex D), water absorption (SRPS EN 1338, annex E), split tensile strength (SRPS EN 1338, annex F), flexural tensile strength (SRPS EN 1339, annex F), abrasion wear resistance - Böhme test (SRPS EN 1338, annex H) and unpolished slip resistance value (SRPS EN 1338, annex I). The test results are presented in table 5.

Tabela 5 - Test results on experimental blocks and flags

Test	Reference (E)	WG	Quality requirement according to SRPS EN 1338/1339
Density[kg/m^3]	2172	2174	-
Resistance to freeze/thaw and de-icing salts[kg/m^2]	No damage	No damage	≤1,0
Water absorption [%]	5,06	5,12	≤6,0
Split tensile strength [MPa]	4,14	3,73	≥ 3,6
Flexural tensile strength [MPa]	4,02	3,78	≥3,5
Abrasion wear resistance test - Bohme method [mm^3/mm^2]	18585	13675	≤ 20 000 mm^3/mm^2 ≤ 18 000 mm^3/mm^2
Unpolished slip resistance value	147,5	136,5	Not prescribed

4.2. SCC concrete used for making of curbs

The following fresh concrete tests were performed: slump and T_{500} spreading tests (SRPS EN 12350-8:2012), L – box test (SRPS EN 12350-10:2012) and test of stability on the sieve (SRPS EN 12350-11:2012). The test results of fresh concrete are presented in table 6.

Water saturated concrete density test was performed on the hardened concrete cubes (SRPS EN 12390-7:2010) having sides of 15 cm at the age of 28 and 90 days. Compressive strength testing was performed according to SRPS EN 12390-3:2010 standard. Flexural tensile strength was tested on the prisms having dimensions 10x10x40 cm at the age of 28 and 90 days according to SRPS EN 12390-5:2010 standard. According to SRPS EN 12390-6:2012 standard tensile splitting test was performed on the specimens having cylindrical form, having diameter of ∅15 cm and height of 30 cm. „Pull – off" bond strength test was performed on the cubes having sides of 15 cm at the age of 28 and 90 days, in all according to SRPS EN 1542:2010 standard. Static modulus of elasticity was tested on the cylindrically shaped specimens according to SRPS IS0 6784:2000 standard. The Boehme abrasion resistance was tested on the sample cubes having sides of 7.07 cm according to SRPS B.B8.015:1984 standard.

The test of resistance to simultaneous action of frost and salt was performed according to SRPS U.M1.055:1984 standard. According to SRPS U.M1.016:1992 standard was performed M-200 test for resistance of concrete against freezing and thawing. Determination of pressurized water penetration was tested on the cubes having 15 cm sides according to SRPS U.M1.015:1998 standard. The review of test results of hardened concrete is provided in table 6.

Table 6: Review of the fresh and hardened concrete test results

Test	Age	Test results
Spreading T_{500} [s]	-	4,5
Slump test [mm]	-	660
L - box test H1/H2 [mm/mm]	-	0,95
Segregation [%]	-	12,8
Water saturated density [kg/m^3]	28 days	2385
	90 days	2370
Compressive strength [MPa]	28 days	59,0
	90 days	72,2
Static modulus of elasticity [GPa]	28 days	29,9
	90 days	33,3
Flexural strength [MPa]	28 days	6,4
	90 days	7,7
Tensile strength [MPa]	28 days	4,2
	90 days	5,5
Bonding strength [MPa]	28 days	4,2
	90 days	5,1
Bohme abrasion resistance [cm^3/50 cm^2]	90 days	9,5
Pressurized water penetration [mm]	≥ 28 days	0
Resistance to simultaneous action of frost and defrosting salt [mg/mm^2]	≥ 28 days	0,11
Test for resistace of concrete against freezing and thawing M200 [%]	≥ 28 days	15,62

5. DISCUSSION OF RESULTS

5.1. Concrete paving blocks and flags

Based on the results presented in table 5, it can be concluded that replacement of 50% of quartz with CRT glass in the visible layer of concrete samples does not affect the density. Regarding the very small share of quartz and CRT glass, and component materials in 1 m^3 of the mix, such impact of glass on the density can be considered as expected. After 28 cycles of simultaneous freezing/thawing and de-icing salt action, there was no damage of the concrete surface either of the reference batch or the CRT glass batch. Water absorption of both experimental batches was regular, and it was in average around 5%. Even though it is known that glass does not absorb water, in this case, no impact of the presence of glass on the variation of water absorption of concrete samples was established, which can again be ascribed to the small amount of this concrete component. On this occasion it is emphasized that the authors are not aware of any example from the available literature where a replacement of a share in the visible layer of concrete with any kind of waste glass was performed. According to the SRPS EN 1338 standard, there is a quality requirement that concrete blocks must have split tensile strength of no less than 3,6 MPa. In the tests which are a subject of this research, split tensile strength ranged between 3,73 MPa and 4,14 MPa, so both experimental batches satisfy the quality condition stipulated by the standard. Regarding that the split tensile strength was tested on only one type of blocks, on this occasion it cannot be with great certainty concluded that the addition of glass reduces this kind of strength. According to the SRPS EN 1339 standard, there is a quality requirement that concrete flags must have flexural tensile strength no less than 3,5 MPa. In the tests which are a subject of this research, the flexural tensile strength ranged between 3,78 MPa and 4,02 MPa, so both experimental batches satisfy the quality condition stipulated by the standard. Based on the test results of abrasion wear resistance (table 5) it can be concluded that there is a considerable difference between the samples with the finish layer with quartz (E) and the finish layer with mixture of quartz and glass (WG). The batch with 50% CRT glass had 26,42% lower abrasion wear resistance value than the reference batch.

The obtained results regarding unpolished slip resistance using pendulum friction tester are excellent. The SRPS EN 1338 standard itself does not define the quality condition for this kind of testing of concrete prefabricated products durability. The presence of glass in the finish layer of concrete only negligibly reduced slip/skid resistance of concrete prefabricates.

5.2. SCC concrete used for making of curbs

Based on the measured spreading of 660 mm, it can be concluded that SCC with recycled cathode ray tube glass admixture belongs to the spreading class SF2 (of 660mm to 750 mm). The time measured for T_{500} test is 4,5s, so it can be concluded that SCC has satisfactory flowability. The percentage of passage through the 5 mm sieve (sieve stability test) amounted to 12,8% which indicates that experimental concrete has satisfactory resistance to segregation. The L-box test, determined that the concrete belongs to the PA2 class (≥0,80).

The compressive strength at the age of 28 days was 59 MPa, while after 90 days the increase of the strength was 22%. This increase can be partially attributed to the puzzolanic activity of the milled CRT glass. The values of tensile splitting strength and tensile flexural strength were at the satisfactory level. The average value of penetration of water under pressure of 7 bars was 0 mm, which proved that SCC is water impermeable. After 25 cycles of simultaneous action of frost and defrosting salt, it was determined that there occurred the flaking of the surface layer of concrete, but that it was less than 0,2 mg/mm^2. On the basis of SRPS U.M1.055:1984 standard it can be concluded that SCC has the damage degree MS1 and that it is resistant to this action. Reduction of compressive strength after 150 cycles of alternating freezing and thawing amounted to 10,20% in comparison to the reference batch, i.e. 15,62% after 200 cycles which proved that concrete had M-200 freezing and thawing resistance. Boehme abrasion resistance was 9,5 cm^3/50 cm^2 which is a satisfactory result.

6. CONCLUSION

The following conclusions can be drawnbased on the obtained experimental results of the tests of concrete paving blocks and flags and concrete curbs modified by recycled CRT glass:

- Replacement of 50% of quartz sand using CRT glass in the finish layer does not cause the change of density of concrete prefabricates,
- Replacement of 50% of quartz sand with the proper particle size of CRT glass in the finish layer of concrete prefabricates does not affect the durability of products in terms of resistance of concrete against freezing and thawing,
- Presence of glass in the finish layer of concrete prefabricates does not cause increase of water absorption due to the relatively low share of glass and concrete component
- Concrete blocks with the modified finish layer meet the quality requirement in terms of split tensile strength according to the SRPS EN 1338 standard,
- Concrete flags with the modified finish layer meet the quality requirement in terms of flexural tensile strength according to the SRPS EN 1339 standard,
- It is necessary to perform a more extensive testing of appropriate tensile strengths of blocks and flags to make a final decision about the impact of the glass addition to the finish layer on the variation of these strengths,
- By adding 50% CRT glass to the finish layer of the prefabricate considerably improve durability of the product in terms of abrasion wear resistance according to the Böhme test,
- Presence of CRT glass in the finish layer only negligibly reduced skid/slip resistance of concrete prefabricates,
- The obtained values of compressive and tensile strength were high which is in agreement with the results in the paper [8],

- On the basis of the obtained results of water permeability testing, resistance of concrete against freezing and thawing and simultaneous resistance to frost and defrosting salt action, and to abrasion resistance it can be concluded that SCC with CRT has satisfactory durability.

Taking into consideration all previously mentioned conclusions, generally speaking, it can be concluded that he recycled cathode ray tube glass can be successfully used for making of the finish layer of concrete paving blocks and flags. Furthermore, self compacting concrete with the addition of recycled cathode ray tube glass can be considered suitable for making of precast concrete elements such as interlocking paving elements and concrete curbs whose cross section does not exceed 300 cm^2.

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