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Eco build

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14. Međunarodna naučna konferencija

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14. International Scientific Conference

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iNDiS 2018

Subkonferencija

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Eco build

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Novi Sad, Srbija
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u saradnji sa
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FACULTY OF TECHNICAL SCIENCES
DEPARTMENT OF CIVIL ENGINEERING AND GEODESY,
DEPARTMENT OF ARCHITECTURE AND URBAN PLANNING

in cooperation with
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iNDiS 2018

Departman za građevinarstvo i geodeziju, Fakulteta tehničkih nauka u Novom Sadu organizuje četrnaestu međunarodnu naučnu konferenciju „iNDiS 2018“. Ove godine, u skladu sa savremenim trendovima u razvoju održivog graditeljstva, obuhvata i „Eco build“ subkonferenciju: Poljoprivredni otpad – izazovi i poslovne mogućnosti, koja se organizuje u okviru realizacije projekta Interreg – IPA CBC Hrvatska – Srbija.

Prvi skup održan 1976. godine bio je na temu „Industrijska izgradnja stanova“, zbog njene aktuelnosti u tom periodu. Kasnije su održavane konferencije sa nešto širom tematikom „Industrijalizacija građevinarstva“, da bi se ubrzo na skupu pojavili radovi iz svih oblasti graditeljstva od prostornog planiranja, projektovanja objekata različite namene do održavanja i većih intervencija na izgrađenom graditeljskom fondu. To je uslovilo i proširivanje oblasti koje obuhvata ovaj skup na kome se, pored građevinskih inženjera različitih usmerenja, pojavljuju urbanisti, arhitekti, inženjeri drugih struka koji rade u graditeljstvu, sociolozi, ekonomisti i drugi.

Ova konferencija, kao i nekoliko prethodnih, obuhvata probleme: planiranja, projektovanja, građenja i obnove graditeljstva, upravljanja rizicima od kastrofalnih događaja i zaštite od požara, što je naišlo na adekvatan odziv istraživača i inženjera različitih profila iz inostranstva i naše zemlje.

Članovi međunarodnog naučnog komiteta aktivno su učestvovali u pripremi konferencije, kako u recenziranju pristiglih radova, tako i radovima koji se objavljuju u ovom zborniku. Očekuje se da će prezentacije radova i diskusije na konferenciji omogućiti definisanje glavnih pravaca razvoja graditeljstva u skladu sa savremenim trendovima, s obzirom na to da je promovisano mnoštvo ideja i rezultata eksperimentalnih i teorijskih istraživanja u oblastima graditeljstva i zaštite životne sredine.

Za ovu konferenciju, „iNDiS 2018“, objavljen je zbornik radova, u kome su uključeni radovi na engleskom i srpskom jeziku, što omogućuje bolju i plodniju komunikaciju i razmenu iskustava sa kolegama iz inostranstva. Od značaja je i mogućnost sklapanja novih i jačanja postojećih profesionalnih i kolegijalnih veza.

Svim autorima radova urednici upućuju veliku zahvalnost.

Novi Sad, novembar 2018. godine. Urednici

iNDiS 2018

Department of Civil Engineering and Geodesy, Faculty of Technical Sciences in Novi Sad organizes the 14th International Scientific Conference "iNDiS 2018". This year, in accordance with the contemporary trends in the development of sustainable construction, includes also subconference "Eco Build": Agricultural Waste - Challenges and Business Opportunities, organized as part of the implementation of the Interreg project - IPA CBC Croatia - Serbia.

The first conference took place in 1976 with main topic "Industrial construction of apartments", due to its actuality in that period. In the following years, conferences were held with a somewhat broader topic "Industrialization of Civil Engineering", and soon, papers from all areas of construction, from urbanism planning and designing to maintenance and major interventions on the built construction fund appeared. This led to the expansion of the conference topics, where urban planners, architects, engineers of other professions working in construction, sociologists, economists and others appear alongside construction engineers of various orientations.

This conference, as well as several previous ones, covers the problems of planning, design, construction and restoration of construction, disaster risk management and fire safety, which resulted in the adequate response of researchers and engineers from various profiles from our country and also from abroad.

Members of the International Scientific Committee actively participated in the preparation of the conference, both in the review of the received papers and with the papers published in this Proceeding. It is expected that the presentations of papers and discussions at the conference will enable the definition of the main directions of construction development in line with contemporary trends, since many ideas and results of experimental and theoretical research in the field of construction and environmental protection have been promoted.

For this conference, "iNDiS 2018", a collection of papers, in English and Serbian was published, which enables better and more fruitful communication and exchange of experiences with colleagues from abroad. Also, it provides great possibility of concluding new and strengthening existing professional and collegial relationships.

The editors would like to express sincere gratitude to all authors for the effort invested in writing papers and for the contribution to this event.

Novi Sad, November 2018 Editors

SCIENTIFIC CONFERENCE
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NOVI SAD, 21-23 NOVEMBER, 2018

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POTENTIAL FOR MAKING CONCRETE PAVING BLOCKS AND TILES USING CATHODE RAY TUBE GLASS

Abstract: The paper presents the results of testing of physical and mechanical properties of paving blocks and tiles, 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 useda combination of quartz sand and ground cathode ray tube glass. The glass is milled to the 0.25/1.00 mm fraction, which is equal to quartz sand fineness. A special attention is paid to measuring of abrasion according to the Böhme test, determining of unpolished slip resistance value (USRV) to evaluate the frictional properties of the specimen on the upper face and determining of freeze/thaw resistance with de-icing salt. Based on the analysis of the obtained results, conclusions about potential for practical application of these products were drawn.

Key words: concrete, recyled glass, Böhme test, slip/skid resistance, frost and sult resistance

MOGUĆNOST PRIMENE STAKLA OD KATODNIH CEVI ZA IZRADU BETONSKIH BLOKOVA I PLOČA ZA POPLOČAVANJE

Rezime: U radu su prikazani rezultati ispitivanja fizičkih i mehaničkih svojstava blokova i ploča za popločavanje, prema standardima SRPS EN 1338 i SRPS EN 1339. Kod etalona je za izradu habajućeg sloja korišćen kvarcni pesak, dok je kod ostalih proizvoda korišćena kombinacija kvarcnog peska i usitnjenog stakla katodnih cevi. Staklo je usitnjeno do frakcije 0,25/1,00 mm što odgovara finoći mliva kvarcnog peska. Posebna pažnja je posvećena ispitivanju otpornosti na habanje po Bemeu, utvrđivanju otpornosti prema klizanju gornje površine proizvoda CRT klatnom i ispitivanju otpornosti na jednovremeno delovanje mraza i soli za odmrzavanje. Na osnovu analize dobijenih rezultata utvrđeni su zaključci o mogućnosti praktične primene ovakvih proizvoda.

Ključne reči: beton, reciklirano staklo, otpronost na habanje, klizanje, mraz i soli

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1. INTRODUCTION

The sales of computer and television monitors with cathode ray tubes have been practically discontinued in Europe since 2011. They were replaced, owing to the technological advancement, by the new TFT-LCD screens. Considering the life time of CRT monitors and the fact that they are still present in the households, it is estimated that each year a considerable quantity of these devices is generated at the disposal sites in Europe [1]. 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.

2. PAST RESEARCH OF RECYCLED GLASS USAGE FOR PRODUCTION OF PREFABRICATED CONCRETE PRODUCTS

2.1. Impact of recycled glass aggregate on the properties of concrete paving blocks

Waste glass management and its reuse represent one of the main problems in multi-million cities worldwide. In Hong Kong only around 300 tons of waste glass is collected daily, and according to the data of the competent ministry, only 1-2% is reused for production of new products. Gerry Lee et al [2] researched the potential to use the glass recycled from food containers to produce concrete blocks of rigid consistency. The recycled glass was used as a substitution for a share of fine natural aggregate. The ratio of coarse and fine aggregate in the concrete mix was 1:1. A total of seventeen concrete mixtures was made, in which the fineness of milled glass and share of replacement of aggregate with glass were varied. Four milled glass finenesses were used: unsifted glass (*the batch designated A-FG*), glass finer than 2,36 mm (*B-FG*), glass finer than 1,18 mm (*C-FG*) and glass finer than 0,60 mm (*D-FG*). The percentage of replacement of the aggregate with glass in terms of mass amounted to 25%, 50%, 75% and 100%. Optimal water/cement ratio for each mixture was determined based on workability of concrete, so that it is sufficiently cohesive for placing into concrete molds, but also that its slump is around 0 cm (*stiff consistency*). The 70 mm concrete cube samples were tested for the following concrete properties: density, water absorption and compressive strength.

whose surface is smooth and impermeable. On the other hand, the batch with the finest glass had the highest values of strength in cmparison to the reference batch. The explanation for such a result can be found in a puzzolanic activity of the recycled glass, when finely milled (<600 μm).

2.2. Comparative research of the impact of waste glass and other recycled materials on production of concrete paving blocks

The research of Eshmaiel Ganjian et al [3] 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. It is interesting to mention here that the glass was not planned for this first phase of the experiment. The control mix had the identical composition as the mix used by the local concrete blocks production plant. The experimental blocks had a cross section 190 x 100 mm and thickness of 80 mm. The concrete samples were obtained using hydraulic compression machine. 24h after placing, the blocks were demolded and cured in a chamber at the temperature 22 ± 2°C and humidity 98% until testing. 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. The mentioned batch met all the conditions regarding durability which was confirmed by the tests of simultaneous action of freeze/thaw and de-icing salt and of slip/skid resistance. 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 1 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.

Table 1 – The testing results of experimental blocks according to the EN 1338 standard [3]

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

3. EXPERIMENTAL RESEARCH

3.1. Materials used in the experiment

For the making of concrete blocks and tiles 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. **N**iš. 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. It is the CRT glass which is obtained by the mentioned company in the process of recycling of old TV-sets and other electronic devices. Coarse shards of glass (figure 3, left) are milled to the size of 0-4mm in a local asphalt production plant. Further milling to the fraction 0,25-1,0mm (figure 3, right) was performed in the laboratory using a steel-ball mill. Chemical composition of cathode glass is presented in table table 2. This fraction of CRT glass was used for production of the visible layer of concrete blocks and tiles. The visible layer of the blocks and tiles can be produced in any color, and in the specific case, the black color produced by “Bayer” was used.

Figure 3 – Glass shards after recycling (left) and CRT glass, fraction 0,25/1,00 mm

Table 2 – Chemical composition of CRT glass

Chemical compound	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2
Share [%]	60,61	2,88	0,58	1,31	0,53	6,45	7,61	0,30

3.2. Composition of concrete mixes

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 tiles 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 mixes (for 0,25 m^3)

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	-	-	18,5	37,0	-	1,10	
WG	Base	280,0	220,0	95,0	-	-	-	0,32
	Finish	-	-	18,5	18,5	18,5	1,10	

3.3. Procedure of making concrete blocks and tiles

Concrete blocks and tiles were produced in the production plant of the company "Arhibet" d.o.o.,Niš. The production process is fully automatized and computerized. The necessary quantities of concrete components are automatically dosed according to a selected mix design and they are firstly poured into steel moulds which are chosen according to the dimensions of the product to be made. The basic layer of concrete is compacted by simultaneous vibration and pressing. In the second step, the components for the finish – visible layer of concrete elements are dosed, whereby the vibration and pressing process is once again repeated. All the elements had a thickness of 80 mm. In this specific case, two sorts of concrete blocks were made, having dimensions 210 x 115 mm and 300 x 165 mm. Also, four sorts of concrete tiles 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. The upper, visible side of the samples is flat, with no irregularities. All the types of elements are presented in figure 4.

Figure 4 – Appearance of experimental concrete blocks and tiles in the company "Arhibet" d.o.o., Niš

3.4. Test results

The following tests were performed on the mentioned products:

- Shape and dimensions (EN 1338, annex C)
- Resistance to freeze/thaw and de-icing salts (EN 1338, annex D)
- water absorption (EN 1338, annex E)
- split tensile strength (EN 1338, annex F)
- flexural tensile strength (EN 1339, annex F)
- abrasion wear resistance - Böhme test (EN 1338, annex H)
- Unpolished slip resistance value (EN 1338, annex I)

Testing of resistance to freeze/thaw and de-icing salts was performed in all according to the annex D of the EN 1338 standard. One should note that the procedure of preparation of testing samples is more complicated than the procedure used in the common practice. The appearance of the samples after 28 testing cycles is presented in figure 5.

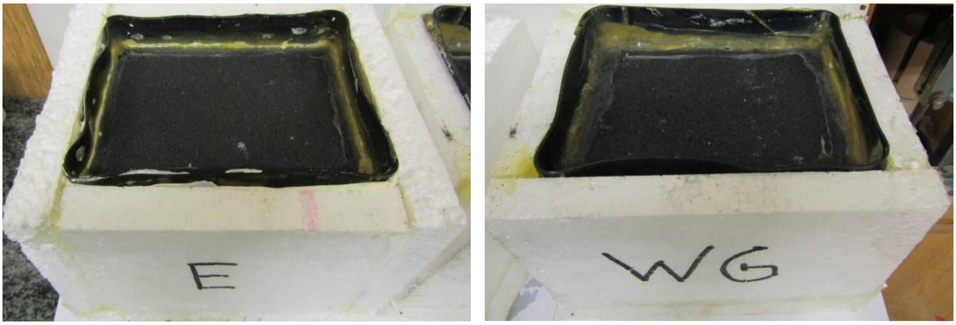

Figure 5 – Appearance of concrete samples after the conducted tests of resistance to freeze/thaw and de-icing salts

Water absorption was conducted according to the EN 1338 standard, annex E. the samples were dipped into a vessel of appropriate dimensions, at a mutual distance larger than 15 mm. Afterwards, the samples were dipped in the water having temperature 20± 5°C so that the water level is 20 mm above the upper edge of the samples. Sample water saturation lasted longer than three days, until a constant mass of the samples was established. After measuring the mass of the samples saturated in water, the samples were dried at the temperature of 105 ± 5°C. According to the well know expression, the water absorption was calculated and the results were presented in table 4.

The split tensile test was conducted on the concrete blocks having dimensions 210 x 115 x 80 mm according to the EN 1338 standard, annex F. Upper and lower block surface were polished prior to the test to provide a smooth surface. The test was conducted on the digital hydraulic press UTEST UTC –5600. The stress increments until failure of the sample was constant and amounted to 0,05 MPa/s. The load was transferred to the sample via two packing pieces. The test results are presented in table 4. In figure 6, left are presented the prepared sample and equipment for the test.

The flexural tensile strength test was performed on the concrete tiles having dimensions 390 x 165 x 80 mm according to the EN 1339 standard, annex F. The tiles were polished on the contact point, in order to provide as good contact as possible. The load increments were such to facilitate failure after 45 s ± 15 s from the onset of loading. The test results are presented in table 4. In figure 6, right, are presented the prepared sample and equipment for this test.

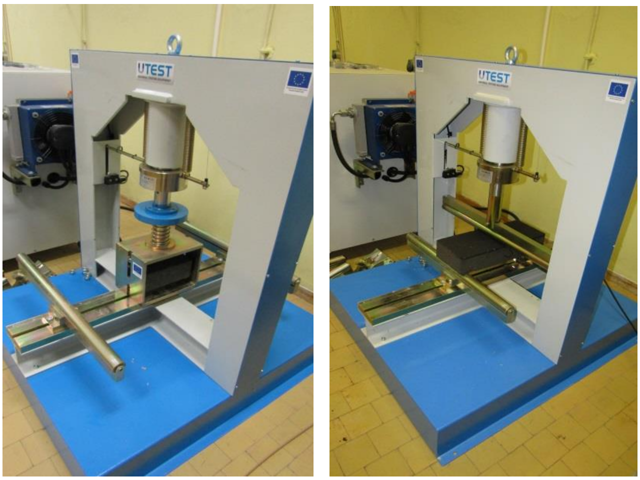

Figure 6 – Appearance of equipment and sample of the tile for split tensile strength testing (left); Appearance of the equipment and sample of the tile for flexural tensile strength test (right)

Cutting the samples formed the cubes having sides of 7,1 cm which were used for testing abrasion wear resistance at the age of 28 days. The test was conducted on the Böhme machine (figure 7, left). Logically, the finish layer of concrete elements was exposed to abrasion wear. The results are presented in table 4. Unpolished slip resistance value was determined using pendulum friction tester in all according to the annex I, of the EN 1338 standard (figure 7, right).

Figure 7 – Abrasion wear test on the Bohme machine (left); Testing of skid resistance by pendulum friction tester (right)

Table 4 – Test results on experimental blocks and tiles

Test	Reference (E)	WG	Quality requirement according to EN 1338/1339
Density [kg/m^3]	2172	2174	-
F/T + S resistance M+S [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 stipulated

4. DISCUSSION OF RESULTS

Based on the results presented in table 4, 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 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 EN 1339 standard, there is a quality requirement that concrete tiles 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 4) 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 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. CONCLUSION

Based on the obtained tests experimental results of the concrete paving blocks and tiles finish layer composition modification using CRT glass, the following conclusions can be drawn:

- Modification of the finish layer of concrete prefabricates using CRT glass does not have any adverse effect on their esthetic appearance,
- 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 simultaneous action of freezing/thawing and de-icing salt,
- 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 EN 1338 standard,
- Concrete tile with the modified finish layer meet the quality requirement in terms of flexural tensile strength according to the EN 1339 standard,

- It is necessary to perform a more extensive testing of appropriate tensile strengths of blocks and tiles 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,
- 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 tiles.

6. REFERENCES

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