



**DRUŠTVO ZA ISPITIVANJE I ISTRAŽIVANJE
MATERIJALA I KONSTRUKCIJA SRBIJE**

**SOCIETY FOR MATERIALS AND
STRUCTURES TESTING OF SERBIA**

MEĐUNARODNI SIMPOZIJUM

**O ISTRAŽIVANJIMA I PRIMENI SAVREMENIH DOSTIGNUĆA
U GRAĐEVINARSTVU U OBLASTI MATERIJALA I
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UTICAJ DODATKA CRT STAKLA NA SVOJSTVA SVEŽEG I OČVRSLJOG MALTERA

Rezime: U radu su prikazani eksperimentalni rezultati ispitivanja maltera u svežem i očvrslom stanju koji je spravljen sa dodatkom recikliranog otpadnog katodnog stakla (CRT). Staklo je usitnjeno pomoću specijalno konstruisanog mlina do finoće mliva koja omogućava da bez ostatka prođe kroz sito otvora 0,063 mm. Dodavanje CRT stakla je rađeno u količini od 0%, 5% i 10% u odnosu na masu cementa. Ispitivanjem pri starosti od 90 dana, utvrđeno je da se dodavanjem 10% stakla povećava čvrstoća pri pritisku i čvrstoća pri savijanju maltera za 7% i 9%, respektivno. Takođe, utvrđeno je da se dodatkom CRT-a poboljšava trajnost maltera u pogledu skupljanja, otpornosti na delovanje mraza i alkalno silikatne reakcije (ASR). Značajniji uticaj dodatka stakla na promenu konzistencije maltera i sadržaj uvučenog vazduha nije utvrđen.

Cljučne reči: CRT, čvrstoća, pucolanska aktivnost, otpornost na mraz, skupljanje, ASR.

EFFECTS OF ADDITION OF CRT GLASS ON PROPERTIES OF FRESH AND HARDENED MORTAR

Abstract: The paper presents the results of experimental testing of mortar in fresh and hardened states, which was made with addition of recycled waste cathode ray tube (CRT) glass. The glass was milled using a specially designed mill, providing the sieve passage fineness of 0,063 mm with no retained material. The CRT glass was performed in the quantity of 0%, 5% and 10% relative to the mass of cement. The testing at the age of 90 days showed that addition of 10% of glass increases compressive strength and flexural strength of the mortar for 7% and 9%, respectively. Also, it was determined that addition of CRT improved durability of mortar in terms of shrinkage, resistance to frost and alkali-silicate reaction (ASR). There were no notable effects of glass addition on the change of mortar consistency and entrained air content found.

Key words: CRT, strength, pozzolanic activity, frost resistance, shrinkage, ASR.

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1. INTRODUCTION

Glass is frequently used material in industry owing to its good physical-mechanical and decorative properties, which in time results in generation of problematically large quantities of waste. A portion of waste glass is successfully recycled, such as glass containers in food processing industry. However, there are other kinds of waste glass which, because of their chemical composition and high cost of recycling, cannot be easily used for production of new products.

Various researchers investigated in their papers the effects of replacement or addition of various kinds of waste glass on the properties of fresh and hardened mortar. Thus, in international publications, one can find experimental results of mortar testing, whose making involved the following types of glass: panel or CRT screen funnel glass, decorative crystal glass, fluorescent lamp glass, glass food containers, façade glass, waste glass sludge which is a side product of the polishing process and lately, the TFT-LCD TV-sets' glass. Maria Bignozzi et al. [3] from the University in Bologna, researched the effects of substitution of a portion of cement with milled glass of different chemical compositions on mortar properties. In the paper, the following types of glass were used: food container glass (0% Pb), fluorescent lamps glass (0,8% Pb), CRT funnel glass (18% Pb) and crystal glass (27% Pb). The share of replacement of cement with glass was constant, and amounted to 25%, while the milled glass fineness was 10-20 μm . By testing the compressive strength, it was determined that at the age of 60 days, the highest strengths were shown by the reference batch which contained no added glass. However, the test results at the age of 90 days showed that mortar batches with CRT glass and recycled food container glass reached and even exceeded the compressive strength parameters of the reference batch.

Ali Aliabdo et al. [1] used recycled food container glass for replacement of a portion of cement, but also as an addition to cement when making mortars and concrete. The share of replacement and addition of glass was performed in terms of mass, in the range from 0% to 25% with the increments of 5%. The waste glass was milled to the fineness higher than 75 μm . Compressive strength of mortar batches was tested only at the early age of mortar of 3 and 7 days. When glass replacement share of cement exceeded 10% there occurred a decrease of mechanical strength. The authors determined that addition of glass up to 15% improved mechanical properties of concrete. Compressive strength of concrete, at the age of 28 days, increases for 4,7% 14,6% and 16,8% in respect to the reference batch for the glass addition share percentage of 5%, 10% and 15%, respectively. Splitting tensile strength tests results also showed improvement after addition of glass to the value of 15%.

Contemporary industrial production of TV sets is based on manufacturing flat screen TV sets, whose commercial designation is TFT-LCD (Thin Film Transistor - Liquid Crystal Display). Her - Yung Wang [8] tested the effects of TFT-LCD glass as a substitution for a portion of cement, when making mortars. Percentage of substitution of cement with milled glass ranged between 0 and 50% of mass, with 10% increments. Specific mass of glass after milling was 2,65 g/cm^3 , while the Blen fineness modulus was 3850 cm^2/g . The author did not find significant changes of splitting tensile strength and flexural tensile strength up to the 20% of glass substituting the cement.

Testing of durability of mortars with added glass is very important, because thus the potential of practical application of the mortars modified in this way can be determined. One of the most important durability tests is examination of alkali-silicate

reaction. Recycled glass contains a high percentage of amorphous silicon which can potentially react with alkali from cement which can result in creation of ASR gel. ASR gel, in the presence of moisture expands, which in long term can lead to material destruction.

Ana Mafalda Matos et al. [7] examined durability of mortar where a part of cement was replaced with milled glass from car windscreens. Glass fineness is higher than 63 μm , while the percentage of substitution was 0%, 10% and 20% of cement mass. ASR testing was conducted according to the ASTM 1567 standard. The results showed that with the increase of the share of glass in the mixture, the sample expanded less in comparison with the reference batch. At the highest percentage of substitution of cement with glass, the expansion of the sample amounted to 0,0410% on average, which does not exceed the permissible limit of 0,10% according to the US standard.

Further on will be presented the test results of mortar properties in fresh and hardened states with the addition of 5% and 10% (of the mortar mass) of CRT glass. These results represent only a small portion of a much more extensive experimental research in the scope of the pending doctoral dissertation with the title "Effects of addition of finely milled recycled glass from cathode ray tubes on the properties of cement mortar and concrete".

2. EXPERIMENTAL RESEARCH

2.1. Materials used in the experiment

The experimental research was conducted on the samples of cement mortar having dimensions 40x40x160 mm. Cement CRH CEM I 52,5R, and standard 3-fraction sand were used for making mortar. The used cement meets all the prescribed quality requirements according to the SRPS EN 197-1 standard.

Panel glass of recycled cathode ray tubes, for the purpose of this experiment, was granted by the company "JUGO-IMEX E.E.R. d.o.o.". The mentioned company operates the state-of-the-art automatic CRT separator (figure 1, left) for separation of the principal screen components. The "hot wire" method is used for removing the screen panel from the screen funnel which is of utmost importance because of the different chemical composition of these two types of CRT glass [5].



Figure 1. Appearance of automatic separator CRT (left); Glass shards after recycling (right)

Large glass shards were milled to the fineness of 0-4 mm in the asphalt plant of the company "Vodogradnja" Pukovac, and then the glass was milled to a fineness higher than 0,063 mm at the Laboratory of Building materials of the Faculty of Civil Engineering and Architecture of Niš in a specially designed mill.

2.2. Puzzolanic activity of CRT glass

Prior to the usage of glass as an addition to the cement, the puzzolanic activity of the experimental glass according to the SRPS B.C1.018:2001 standard was performed. According to the mentioned standard, a material is considered to be active in terms of puzzolanic activity and it is ranked as class 5 if at the mortar age of 7 days the minimal flexural tensile strength is 2 N/mm² and compressive strength is 5 N/mm². The test results of mechanical properties of mortar at the age of 7 days after curing according to the standard are presented in the table 1 [4].

Specimen:	Flexural strength [N/mm ²]	Compressive strength [N/mm ²]
1	2,36	5,76
		5,82
2	2,28	5,76
		5,82
3	2,43	5,95
		5,82

Table 1. Results of mechanical properties of mortar

2.3. Alkali – silicate reactivity of mortars with addition of CRT glass

Testing of alkali - silicate reactivity of glass was conducted according to the ASTM C227 standard. The test was performed in the Laboratory for binders, chemistry and mortars of the IMS Institute. According to the standard, the test is performed on the mortar specimens having dimensions 25 x 25 x 285 mm. Measuring of dilatation – expansion of mortar prisms was done at the age of mortar of 14, 28, 60, 90, 120, 150 and 180 days. Alkali – silicate reactivity was tested on a reference batch (without added glass) and on a batch with 20% of added glass (designation WGD20) [6]. The volume variation results are displayed in table 2.

Mortar age	Etalon	WGD20 batch
14	+0,0100	+0,0074
28	+0,0100	+0,0074
60	+0,0158	+0,0097
90	+0,0159	+0,0097
120	+0,0159	+0,0124
150	+0,0175	+0,0128
180	+0,0180	+0,0139

Table 2. Test results of volume variation of mortar specimens according to ASTM C227

2.4. Mortar mixtures composition and test results

Three mortar prisms were made for the purpose of testing the effects of adding recycled cathode ray tube glass. The ratio of cement (m_c) and standard sand (m_p) in the mixture was constant, and amounted to $m_c : m_p = 1 : 3$. The CRT glass was added to cement regarding the mass criterion. Water/cement ratio varied with the increase of glass addition, and it was 0,50% for the reference mortar, 0,48% for the mortar with 5% glass added (WGD5) and 0,45% for the mortar with 10% glass added (WGD10). The mentioned designations of the mortar mixtures were made in agreement with the percentage of added glass. The mortar mixtures composition is displayed in table 3. In the same table are presented the following results: consistency tests on the flow table (SRPS B.C8.042), entrained air content (SRPS B.C8.050) and density of hardened mortar in water saturated state (SRPS ISO 6275).

Composition and properties:	Mortar designation:		
	E	WGD5	WGD10
Cement mass [g]	450	450	450
River aggregate mass [g]	1350	1350	1350
Recycled glass mass [g]	-	22,5	45,0
Water mass [g]	225	225	225
Consistency [mm]	120/120	120/120	120/120
Entrained air [%]	8,0	8,5	8,0
Density of hardened mortar [kg/m ³]	2211	2192	2197

Table 3. Composition of mortar mixtures and test results of consistency, entrained air and density of hardened mortar

Compressive and flexural strength tests were performed according to the SRPS EN 196-1 standard. The test was conducted at the age of mortars of 2, 7, 28 and 90 days. In figure 2 is presented the variation of compressive strength of mortar batches in the function of time. Variation of flexural strength of experimental batches in the function of mortar age is presented in figure 3.

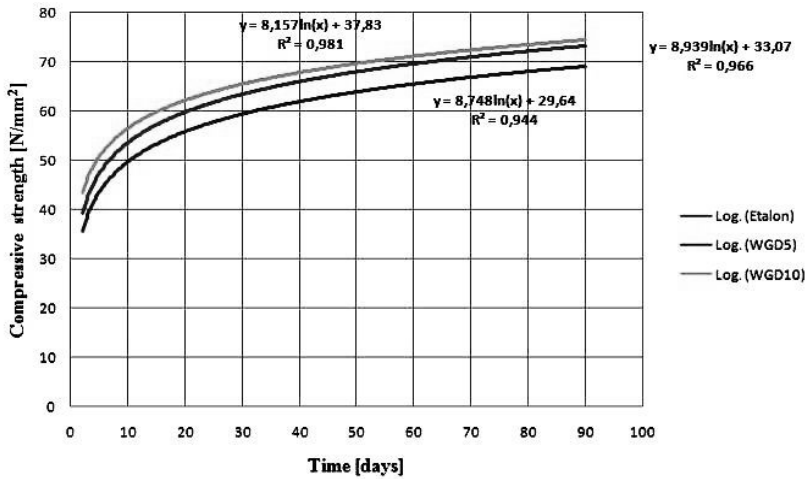


Figure 2. Compressive strength variation of mortar batches with added glass in the function of time

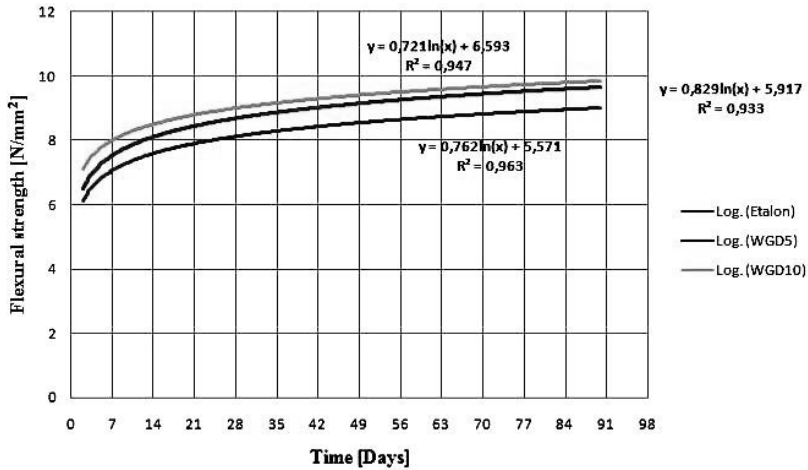


Figure 3. Flexural strength variation of mortar batches with added glass in the function of time

Mortar batch:	Compressive strength after 33 days [N/mm ²]	Compressive strength after 25 freezing-thawing cycles [N/mm ²]	Decrease of compressive strength [%]
Etalon	60,23	55,89	7,2
WGD5	64,33	60,73	5,6
WGD10	67,93	64,58	4,9

Table 4. Test results of resistance of mortars with added glass to frost action

Testing of mortar resistance to frost action was conducted according to the SRPS U.M8.002 standard. The results of compressive strength of experimental batches at the age of 33 days, of compressive strength after 25 freezing-thawing cycles after the conducted research are presented in table 4. Mortar shrinkage was tested according to the standard SRPS B.C8.029 at the ages of 3, 4, 7, 14, 21 and 28 days. In figure 4 is presented shrinkage of mortar specimens in the function of time.

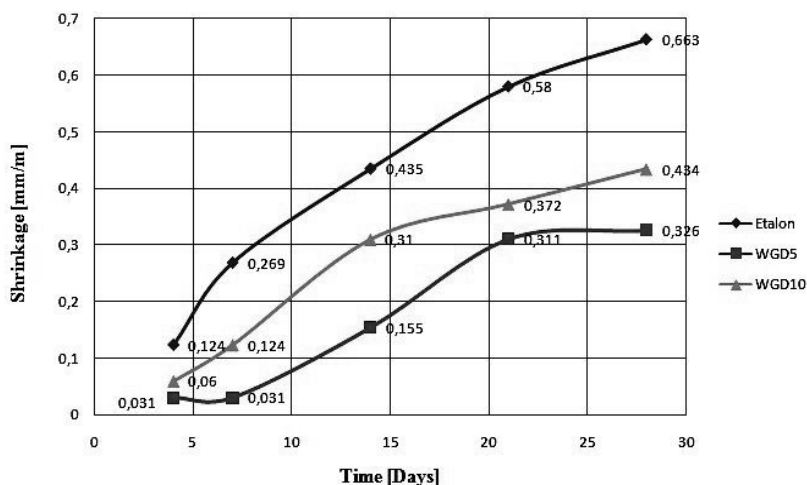


Figure 4. Shrinkage of mortar batches with various percentage of glass addition in the function of time

3. DISUSSION OF THE RESULTS

In order to justify the usage of glass as an addition to cement, it is necessary to prove the pozzolanic activity of glass. By testing the pozzolanic activity of glass, on the basis of the presented results in table 1, it can be seen that glass exhibits pozzolanic activity class 5, considering that the values of tensile flexural strength values are higher than 2 N/mm^2 , and that the compressive strength values are higher than 5 N/mm^2 .

The slump test on the flow table demonstrated that the addition of up to 10% does not affect the mortar consistency (table 3). The amount of entrained air is the same for all the mortar batches, around 8% (table 3). A small variation of entrained air variation in WGD5 batch cannot be considered relevant and in part it can be ascribed to the technical characteristics of the porosimeter device. Density of the hardened mortar in water saturated condition (table 3) is uniform for all three mortar batches and amounts to cca 2200 kg/m^3 , so there cannot be a mention of the effects of glass on this property of hardened mortar.

One of the most important tests in terms of durability is alkali – silicate reaction test. By measuring expansion of mortar specimens, it was determined that the batch with the 20% addition of glass has a lower change of density in relation to the reference mortar batch (without added glass) at all ages, despite the fact that glass contains a considerable amount of amorphous silicon dioxide. Also, the total value of volume variation is far below the limit value $+0,10 \text{ mm}$ defined by the ASTM C33/C33M-13 standard. By

reviewing literature, one can find explanation of such phenomenon in the research [7]. Free silicon in glass powder, which is an amorphous material, will soon be consumed during the pozzolanic reaction and it will react with other compounds to form a mineral phase. In this way, the diluted silicon dioxide will be included in the crystal grid of cement gel and it will not be available for the alkali – silicate reaction process, which should take place much later than the pozzolanic reaction [7].

Compressive strength of the mortar batches with added glass has a larger value in comparison with the reference mortar at all ages (figure 2). The change of strength in time is a logarithmic function with a high degree of correlation. At the age of 28 days, the compressive strength of the reference batch, WGD5 and WGD10 were: 57,35 N/mm², 63,28 N/mm² and 66,93 N/mm², respectively. At the age of 90 days the values of compressive strengths of experimental batches were: 68,34 N/mm², 71,79 N/mm² and 72,81 N/mm², respectively. The highest increase of the compressive strength in comparison with the reference batch was 7%.

A similar effect of the added glass can be observed in the flexural strength tests (figure 3). The increase of flexural strength of WGD10 batch in comparison to the reference batch was 11% at the age of 28 days, and 9% at the age of 90 days.

The highest reduction of compressive strength after 25 cycles of alternate freezing – thawing was measured in case of the reference batch - 7,2%. In case of WGD5 batch, this reduction was 5,6%, i.e. 4,9% in case of WGD10 batch (table 4).

The lowest values of mortar shrinkage in the 28 day period were measured in case of WGD5 mortar batch. Finally, shrinkage, measured at 28 days, of the mentioned mortar batch was as much as 50% lower than the reference mortar. (figure 4). WG10 batch had somewhat higher shrinkage than the batch WGD5, whereby the total shrinkage of this batch was 35% lower than the reference batch.

4. CONCLUSION

Based on the experimental results, the following conclusions regarding the effects of addition of glass on the fresh and hardened mortar properties can be drawn:

- Recycled glass is pozzolantically active, and on the basis of the tested mechanical properties, it can be concluded that it belongs to class 5.
- Addition of milled glass up to 10% does not affect the change of mortar consistency.
- The contents of entrained air is correlated with the increase of glass addition and amounts to around 8%.
- Addition of milled glass up to 10% does not cause the density of hardened mortar to change.
- The batch with 20% of added glass has a lower expansion than the reference batch when testing alkali – silicate reactivity at all ages of mortar. Also, the final value of volume change is far below the limit value of +0,10 mm.
- With the increase of percentage of added glass, the compressive and flexural strength of mortar are increased. For the highest share of added glass, at the age of 90 days, compressive strength of mortar is 7% higher, i.e. 9% in case of flexural strength.
- Mortar batches with added glass are resistant to frost action. In the case of WGD5 batch, reduction of strength after 25 cycles is 5,6%, i.e. 4,9% in case of WGD10 batch.

- Mortar shrinkage reduces with the increase of glass addition up to the share of 10%. Mortar WGD5 has 35% lower shrinkage than the reference mortar, while WGD10 mortar has as much as 50% lower shrinkage than the reference batch.
- In overall terms, addition of glass to mortars improves mortar properties concerning material properties and durability.

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5. REFERENCE

- [1] Aliabdo A., Elmoaty A., Aboshama A.: "Utilization of waste glass powder in the production of cement and concrete", *Construction and Building Materials*, 2016, Volume 131, Pages 739-799.
- [2] Bashar T., Ghassan N.: "Using lithium nitrate and pozzolanic glass powder in concrete as ASR suppressors", *Cement and Concrete Composites*, Volume 30, Issue 6, 2008, Pages 497-505.
- [3] Bignozci M.C., Saccani A., Barbieri L., Lancelloti I.: "Glass waste as supplementary cementing materials: The effect of glass chemical composition", *Cement and Concrete Composites*, 2015, Volume 55, Pages 45-52.
- [4] Grdić D., Ristić N., Topličić-Ćurčić G.: „Effects of Addition of Finely Milled Cathode Tube Glass Powder on Concrete Properties“, *Proceedings 13th International Scientific Conference INDIS 2015 – Planning, Design, Construction and Renewal in the Civil Engineering*, University of Novi Sad, Faculty of Technical Sciences, Department of Civil Engineering and Geodesy, Novi Sad, November 2015, Pages. 179 – 187.
- [5] Jugo – Impex E.E.R. d.o.o.: "Uputstvo za upotrebu automatskog separatora CRT-a visoke brzine - Loyalty Equipment – Making Co. Ltd., Sichuan, China".
- [6] Ljiljana Miličić: "Izveštaj o ispitivanju br. VHM-59/16 - Alkalno - silikatna reaktivnost prirodnog rečnog agregata za beton sa različitim tipovima cementa, metoda malter štapa", *Institut za ispitivanje materijala a.d. Beograd, Centralna laboratorija za ispitivanje materijala, Laboratorija za veziva, hemiju i maltere*, septembar 2016., Beograd.
- [7] Matos M. A., Sousa -Coutinho J.: "Durability of mortar using waste glass powder as cement replacement", *Construction and Building Materials*, 2012, Volume 36, Pages 205-215.
- [8] Yung W. H.: "The effect of the proportion of thin film transistor - liquid crystal display (TFT-LCD) optical waste glass as a partial substitution of cement in cement mortar", *Construction and Building Materials*, 2011, Volume 25, Pages 791-797.