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STUDY OF APPLICATION OF WASTE GLASS POWDER IN VIRGIN RUBBER BLENDS

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Abstract: One major waste stream emerging as a serious challenge worldwide is glass, despite its ideal properties for recycling and its unsuitability for land filling. Although glass can repeatedly be recycled with no loss of quality, large volumes of glass are ending up in the landfill. If the waste glass could be used as a raw material for some products, a problem could be solved such as concrete, mortars, polymers and so on. This would increase the price of waste glass and, therefore, its interest in recycling of it. One of the ways, that this problem can be solved, is to add waste glass powder (WG powder) to rubber mixture as replacement of silicate filler. The paper presents the possibility of using waste powdered glass as a replacement for silicate filler. In this study different percentages of white waste glass powder, with an average particle size smaller than 63 μm, was added to virgin rubber blends and their influence on the mechanical properties of the rubber mixtures was analyzed. The paper also provides recommendations on the amount of waste glass powder for usage in rubber product. This paper presents a study to replacement of Kaolinite ($Al_2Si_2O_5(OH)_4$) with waste glass powder which has SiO_4 as its base. This paper also shows the effect of WG powder on the mechanical properties of the rubber blends
Keywords: waste glass, rubber blends, mechanical

INTRODUCTION

In Serbia, 97% of waste is located at landfills, which is the least economical and environmentally-friendly option for waste management. Austria, for example, recycles that amount of waste, while only three percent ends up at the landfill. Waste glass falls into the category that is least recycled. The reason lies in the fact that the collection costs are very high per ton of collected material goes up to 50 euros per tonne, while the purchase price is barely 10 euros per tonne [1]. Because of the low price of purchase, secondary raw material collectors are not interested in collecting waste glass and recycling centers to buy them.

However, if the waste glass could be used as a raw material for some products, a problem could be solved such as concrete, mortars, polymers and so on [2-5]. This would increase the price of waste glass and, therefore, its interest in recycling of it. One of the ways, that this problem can be solved, is to add waste glass powder (WG powder) to rubber mixture as replacement of silicate filler. This paper presents a study to replacement of Kaolinite ($Al_2Si_2O_5(OH)_4$) with waste glass powder which has SiO_4 as its base. This paper also shows the effect of WG powder on the mechanical properties of the rubber blends.

EXPERIMENTAL RESERCH

— Rubber blends

In this paper, the use of white packaging glass is considered. For the purpose of this research, grinding of white glass bottles was done it the Pulversette-FRITISCH 2 mill with porcelain grinding set. After grinding, the shaking of this powder was obtained in a shaker with a set of sieves up to a particle size below 63 μm. After that, the chemical composition was determined using the Energy-Dispersive X-ray spectroscopy and shown in Table 1.

Table 1. Chemical composition of waste glass powder

Compound	Mass (%)
SiO_2	71,25
Al_2O_3	1,11
Fe_2O_3	0,77
CaO	8,60
MgO	3,35
SO_3	0,2
Na_2O	12,13
TiO_2	0,08

After grinding and screening, the waste glass powder (WG powder) was added to a rubber mixture based on SBR rubber. The mixture in which waste glass powder is added is used to make rubber floor coverings. For the purposes of this experiment, the entire amount of chalk was changed with waste glass powder. The composition of the resulting rubber blends is shown in Table 2.

The blends were mixed in a laboratory size two-roll mill at temperature around 80 °C and the mixing time of 15 min. The time and length of the curing process was determined by the Monsanto Rheometer 100S according to ASTM D 2240-93, with the vulcanization time of 15 min, and the vulcanization temperature of 150°C.

Table 2. Composition of rubberblends

Ingredients	Virgin rubber blend (g)	Rubber blend with waste glasse powder (g)	
		50% replacement	100% replacement
Hypren 1502	25500	25500	22500
Regenerated rubber	43500	43500	43500
ZnO	1900	1900	1900
Stearin	770	700	700
TMQ	275	275	275
SOLAR-3	1600	1600	1600
ROF-58	4300	4300	4300
Chalk	48500	48500	48500
Kaolinite	31000	15500	0
WG powder	0	15500	31000

— **Mechanical testing**

All measurements were performed before and after aging. The aging process was conducted in the aging oven at air atmosphere for the period of 7 days at a temperature of 85±1 °C.

Hardness measurements were performed in accordance with ISO 868-1 [6], using a manual durometer type Shore A. The measurements were carried out 5 times for each sample.

The testing of wear resistance was performed in accordance with ISO 4649 [7] using a Shopper cylindrical device with 5 measurements per sample.

The determination of tensile strength was carried out in accordance with ISO 37 [8] at the Instron testing machines, on dumbbell specimen type "2" of 2 mm in thickness, strained to break. The clamp separation speed was 100 mm/min.

Tear resistance was analyzed in accordance with ISO 34 [9]. Three angular type "A" tubes of 3 mm in thickness were strained to break in the measuring point, where the speed of clamp separation was constant at 500 mm/min.

Scanning electronic microscope and Energy-Dispersive X-ray spectroscopy was peroformed at JFC-1100E. (JEOL, Japan).

RESULTS AND DISCUSSION

The results of the measurement of the hardness of the samples before and after aging are shown in Figure 1. With the increase in the share of WG powder and the decrease in the proportion of Kaolinite, the hardness is increased, but this increase is not significant. A significant change in hardness occurs when testing aging, which could be expected as the result future vulcanisation.

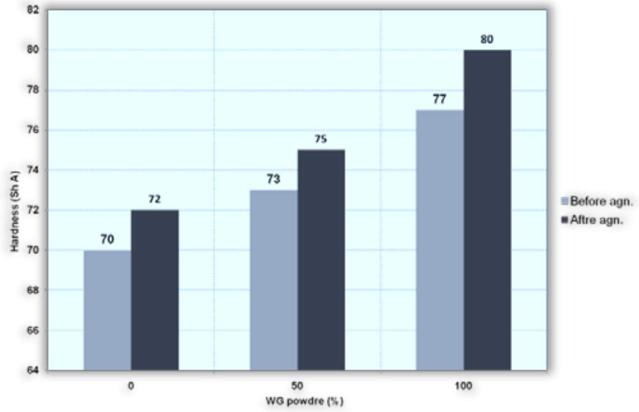

Figure 1. Results of hardness testing

At products such as rubber floor coverings tensile properties (tensile strenght and elocation at brake) do not have high values, ie, the change of this property does not significantly affect at the quality of the product. The results of measuring this property before and after aging are shown in Figure 2.

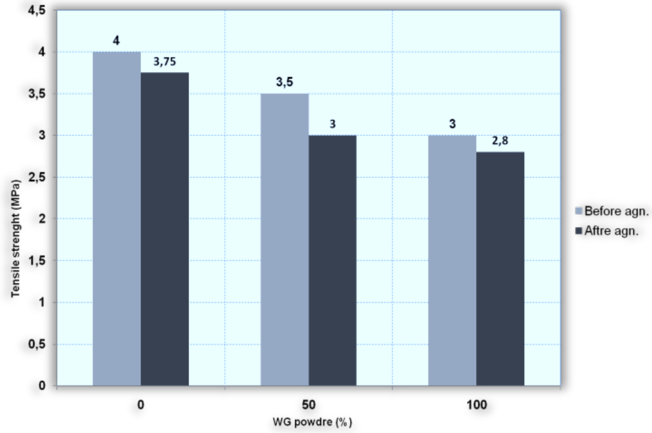

Figure 2. Results of tensile strength of rubber blends

One of the most important properties of the product such as floor coverings is tear strength. It represents a measure of the resistance of the material towards further spread of the crack. Figure 3 shows the results of measuring this property before and after aging.

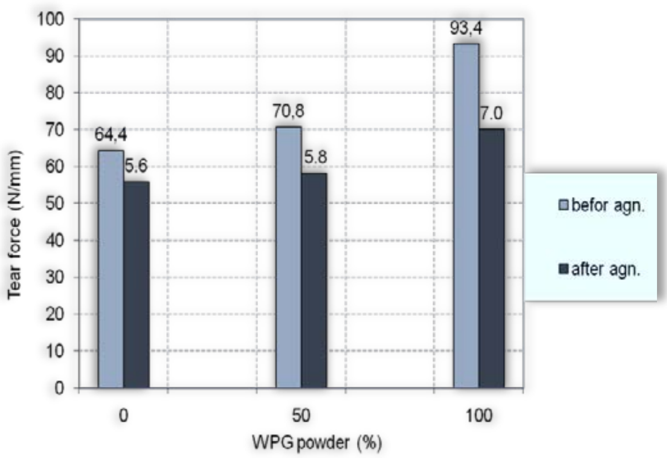

Figure 3. Results of tear resistance testing

Test results for wear resistance are shown in Figure 4. It can be concluded, from the diagram, that WG powder particles have higher effect on this property either before or after aging.

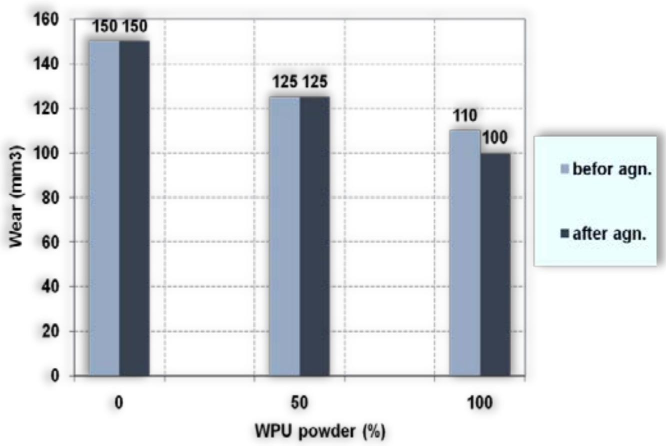

Figure 4. Results of wear resistance test

The appearance and shape of the particles waste glass powder is shown in Figure 5.

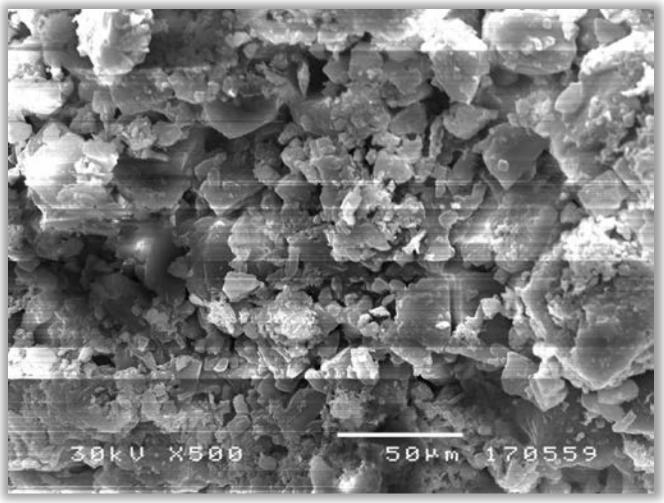

Figure 5. Waste glasse powder

Silicate fillers are obtained by precipitation and have small primary particles. These fillers belong to the group of semi-active fillers, which in the case of increased dosage at the rubber increases its elastics properties.

Sodium-aluminum silicate, potassium-aluminum silicate, potassium-aluminum silicate, etc. are used as semi-active fillers. As it can be seen from the results of the examination the impact on hardness and tensile is insignificant.

While the impact on tear strenght and wear resistance is significant. This can be assumed that the increased share of SiO_4 has a positive effect on the properties, which has a more pronounced effect of reinforcement. Also, the positive properties of WG powder is transparency, so products can easily be painted.

As SiO4 is on the seventh place of the Mohs' Scale of hardness and has a pronounced wear resistance, excessive use can lead to accelerated wear and tear of machines and tools so research should be carried out in that direction.

CONCLUSION

Solving of the waste glass problem is a great challenge for a modern society. Because the low purchase price negatively affects on recycling and demand for waste glass as raw material. One way of overcoming the problem is that waste glass is used as a raw material for some products (cements, mortars, polymers, etc.). This paper presents the possibility of usage of WG powder as a substitute for Kaolinite. In doing so, improvements are made in products where the tear strength and wear resistance are the dominant properties such as floor coverings, lower footwear, and so on.

The negative side of the application is reflected in high resilience resistance, as the working machines are damaged. So further research should be carried out in that direction too.

Note:

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References

[1] https://www.tehnologijahrane.com/iz-novina/koje-su-prepreke-u-razvoju-reciklaze-ambalaznog-stakla
[2] Lu, J.X., Poon, C.S., (2018.) Use of waste glass in alkali activated cement mortar. Constr. Build. Mater. 160, 399-407
[3] Lu, J.X., Zhan, B.J., Duan, Z.H., Poon, C.S., (2017). Improving thc pcrformance of architec- tural mortar containing 100% recycled glass aggregates by using SCMs. Constr. Build. Mater. 153,975-985.
[4] Balkan e-Waste Management Advocacy Network, Upravljanje e-otpadom u Srbiji, 2010.
[5] Widmera R., Oswald-Krapf H., Sinha-Khetriwal D., Schnellmann M., Bonia H. (2005). Global perspectives on e-waste, Environmental Impact Assessment, vol. 25, p. 436– 458.
[6] ISO 7619-1:2010. Rubber, vulcanized or thermoplastic -- Determination of indentation hardness -- Part 1: Durometer method (Shore hardness).

[7] ISO 4649:2010. Rubber, vulcanized or thermoplastic -- Determination of abrasion resistance using a rotating cylindrical drum device.
[8] ISO 37:2011. Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties.
[9] ISO 34-1:2015. Rubber, vulcanized or thermoplastic -- Determination of tear strength -- Part 1: Trouser, angle and crescent test pieces.

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