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# PROPERTIES OF CONCRETE WITH CRUMB RUBBER IN RELATION TO ORDINARY AND AERATED CONCRETE

***Abstract***

Waste tires have long been a challenge for waste disposal. In an effort to mitigate the impact of solid waste on the environment and recycle it as much as possible, research has been conducted into the possibility of using this waste in concrete mixes. However, the use of these waste materials in concrete is still not popular due to the lack of knowledge of the properties that can be obtained with this material. Hence, the aim is to use waste material in the production of concrete, and that concrete mixes with this material have satisfactory performance. The paper presents the results of research on concrete in which volume replacement of fine aggregate with crumb rubber was performed in the amount of 5%, and this concrete was compared with the control concrete mix and aerated concrete. All concrete are made with a water-cement factor of 0.45. The performance of fresh concrete was monitored for 10, 30 and 60 min. In the case of concrete with the addition of crumb rubber, after 60 min, higher values of air content were obtained, and lower values of volume mass of fresh concrete compared to the initial measurements. The obtained test results of hardened concrete indicate that concrete with crumb rubber has a lower compressive strength compared to the control concrete mix, while compared to aerated concrete, they obtain approximate compressive strength values.

***Keywords***

Rubber Concrete; Crumb rubber; Slump test; Air content; Compressive strength.

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# 1. INTRODUCTION

With the rapid growth of the world economy and the surge in population as well as the increase in urbanization, which leads to a corresponding growth in the demand for many infrastructures such as housing and transportation. As everyone knows, the natural aggregates in concrete mainly originate from crumb gravel and sand [1,2]. However, the lack of virgin aggregates and the ongoing exploitation of natural resources by people lead to a serious ecological threat [3]. Hence, there is an urgent need for new alternative materials to meet the requirement of concrete to be more sustainable in the construction industry [4]. In this context, different forms of solid wastes such as waste plastics, tyre rubber waste, waste glass, steel slag, and steel fibers are applied as materials investigated in the field of civil engineering [5].

According to the European Tire and Rubber Manufacturers Association (ETRMA), world tire production was 5.1 million tons in 2018 [6]. From an ecological perspective, the use of (CR) in concrete is beneficial, as it leads to the conservation of mineral resources, i.e. aggregates and thus minimizes the need for new landfills needed to dispose of waste tires, thus solving related environmental problems [7].

However, a decrease in the compressive strength of CRC in comparison with the normal concrete is the most important shortcoming reported for this material. This drawback can, however, be overcome by increasing the quantity of cement, decreasing the water to cement ratio and using suitable admixture [8]. Wang et al. [9] reported that the compressive strength of polymer concrete overlays increased due to 5% replacement of natural aggregate with CR. They indicated that CR particles enhanced the solidification process of epoxy resin leading to a decrease in the rate of crack propagation.

Bisht and Ramana [10] recorded the observation for the use of four different percentages of 4%, 4.5%, 5% and 5.5% crumb rubber as fine aggregate. From the experiments, crumb rubber allows the blended concrete to obtain a maximum decrease of approximately 17.8% in compressive strength and a 16.5% reduction in flexural strength, whereas it has the ability to improve abrasion resistance and water absorption. Likewise, Steyn et al. [11] also drew a similar results by replacing fine aggregate with 15% and 30% of crumb tyre rubber on concrete (by volume). Additionally, Ganjian et al. [12] investigated the replacement of aggregates and cement with waste tyre rubber at different proportions from 5% to 10%. They indicated that concrete prepared by replacing aggregates with powdered rubber was higher in terms of compressive and tensile strengths than that of concrete prepared by replacing cement with chipped rubber, while the opposite was true for water absorption and permeability. Moreover, Eldin and Senouci [13] presented that a worsening of mechanical property with a compressive strength reduction by up to 16.5% when fine aggregates were replaced, whereas it was in the level of 85% when 100% coarse aggregates were substituted with rubber chips. Related literatures have reported a subsequent decrease in compressive strengths of rubber concrete with increasing rubber dosages [12-14].

The paper presents the possibility of using crumb rubber in concrete as a volumetric replacement of fine aggregate with 5% of crumb rubber. The design of three concrete mixtures was carried out, with each of them tests of fresh concrete were carried out: Slump consistency, bulk density and air content. The change in the properties of fresh concrete was monitored over time, after 10, 30 and 60 minutes from the moment of adding water to the concrete mix. Tests of hardened concrete, bulk density and compressive strength at the ages of 3, 7, 28 days were performed.

A comparison was made of the obtained results of concrete with 5% volumetric replacement of the fine fraction with crumb rubber in relation to the reference concrete and aerated concrete which was made with a water-cement ratio of w/c=0.45.

# 2. EXPERIMENTAL RESEARCH

## 2.1. MATERIALS USED IN THE EXPERIMENT

During the design of the concrete mix, volume replacement of fine aggregate in the amount of 5% with crumb rubber, water-cement ratio w/c=0.45 and cement amount of 360 kg/m$^3$ was performed.

The component materials for making CRC are cement, fine and coarse aggregate in fractions 0/4, 4/8 and 8/16 mm, crumb rubber, superplasticizer and water.

Ordinary Portland cement clinker, strength class 42.5 R, produced by "Lafarge BFC" was used. The specific mass of cement is 3110 kg/m$^3$, the specific surface is 4320 cm$^2$/g. The chemical composition of cement is shown in Figure 1.

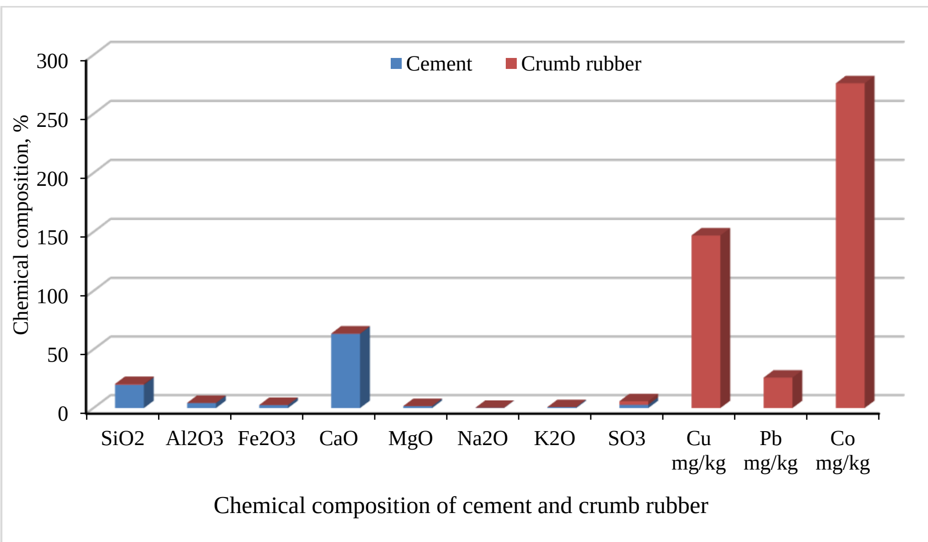


*Figure 1. Chemical composition of cement and crumb rubber.*

Natural, fractionated stone aggregate, of limestone origin, fractions 0/4, 4/8, 8/16 mm, specific mass 2650 kg/m$^3$, and fineness modulus of 3.06 was used. The granulometric composition of the aggregates is shown in Figure 2.

Finely crumbled rubber (CR), which is obtained by crushing used pneumatic tires, was obtained from the producer of recycled rubber waste "ECO-RECYCLING" doo, the specific mass of the rubber is 1170 kg/m$^3$, the granulometric and chemical composition are shown in Figure 2 and Figure 1.

Superplasticizer based on polycarboxylate "Sika Viscocrete 4077x", manufactured by "Sika Serbia", specific mass 1065 kg/m$^3$ and tap water were used in this research.

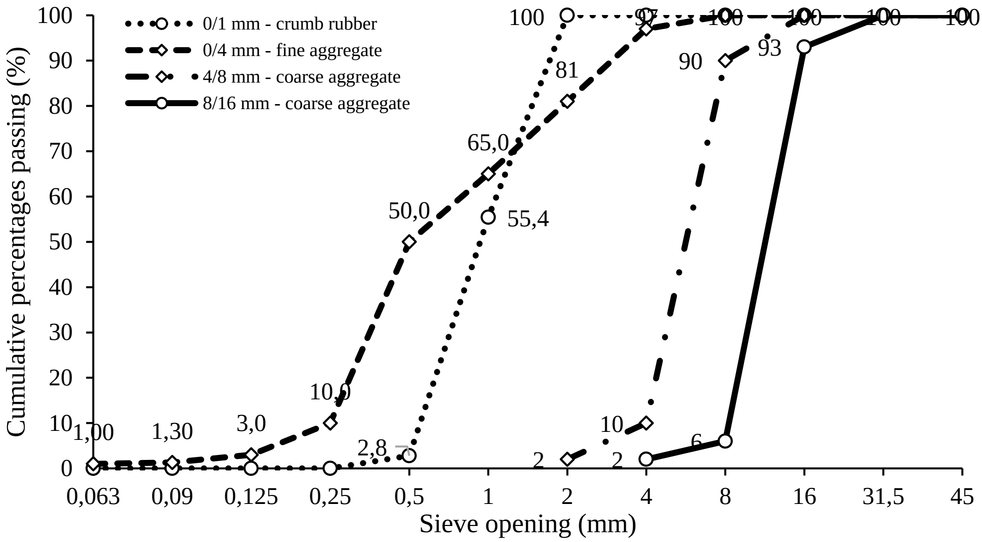


*Figure 2. Particle size composition of crumb rubbers (CR) and natural aggregate.*

## 2.2. CONCRETE MIXTURE

For the purposes of this experiment, three types of concrete were designed: Ordinary Concrete, Aerated Concrete and Concrete with volume replacement of fine aggregate with crumb Rubber in the amount of 5%.

All three types of concrete are made with one water-cement ratios: 0.45.

Engineered concrete mixes are marked with the following label:

1. P3 - Ordinary Concrete,
2. P7 – Concrete with air-entraining admixture,
3. P15 - Concretes with volumetric replacement of fine aggregate with 5% crumb rubber.

The design of the lines of the granulometric composition of the aggregate mixture was used out with natural, separated river aggregate from the Drina river, fractions 0/4, 4/8, 8/16 mm and with crumb rubber, fraction 0/1 mm, which was obtained by the recycling process of car tires.

In the case of ordinary concrete and aerated concrete mixes (Mix P3 and Mix P7), the line of granulometric composition of the aggregate mixture with the following percentage share of aggregates was designed:

Fraction 0/4 mm – 45%, (Sand),

Fraction 4/8 mm – 15%, (Gravel),

Fraction 8/16 mm – 40% (Gravel).

For concrete mixes (Mix P15) with volume replacement of fine aggregate with 5% crumb rubber (crumb rubber: river sand = 5:95 by volume), was designed is line of granulometric composition of the mix aggregate with the following percentages participation of aggregates:

Fraction 0/1 mm – 0.96%, (Crumb Rubber), Fraction 0/4 mm – 44.04%, (Sand),

Fraction 4/8 mm – 15%, (Gravel),

Fraction 8/16 mm – 40%. (Gravel).

A total of three concrete mixtures were designed, on which, after preparation in a laboratory concrete mixer, the properties of fresh concrete were tested, after which cube-shaped samples with edge dimensions of 150 mm were made and curing until the moment of testing, on which the physical and mechanical properties of hardened concrete were tested.

Concrete mixing was performed in a laboratory planetary mixer with a volume of 0.150 $m^3$. Order of adding components into mixer:

Mixtures P3- aggregate, cement, water, superplasticizer,

Mixtures P7 - aggregate, cement, water, superplasticizer and air-entraining admixture,

Mixtures P15 - aggregate, crumb rubbers –5%, cement, water, superplasticizer.

Mixing time for all concrete Mixtures was 90 seconds.

The quantities of component materials of concrete mixes are shown in Figure 3.

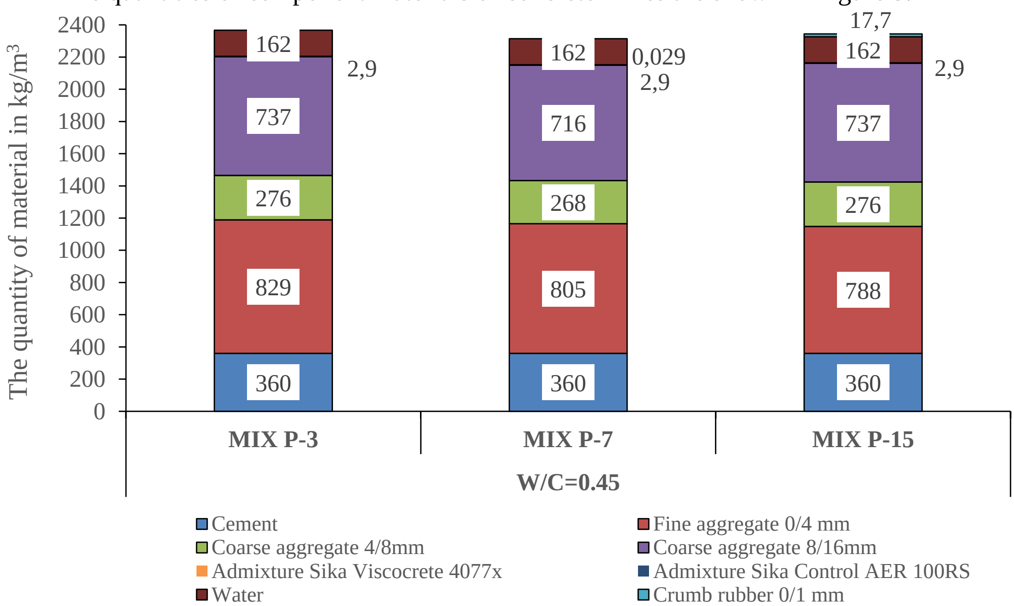


*Figure 3. Compositions of concretes (values are given in kg/m³), w/c=0.45.*

## 3. RESULTS AND DISCUSSION

Concrete mixes are designed so that after 5 minutes from the moment of adding water to the concrete mix, consistency class S4 (160-240 mm) is obtained by the settling method. The amount of cement for all concrete mixes is 360 kg/$m^3$, and the amount of chemical admixture is varied in order to obtain a consistency of 160-210 mm by the slump test method.

The testing of concrete properties in fresh state was performed: consistency by the slump method SRPS EN 12350-2, air content SRPS EN 12350-8 and bulk density SRPS EN 12350-6 (10, 30 and 60 minutes after the addition of water).

Besides previously mentioned cement (CEM I 42.5R), natural separated aggregate (0/4, 4/8, and 8/16mm fractions), recycled rubber waste, superplasticizer and air entraining admixture was employed as admixture, as well as tap water. Fresh concrete was designed to meet the minimum of required properties of transported concrete, according to EN 206 standard.
The test results for concrete in the fresh state are shown in Figure 4 and 5.

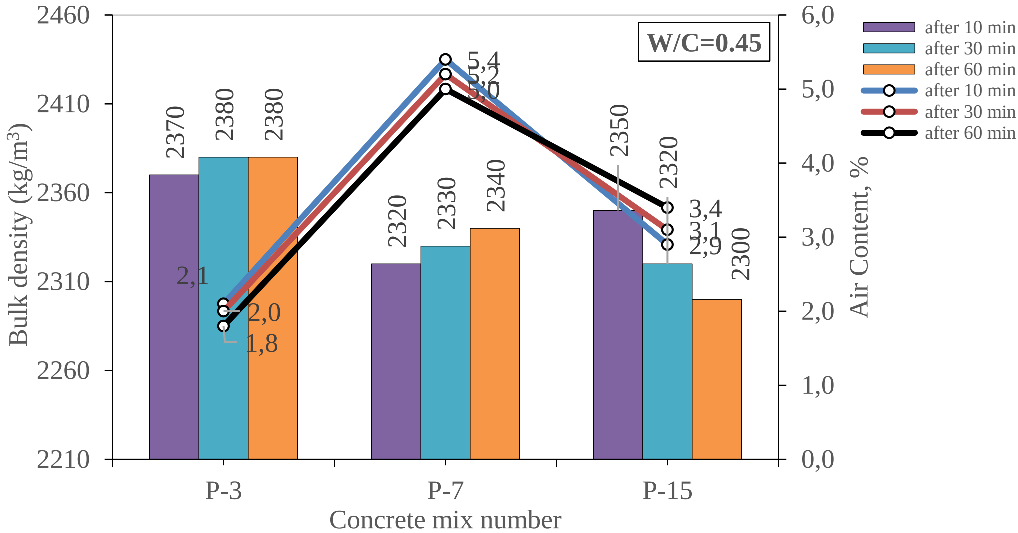


*Figure 4. Test results of fresh concrete bulk density and air content, w/c=0.45.*

The bulk density of fresh concrete gives us a picture of the compactness of concrete mixes, so that after 10 minutes from the addition of water had values of 2370, 2320 and 2350 for P-3, P-7 and P-15. After 30 minutes those values were 2380, 2330 and 2320, and after 60 minutes 2380, 2340 and 2300 for P-3, P-7 and P-15.

The air content in concrete gives us a picture of the porosity of the concrete mix. So that in the P-3 concrete mix over time, approximately the same values of 1.8-2.1% were obtained, for the P-7 concrete mix: 5.0-5.4%, and for the P-15: 2.9 to 3.4%.

The workability of concretes mixes was checked by the method of consistency by slump test. The consistency values obtained by the slump test method measured after 30 and 60 minutes are reduced by: 17% and 39% - P3; 19% and 43% - P7; 22% and 44% - P15, in relation to the consistency values obtained after 10 minutes.

After checking the performance of the concrete in its fresh state, the concrete was placed in cube-shaped moulds with edge dimensions of 150 mm. The samples were treated for 24 hours in air at a temperature of 20ºC, and then in water at a temperature of 20ºC in accordance with EN 12390-2, up to the moment of the compressive strength test.

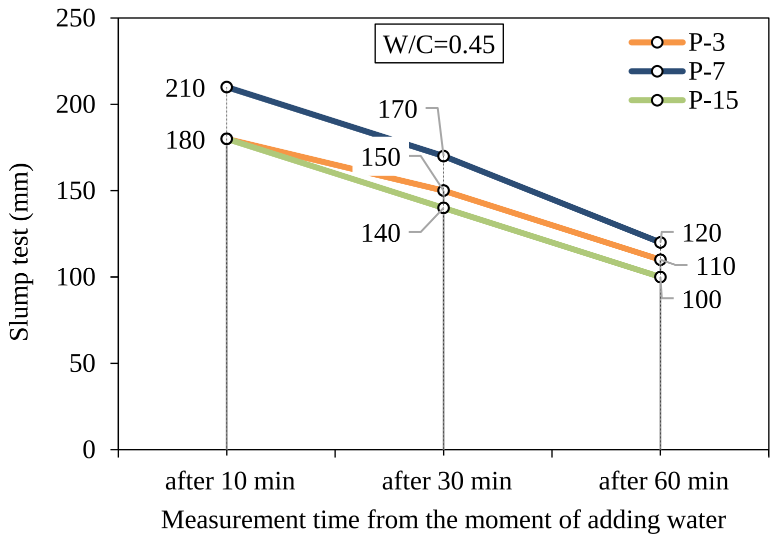


*Figure 5. Test results of fresh concrete slump test, w/c=0.45.*

The compressive strength test was performed at 3, 7 and 28 days of age. A digital hydraulic press of 2000 kN with automatic force control over time according to EN 12390-3 was used for testing.

The results of the compressive strength test are shown in Figure 6.

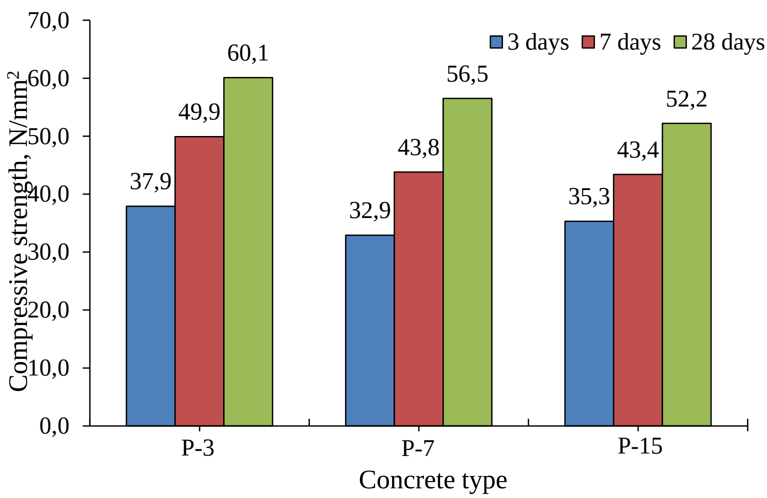


*Figure 6. Test results of hardened concrete, compressive strength after 3, 7 and 28 days.*

## 4. CONCLUSIONS

Crumb rubber as a waste material was used as a substitute for the small aggregate fraction in a volume amount of 5%, a concrete mix was designed that was compared with a concrete mix of ordinary and concrete with air-entraining admixtures, and based on the obtained test values, the following conclusions were reached:

- The designed volume value of concrete with crumb rubber is lower compared to ordinary concrete, and higher compared to concrete with air-entraining admixtures;
- The obtained values of air content in fresh concrete with crumbs rubber have a higher value compared to ordinary concrete after 10, 30 and 60 minutes by 38%, 55% and 89% respectively;
- All concretes after 10 min from the moment of adding water to the concrete mix fall into consistency class S4 (160-210mm) by the slump test method, after 30 min P-7 falls into consistency class S4, while concrete mixes marked P-3 and P-15 fall into in consistency class S3 (100-150 mm), and after 60 min all concrete mixes fall into consistency class S3 (100-150 mm);
- Compared to ordinary concrete, the compressive strength of the concrete mixture with crumb rubber and concrete with air-entraining admixtures at the age of 3, 7 and 28 days achieved a lower compressive strength value by 7%, 15% and 15% (for concrete with crumb rubber) and 15%, 14% and 6% (for concrete with air-entraining admixtures).

Based on the obtained values in the fresh and hardened state, we can conclude that with a volume replacement of 5% of fine aggregate with crumb rubber, satisfactory concrete properties can be achieved in fresh and hardened concrete. Further research of concrete mixtures with volumetric replacement of fine aggregate with crumb rubber, aims to determine the durability of such concrete mixtures that will be exposed to various influences.

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