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Freezing-thawing and impact resistance of concretes containing waste crumb rubbers

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HIGHLIGHTS

- Concrete was produced by using fine waste crumb rubber.
- The freezing-thawing and impact resistance of these concretes have been studied.
- The performance of grained crump rubber was better in both freezing-thawing and impact.
- It is suitable for use in non-load-bearing exterior concrete elements.

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ABSTRACT

Millions of tires are discarded every year. Disposal or recycling-reusing of waste tire rubber has become a big environmental problem in the world. In this study, it was aimed to determine the freezing-thawing, impact resistance, compressive strength and capillary water absorption rate, when the granulated waste rubber parts are used in the non-load-bearing concrete. Granulated crumb rubbers obtained from waste tires were used at two different grain diameters of 1 and 2 mm as the maximum value. A total of 9 different series were prepared, one of them being the control group and the others being changed with the aggregate in the ratios of 0.5%, 1%, 2% and 4%. In all of the blends, the water/cement ratio was kept constant at 0.50. A drop-weight type impact test was applied to the specimens produced with and without waste rubbers. The impact energy required for the first crack and final dent was determined with the free-falling steel ball at a certain height. Freezing thawing experiments were carried out on the samples with 3% NaCl solution ponded on the surface, and weight losses were determined. As the result, significant improvements were observed in the freezing-thawing and impact resistances of waste tire added samples. Weight loss of specimens because of the freezing-thawing was decreased about 90% and impact resistance was increased different rate depending using rate.

1. Introduction

Parallel to the increase in the number of motor vehicles in the world, environmental pollution caused by the used tires has also been increasing. Vehicle tires are made of natural and synthetic rubbers consisting of polymers that are highly durable and that have strong molecular structure. For this reason, after completing their useful life, they turn into waste tires that need a century to be self-destructed in the environment [1,2]. Since the increase in the number of used vehicle tires and their storage in inappropriate conditions lead to adverse environmental impacts, the studies, which have been conducted in this direction, continue to be carried out. Today, the disposal of waste tires is usually in the form of unearthing them, accumulating in piles, using in rubber coating, using as fuel, and recently, reclamation after mechanically granulating in various sectors.

The inclusion of waste rubber in concrete has significant effects on the physical, thermal and mechanical properties of the concrete, thus, some researchers [3–8] have used waste tire particles in the concrete mix and have studied the effects of these particles on the characteristics of the concrete. According to the literature, it has been found that the use of rubber reduces the compressive strength of the concrete to a certain extent [9]. It has been observed that there is a further decrease in the compressive strength due to the use of coarse aggregate and waste tire particles. When replaced with coarse aggregate, the loss of compressive

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strength is around 50%, while in the case of substitution with fine aggregate, it is in the level of 25%. To reduce this adverse effect on compressive strength, certain investigators [10–12] increased the adherence and minimized the decrease in compressive strength by treating the waste rubber with NaOH solution, before being involved in the mix. In previous studies, it was observed that concrete samples containing tire particles had high toughness. Concrete elements, in some cases, are required to have low unit weights and high toughness and impact resistance values. It has been noted by various researchers that increasing the toughness of the concrete against the reduction of the compressive strength, which is one of the concrete's mechanical properties, may provide a significant advantage to the elements subjected to vibration and impact [13–15].

One of the biggest problems faced in terms of the useful life of concretes produced for outdoor use is the effect of repeated freezing-thawing. Especially when there is terrestrial climate, the increase in the number of freezing-thawing cycles leads to a shortening of the useful life of concrete-produced elements such as curbs, paving stones, roads, bridges and viaducts. If the temperature falls below zero, the water present in the cavities in the concrete interior freezes and exhibits a volume increase of about 8–9%. This event causes the tensile stresses to occur in the concrete. Due to the fact that the concrete is a rigid building material and its tensile strength is low, there is cracking due to the internal stresses which occur as a result of freezing-thawing. In places where freezing-thawing is frequent, frost-induced ice pressure can be reduced by adding air-entraining additives and creating regular spherical voids. However, as this process increases the cost of the mixture, it is generally preferred only for the important building elements. Although they are produced in small pieces, especially the concrete paving stones are one of the most degraded concrete elements. The fracture network starting in the material after repeated freezing-thawing is shown in Fig. 1a which were taken from Bishkek in Kyrgyzstan. These cracks progress over time and cause further cracking, resulting in the complete disintegration of the element as seen in Fig. 1b. Another important problem faced by concrete paving stone elements is the impact. Replacement and renovation of the damaged parts is a more labor-intensive and costly task than the first installation. In this respect, the life of the material is important in terms of operating costs. Although concrete is a widely used construction material, freezing-thawing resistance and impact resistance are often not met by conventional designs. Additive materials that give concrete these properties increase the production cost. In certain concrete elements, such as tile paving stones, which remain in the external environment and do not have carrier properties, resistance to extreme conditions becomes more important than compressive strength. The purpose of this study is to use the tires, which are in idle condition, as an additive material to the concrete by partially replacing them with sand after granulating them, in concrete paving stone production. Thus, it is expected that both environmental benefits will be obtained by evaluating an inert material and the freezing-thawing resistance and the toughness (resistance to impact) of the concrete will be increased.

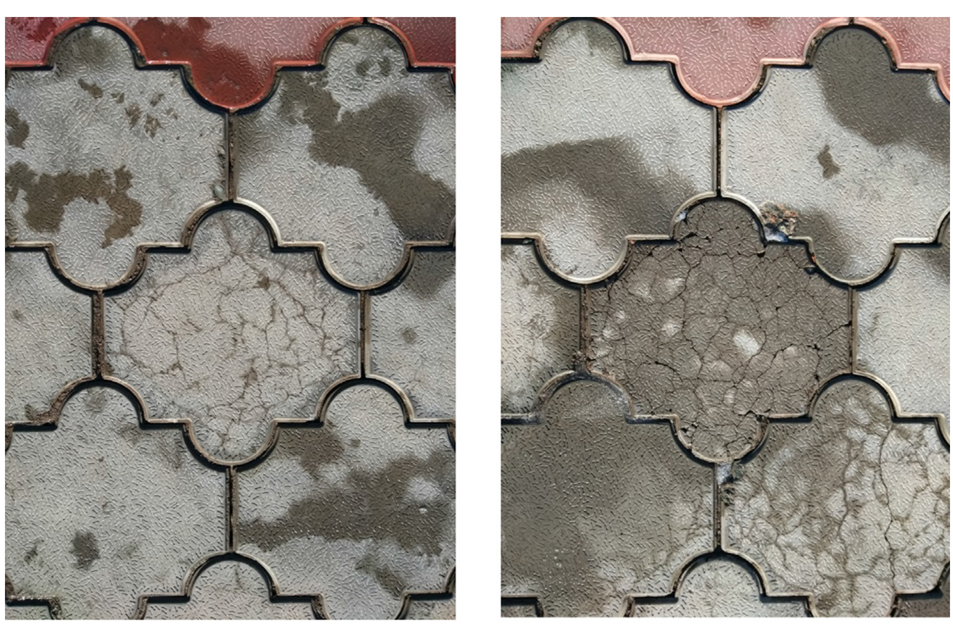
2. Material and method

2.1. Materials used

In experimental studies, CEM II cement was used. The physical properties of the aggregates used for paving stone production are given in Table 1. In the study, waste tires collected from different locations to be used for replacing the sand were manually dismantled by hand tools (Fig. 2). The grain distribution after mixing with the aggregate of the granulated waste tire produced during this laminating is given in Table 2.

2.2. Preparing the sample

Freezing-thawing experiments were carried out on the samples in the form of cylinders, with a diameter of 100 mm and a thickness of 35 mm. Specimens with 150 mm diameter and 55 mm thickness were tested with capillary water absorption, impact strength and unit volume weight. Finally, for the compressive strength test, 150 mm sized cube samples were produced. In the study, one control serie with 0.50 water-cement ratio was prepared. In the way that all the parameters will remain the same, granulated waste rubber was replaced by sand and gravel in the rates of 0.5%, 1%, 2% and 4%. A total of 9 different concrete series were produced, one of which was the control serie, with granulated waste tires with a maximum grain diameter of 1 and 2 mm, and was stored in lime-saturated water for 28 days. The mixing ratios of the produced concrete series are given in Table 3.



(a) (b)

Fig. 1. The start of a crack network with freezing-thawing effect (a), Degradation after repeated freezing-thawing (b).