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Research Article

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Determination of the Effect of Brick Ballast on Strength Properties of Concrete

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Abstract The limited availability of natural resources on the earth, rapid population growth and industrialization, reveal the environmental pollution and unconscious usage of natural resources problems. In order to solve these problems, recycle of industrial wastes is a one the most important methods. Many industrial wastes such as brick ballast can be used as binders and aggregates in concrete production. For this purpose, the different concrete mixtures which contained 0%, 10%, 20%, 30%, 40% and 50% of brick ballast aggregates replaced by coarse aggregate were produced. After 28 days, the concrete samples were removed from the water tank and the compressive strength, splitting tensile strength, water absorption rate, freezing-thawing resistance, unit weight, specific gravity and wearing tests of concrete samples were performed. As a result of the study, it was observed that there were not great differences between normal concrete and brick ballast aggregate concrete.

Keywords brick ballast, concrete, waste management, concrete production, concrete strength

Introduction

Concrete is an artificial structure material, which is produced by the mixing of aggregate, cement, water, some mineral and chemical additives, takes easily shape of mold because of the fact that concrete is fluid phase in the initial stage and reaches specific bearing capacity with high durability after hardening [1, 2].

The changes in the world with the development of technology reveal some problems. The main problems are industrial waste and disposal of these wastes. The one of the most effective solution method for this environmental problem is the re-evaluation of waste materials.

Industrial wastes, which are used both as binders and as aggregate in concrete technology, are pretty much. These are granulated blast furnace slag, fly ash, silica fume, limestone filler, plastic wastes, waste water treatment sludge ash, waste marble dust, bottom ash, waste glass fractures, waste concrete, waste gas concrete fractures, waste brick and tile pieces [3].

Brick and tile wastes can be used by grinding for flooring elements, tennis courts, park walkways, bicycle paths and garden arrangements because they do not contain any chemicals harmful to human health and environment. Also, the defective production occurring in the factories, the casualties during the delivery process and the amount of brick and tile fractures in the rubble of the collapsed buildings can not to be underestimated.

Brick and tile industry in Turkey is an important sector with a large number of production units, 7.5 billion pieces of bricks and 700 million pieces of tiles are produced annually. Approximately 7% of them become waste due to their defects and breakage [4]. These wastes, which are rapidly growing in stock areas, can be used as an alternative material for concrete in the world. In this way, the energy and unit weight can be reduced during the preparation of the mixture [5, 6].

It was found that the concrete produced by using bricks as coarse aggregate in concrete had 7% lower compressive strength compared to the concrete produced with normal aggregate, but a decrease of 9.5% in unit weights was observed [7].

In the studies, it was found that the brick ballast aggregate concrete had lower strengths at early ages, but the increase in strength was found to be higher at later ages. The pozzolanic effect of brick fracture aggregates is shown as the reason of the improvement in strength [8].

When the concrete is considered as a whole, it is generally known that the thermal expansions of the aggregate and cement paste are different from each other. So, temperature changes and high temperatures in the concrete cause different volume changes, cracking and resistance of concrete components. The bricks or tile aggregates are thermally stable and have a low thermal conductivity and prevent premature heating in reinforced concrete structures. They perform well because they retain their structural integrity when used in concrete under high temperature effect [5, 9-13].

The aim of this study is to investigate the effect of brick ballast, which is occurred due to defective production in the factories located around Tekirdag, stored as waste and cause important environmental problems on mechanical and physical properties.

Material and Methods

The research material consisted of brick which are brick ballast, cement, sand, stone ballast and concrete samples which are produced by the mixture of them. Brick ballast were obtained from brick factories located around Tekirdag. After the brick wastes were broken, they were sieved by 4 mm standard mesh and divided into two sections as fine and coarse aggregate. CEM I 42,5 R Portland cement was used as a binder in concrete production. The number of 1- 2 stone ballast and sand were used as aggregates. The largest grainsize was 16 mm.

The different concrete mixtures which contained 0%, 10%, 20%, 30%, 40% and 50% of brick ballast aggregates replaced by coarse aggregate were produced and it was aimed to produce C20 class concrete with 300 dose. For this purpose, granulometry and specific gravity tests of aggregates were implemented.

According to [14], fresh concrete slump test was performed and the slump value was determined to be 8 cm. There were differences in the ratio of w/c (water/cement) due to keeping constant of slump value and cement amount in the mixture.

After the mixture calculations were made, the materials were weighed in the laboratory conditions on the sensitive electronic scale and put into the concrete mixer machine. All materials were mixed and a homogeneous mixture was formed before the mixing water was placed in the machine reservoir. Spilled fresh concrete was molded according to the principles stated in [15], it was removed from the molds after 24 hours and the temperature was kept in the curing pool at a temperature of 20 ± 2 ° C until the day of the experiment.

After 28 days, the compressive strength, splitting tensile strength, water absorption rate, freezing-thawing resistance, unit weight and specific gravity, wearing tests of prepared samples were performed with the direction of method stated in [16-20].

Results and Discussion

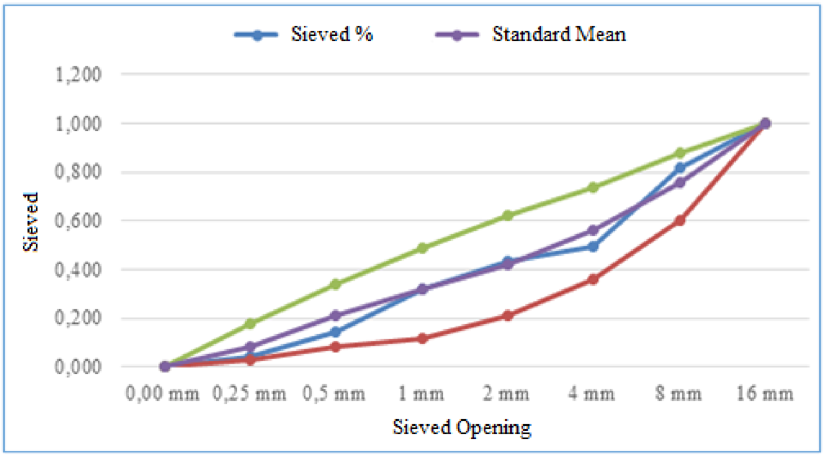

Figure 1: Sieve analysis of natural aggregate and brick ballast mixture

Table 1: Physical and mechanical properties of hardened light concrete

Ratio of Brick Ballast (BB)	Compressive Strength (kg/cm^2)	Unit Weight (kg/m^3)	Water Absorption Rate (%)	Splitting Tensile Strength (kg/cm^2)	Freezing-Thawing Resistance*(kg/cm^2)
BB00	251	2199	5.54	39	244
BB10	233	2099	7.99	31	225
BB20	184	2007	10.90	27	180
BB30	174	1975	12.16	24	153
BB40	137	1940	13.21	21	105
BB50	104	1828	13.97	17	72

*Compressive strength were made after freezing and thawing resistance.

Aggregate granulometry, which affects the composites of the concrete, the amount of mixing water, strength, durability and workability of concrete should be find out before the mixture calculations [21]. The granulometry curve of the mixture of natural aggregates and bricks used in the study was given in Figure 1. As it has been seen from the Figure 1, the values of the mixture remained within the limits given by [22-24].

The results obtained from pressure and splitting tensile strength, unit weight, water absorption, freezing and thawing resistance tests of 28 days concrete samples were given in Table 1.

The pressure and tensile strength results of the samples were given in Figure 2. It was determined that the compressive strength values decreased as brick fracture additive ratio increased and these values ranged between 104-251 kg/cm^2 values. The decreases in compressive strengths were determined as 7%, 27%, 31%, 45% and 59%, respectively, depending on the amount of BB. Khaloo (1994) stated that there was a 7 percent decrease in compressive strength when BB was used as coarse aggregate in Portland cement concrete.

Pressure and splitting tensile strength in concrete are closely related each other. Splitting tensile strength of concrete is between 9% or 10% of the compressive strength under general condition, but this ratio varies between 7% and 17% depending on the quality and age of the concrete, as it has been seen from Table 1 and Figure 2, the splitting tensile strength values of the concrete samples ranged between 17-29kg/cm^2. The proportion values between compressive strength and splitting tensile strength varied between 13% and 16%.

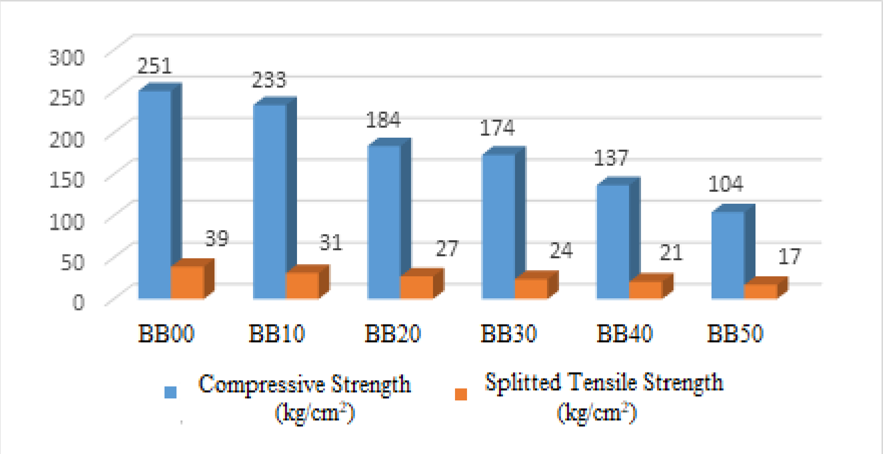

Figure 2: The obtained strength values depending on the ratio of BB

As it was seen in Table 1, the unit weights of the produced concrete samples decreased from 2199 kg/m^3 to 1828 kg/m^3 in inverse proportion to the amount of BB. The fact that the unit weight of the bricks was lower compared to the normal aggregate caused the same situation to be observed in the concrete samples. As it was shown in Figure 3, the compressive strengths decreased in parallel with decreasing of unit weight.

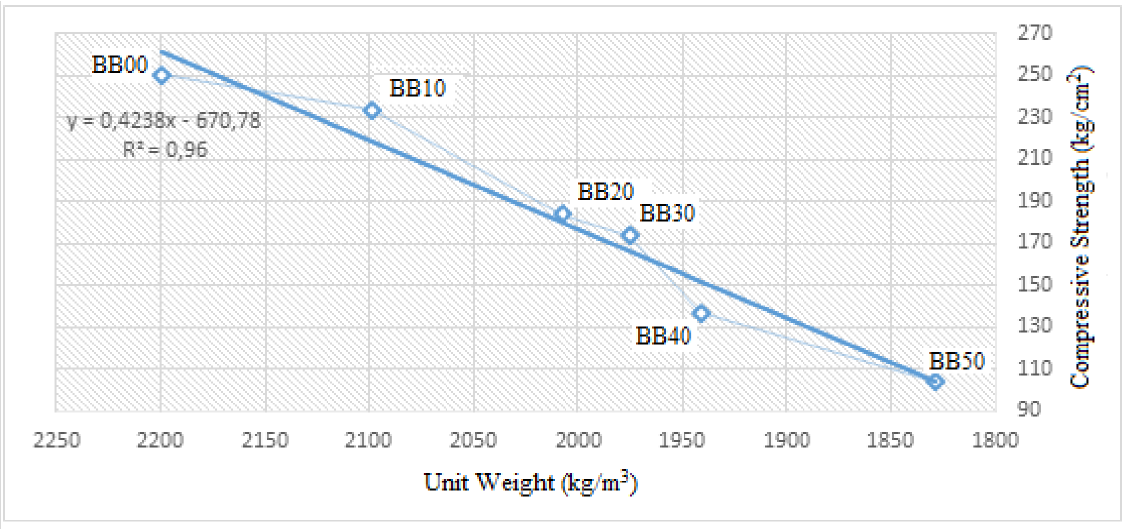

Figure 3: The relationship between unit weight and compressive strength values of concrete samples

The void and water absorption rate of the concrete samples increased due to the amount of BB in the produced concrete samples. BB has higher water absorption characteristic than normal aggregate. Also, the unit weights decreased depending on the amount of BB. The increasing ratio of water absorption ranged from 5.5% to 14% (Table 1). Figure 4 showed that there was a linear and inverse relationship between the unit weight and the water absorption rates.

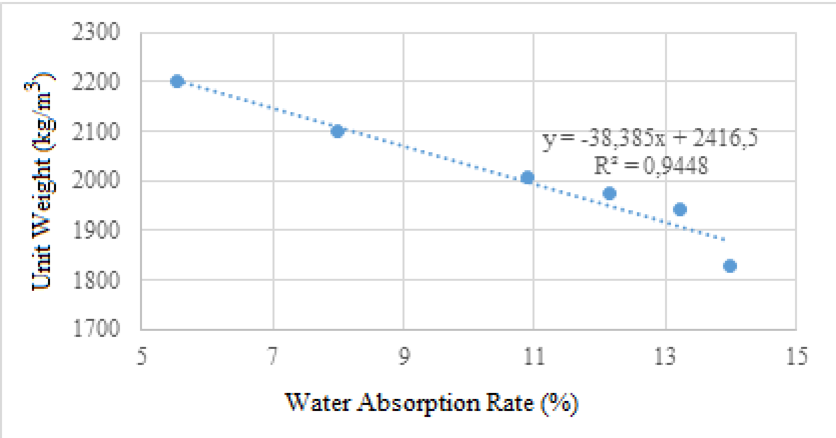

Figure 4: The relationship between unit weight and the water absorption rates of concrete samples

As a result of the freezing and thawing test which represents the decrease of compressive strength after freezing and thawing process (Table 1), it was determined that all the test subjects except the BB40 and BB50 subjects was resistant for freezing and thawing. As [25] stated, the recovered brick and tile ballast aggregate are more angular and have higher water absorption property than normal aggregates, so this properties had a negative effect on freezing and thawing resistance. Similarly, in the study by [26], the water permeability rates in the concrete adding with brick and tile ballast concrete were found to be 50% higher than normal concrete

When the reinforced concrete structures are exposed to high temperatures, the changes of physical and mechanical properties (reduction in compressive strength of concrete and modulus of elasticity, crack formation, disintegration and dispersion etc.) are observed [27]. Table 2 showed the compressive strength of concrete samples exposed to different temperatures. As a result of the compressive strength test which was carried out after the application of, the highest values were obtainedin the BB10 concrete samples, these were 25.95 k /cm^2, 21.96 kg/cm^2 and 15.39 kg/cm^{2}for 300 °C, 600 °C and 900 °C temperatures, respectively. When the temperature of 900 °C was applied to the concrete samples, the compressive strengths could not be determined due to cracks on the concrete samples of BB20, BB30, BB40 and BB50.

Table 2: The values of compressive strength after high temperature application

Ratio of BB	300 °C	600 °C	900 °C
BB00	25.95	20.17	12.58
BB10	26.67	21.96	15.39
BB20	22.11	20.26	-
BB30	23.54	20.32	-
BB40	24.17	18.35	-
BB50	25.54	20.98	-

One of the physical factors causing deterioration in concrete is wearing [28]. The wearing test results of the concrete samples were given in Table 3. When the results were examined, the increasing of BB amount directly affected wearing results. The lowest wear value is 8.7 $cm^3/50\ cm^2$ in BB00, which represented control group and the highest wear value is obtained from BB50 with 14.1 $cm^3/50\ cm^2$. Two recycled coarse aggregates containing concrete fractures and bricks was compared and it was indicated that the shape of the brick ballast aggregate was more rounded than the concrete fractures and the resistance to wearing was found to be lower than concrete fracture aggregate [29].

Table 3: The results of Bohme wearing ($cm^3/50\ cm^2$)

Ratio of BB	Amount of wearing ($cm^3/50\ cm^2$)
BB00	8.7
BB10	9.6
BB20	11.3
BB30	11.8
BB40	12.9
BB50	14.1

Conclusion and Suggestions

Within the scope of this study, the usage of BB as coarse aggregate in concrete were investigated and control experiments were carried out to determine the changes in physical and mechanical properties of the produced concrete samples. The results obtained from the studies are explained below.

As a result of this study, as the amount of BB aggregate increased, the compressive strength values of concrete samples decreased. The compressive strength of BB00 was 264.35 kg /cm^2 and the compressive strength value of BB10 was 251.62 kg/cm^2. There was a loss of approximately 5% between the concrete sample with the least amount of BB aggregate and the control sample.

The unit weight values decreased as the amount of BB aggregate increased. When the unit weight of the control sample (BB00) was 2200 kg/m^3, the unit weight of the BB50 was 1828.3 kg/m^3, with a reduction of about 16.9%. The reasons for the decrease in unit weights are the specific gravity of the BB aggregates are lower than and the shapes of the BB aggregates are more angular than that of the stone ballast aggregates.

BB10, BB20, BB30, BB40 and BB50 mixtures have more water absorption rate values than BB00. Because BB aggregates are multiple-cavity material and their tendency to absorb water is very high.

The concrete samples were subjected to temperatures of 300, 600 and 900 °C and their resistance to high temperatures was tested. As a result of high temperature application, it was showed that compressive strength values after temperature applications equal to 10-20% of normal compressive strength values.

As a result of the tests on concrete, it was revealed that BB aggregates can be used in concrete as coarse aggregate. BB10 samples, which produced by using 10% brick fracture aggregate gave the closest results to the control sample (BB00).

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