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Durability of concrete made by partial replacement of fine aggregate by colemanite and barite and cement by ashes of corn stalk, wheat straw and sunflower stalk ashes

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HIGHLIGHTS

- Durability of concretes made of corn stalk, wheat straw and sunflower stalk ash with barite, colemanite are investigated.
- This ashes can improved many durability properties of concrete.
- Colemanite and barite and these ashes can be used with concrete production.
- Wheat straw, corn stalk and sunflower stalk ash with barite can be used for radiation attack.
- Mineral admixtures generally made a positive contribution against freeze–thaw.

GRAPHICAL ABSTRACT

The images of the wheat stalk and its ash, corn stalk and its ash, sunflower stalk and its ash.

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ABSTRACT

In this study, the durability properties of concretes involving corn stalk, wheat straw and sunflower stalk ash along with barite and colemanite are investigated. Corn stalk, wheat straw and sunflower stalk ash are substituted in place of cement, while barite and colemanite are substituted in place of fine aggregate with different percentages. Concrete specimens were tested for compressive strength at 7, 28 and 180 days. Furthermore, abrasion and freeze–thaw tests were performed to investigate the physical and mechanical properties. 180 day sulfate resistance tests were applied in 5% sodium sulfate solution (Na_2SO_4) for investigating the chemical effect on concrete. Moreover, $12 \times 12 \times 2$ cm mortar samples were produced to apply radiation shielding test. Am-241 gamma ray source was used for the radiation shielding test. The present study showed that the use of the abovementioned ashes improves many engineering properties of concrete. By filling the voids, the ashes produce a stronger concrete, which is further enhanced by colemanite and barite. Additionally, the described additives improve the radiation shielding property of concrete.

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1. Introduction

To improve the durability of concrete, many additives are used. These additives also decrease the cost of cement [1–6]. Wheat straw ash is used as a pozzolanic additive [7]. Wheat straw ash can be also utilized as a concrete additive due to its high silicium content [8]. SEM scans of autoclave test samples show that 7% pozzolan which has organic origin contribute to the development of many hydration products [9].

"Durability" of concrete expresses its endurance and service for many years without loosing its strength. The resistance of concrete can be defined as the continuation of its initial features and design functions under the environmental and service conditions. If concrete looses its features by wearing out under the abovementioned conditions, further use of it will not be economic and its useful life ends [10,11]. Physical factors which wear out concrete, cause weight loss on its surface [10]. The effects of physical conditions, external factors, liquids, load and temperature cause abrasion and, consequently, cracking and increase of permeability takes place [11].

One of the problems of durability is radiation. Radiation is a phenomenon that is intertwined in nature. Radiation is used in many branches of physics, chemistry and biology and is obtained from different radioisotopes [12]. The use of radiation in basic science, medicine, agriculture, industry and military has reached a high level [13]. In modern life, the use of radiation for different purposes more and more, threatens all living creatures [14]. The main point in the protection against radiation is to know permissable doses of it and prevent people from its overdose [15]. The objective of radiation protection is to prevent effects that lead to tissue damage and keep these effects at acceptable levels [16]. Lead is an excellent radiation shield. However, it is both expensive and toxic. Hence, alternatives which are cheaper and harmless for human life are being searched. Barite ($BaSO_4$) is composed of barium minerals which have the retention of high radiation [17,18]. Due to its barium element content, barite, with its high specific weight is used in producing heavy concretes, particularly for its hinderance against lethal gamma rays and neutrons and to minimize the effects of radiation [5,15,18].

Concretes which consist of different rates of barite and colemanite are used for hindering the effect of 133 Ba and 241 Am radioactive sources. The calculation of gamma rays has been carried out with NaLi detector which has 662 keV resolution at 122 keV. The scope of work conveys the fact that the attenuation of gamma rays in concrete is more effective than that in ordinary concrete [19]. In this research, it is found out that the radiation absorbing property of concrete increases depends on increasing concentration of bauxite and colemanite and reduces with increasing concentration of linear attenuation coefficients. Its theoretical value is obtained using WinXCom Penelope and the experimental results are compared with those of computer programmes.

There are appreciable amounts of boron and barite reserves in Turkey. There is also a significant market in producing corn, wheat and sunflower. Wheat, corn and sunflower stalks are abundant in Kahramanmaraş region. They are gathered with suitable techniques. Then, they are burnt and their ashes are evaluated as additives in concrete and cement production. The aim of this work was to gain these materials into the economy and also prevent environmental pollution. At the same time, the radiation armouring effect of these materials was also investigated.

2. Material and method

2.1. Material

2.1.1. Barite

Barite is a clean, soft, naturally unresponsive and inexpensive mineral. 2.1% of the world's total reserves of barite is obtained in Turkey. These reserves contain beaten, crumbled or raw, good quality barite and are located in Konya, Kahramanmaraş, Osmaniye, Muş, Antalya and Kütahya. Turkey produces 120 thousand tons of barite each year which makes it the eighth in the world with a share of 1.7% [15]. Barite which is used in this study, was obtained from Osmaniye – Bahçe region.

2.1.2. Colemanite

Colemanite is as hard as diamond and its appearance is similar to it [16]. Presently, most of the world's colemanite reserves and production is realized by the U.S. and Turkey. The shares of different producing countries are as follows: Turkey 33%, the U.S. 28%, Russia 23% and other countries 16%. Colemanite which is used in this study, was obtained from Balıkesir – Bigadiç region.

2.1.3. Wheat straw ash

A group of the most-produced cereal in the world and Turkey is wheat. The wheat straw, which is used in this study, was obtained from Kahramanmaraş region. After being gathered, wheat straws were burned for 3 h in an appropriate environment at 600 °C and, then, left to cool for 24 h.

2.1.4. Corn stalk ash

The corn stalk used in this study, was obtained from Kahramanmaraş region. Corn is produced in the region abundantly. After the harvest of the crop, the stalks are cut and thanks to their high silicium content, they are used as an additive in cement and concrete production. After being collected in an appropriate manner, they are stored for drying to zero moisture and burned appropriately to obtain its ash.

2.1.5. Sunflower stalk ash

Sunflower, which belongs to the daisy family is grown for its oil seeds and yellow agricultural plants. In particular, in the northern districts of Kahramanmaraş, sunflower is grown abundantly. After being collected in an appropriate manner it is stored for drying to zero moisture and burned to obtain its ash. The chemical analysis results of the ashes of the wheat, corn and sunflower stalks used in this study are given in Table 1 and those of barite (B) and colemanite (K) are given in Table 2.

2.1.6. Aggregate

For the experimental study, the aggregates were taken from the ores of the river of Kahramanmaraş – Aksu and were used after being washed and sieved. Their physical properties are given in Table 3.

2.1.7. Cement

The chemical and physical features of the cement used in this study, CEM I 42.5, are given in Table 4.

2.2. Method

2.2.1. The preparation of concrete mixtures

In the concrete mix which is in accordance with the TS 802, the fine aggregate was replaced by 5% and 10% barite (BA) or 0.5% and 1% colemanite (K) by mass [17]. In addition, 2.5% and 5% of the cement was replaced by corn stalk ash (M), wheat straw ash (B) and sunflower stalk ash (A) by mass. Consequently, including the control sample 29 kinds of mixes were prepared. When 2% or more colemanite was substituted in place of fine aggregate, undesired disturbances took place in the physical properties of concrete [5]. For this reason, colemanite substitution ratio was selected different from the others to be 0.5% and 1%. The names of the samples, materials used and mix proportions are given in Table 5.

2.2.2. The preparation of the mortar mixtures

The mortar mixtures were prepared in accordance with TS EN 196-1. Replacing cement and standard Rilem sand of the control sample by 5% and 10% barite and 0.5% and 1% colemanite by mass, 29 different types of samples, including the control sample, were produced. The names, the ingredients and the ratios for each type of sample, having 120 × 120 × 20 mm dimensions, are given in Table 6.

2.2.3. The compressive strengths of the concrete samples

7, 28 and 180 day compressive strengths of standard 10 cm cubic samples were tested with a 200-tons press according to TS EN 12390-3 [20].