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An investigation on the effect of cement replacement with waste materials on the strength properties of concretes

Muhammed Tanyıldızı*[1], Erden Ozan Karaca [1]

[1]*Bitlis Eren Universitesi, Engineering-Architecture Faculty, Civil Engineering Department, Türkiye*
**mtanyildizi@beu.edu.tr; eokaraca@beu.edu.tr*

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Abstract

This article presents pieces of information obtained from the literature reviews related to the effect of cement replacement with waste materials in various ratios on the strength performances of concretes. Eggshell powder (ESP), ceramic waste powder (CWP), rice husk ash (RHA), and corn cob ash (CCA) are waste materials that were the subject of this paper. One of the aims of this study is to indicate the usability of these materials as cement substitutes is a beneficial way both reducing the possible threat of them to the environment and living health and reducing greenhouse gas release to the ecosystem by minimizing cement production. It is also aimed with this study to create an awareness in the concrete industry and researchers to support developments in the sustainability of concrete.

Introduction

Sustainability is very important for societies as it helps to protect the ecosystem, increase our quality of life, improve the welfare of societies and prevent excessive depletion of natural resources [1]. In the construction industry, the sustainability of construction materials is very important due to the huge amount of natural resources consumed in the production phase. Concrete is the most widely used construction material in almost all civil engineering sectors due to its versatility and availability worldwide [2]. Because concrete has such a wide usage area in the construction industry, its sustainability is the topic of interest among researchers and sector representatives. The sustainability of concrete is provided with its constituents, especially cement, and cement which is the main ingredient of concrete affects both the cost of concrete and a threat to the environment because of releasing the noteworthy amount of greenhouse gas of CO_2 in production of it. So, the construction sector faces up some challenges in bringing sustainability to their production processes, especially cement. This may be carried out either by searching a new raw materials and products more environmentally friendly contributing the minimize of greenhouse gases releasing to nature. In this regard, wastes from other industrial activities can be a good solution to this goal [3,4].

An increase in population and growing industrialization with urbanization generate plentiful waste. It is claimed that approximately 2 billion tons of waste are produced annually all over the world, and it is estimated that 3.4 billion tonnes of waste will be generated annually worldwide by 2050 [5]. Approximately 62% of these wastes are not properly handled, which causes pollution of the environment and public health as well as global warming [6]. Recycling these wastes is an effective way for creating sustainable waste management [7]. Recently, there is a growing interest in the usage of waste materials in the construction industry, especially in concrete production as cement replacement and remarkable results have been obtained [8]. In this study, waste materials such as eggshell powder (ESP), ceramic waste powder (CWP), rice husk ash (RHA), and corn cob ash (CCA), have been subject to this review study. In this regard, the latest studies performed about this concern were reviewed and their results were presented succinctly. The main goal of this study is to arise consciousness for sustainable waste management in the construction industry and light the way of researchers and sector representatives.

Waste materials used as cement substitute

Eggshell powder (ESP)

Eggshell is a biowaste material obtained from bakeries, patisseries and poultry farms. The disposition of this waste into landfills causes toxic gases and environmental pollution eventually poses a threat to living health [9]. The utilization of eggshell powder as a cement replacement material is a beneficial solution to recycle it. In this regard, Yerremala [10] conducted a study to investigate the effect of cement replacement with ESP in ratios of 5-15% with 5% increment on concrete strength properties. At the end of 28-days of water curing, the concrete with 5% ESP content gained strength more than 7.62% compared with control concrete. However, the decrease in compressive strength emerged as 15.25% and 27.80% with 10% and 15% ESP content respectively. As for splitting tensile strength, it did not change for a 5% replacement ratio but decreased steadily with the increasing content of ESP compared with control concrete. The author indicated concerning the results that 5% ESP is optimum for maximum strength. In another study, Jhatial et al. [11] that the 10% ESP content among 5-20% is optimum content to achieve higher strength compared to the control concrete. Arif et al. [12] performed a study to investigate the strength performances of concretes containing eggshell powder as partial cement replacement. They prepared four mix proportions namely with 0%, 5%, 10% and 15% ESP content. Test results indicated that the compressive strength of concrete with 10% ESP showed 10% higher strength when compared with control concrete.

Ceramic Waste Powder (CWP)

Ceramic wastes powder are collected from factories and construction sites during the packing and labor process from crushed ceramics in noteworthy amount. Ceramic waste poses a threat to the environment and recycling it as a cement substitute in concrete in the building sector is a good way [13]. Herein, El-Dieb et al. [14] performed a study to investigate the CWP effect on the compressive strength of concrete specimens. They declared the compressive strength increase at 20% replacement ratio. However, substitutes above 20% resulted in a decrease in compressive resistance of concrete specimens. From another study, Arthi [15] searched the change in compressive strength of concrete specimen when its cement content was replaced with CWP in levels of 15%, 30%, 35% and 45%. It was noted that compressive strength increased with CWP content up to 35%, but after this replacement ratio, the increase in CWP content resulted in a decrease in compressive strength. Bhargav and Kansal [16] tested the flexural strength of concretes that cement contents replaced with CWP at 5-20%. According to the results, flexural strength increased with CWP content and the optimum substitute ratio was noted as 15%.

Rice Husk Ash (RHA)

Rice husk is a waste produced from the rice mill process and burned in the oven to take ash form. It is obtained roughly 200 kg per ton of rice and has been taken advantage of in cement replacement material to form sustainable concrete for years [17]. With this aim, Zareei and Ahmadi [17] studied to benefit from rice husk ash as cement substitute material in proportions of 5%, 10%, 15%, 20% and 25%. Authors reported from test results that 15% replacement of RHA with cement increased the compressive strength of concrete by 20%. Patil and Paliwal [18] conducted research performed on the usability of RHA as cement substitute material at different percent as 0%, 5%, 10%, 15% and 20% by weight. From test results, it was noticed that the compressive and splitting tensile strength was improved with RHA by 15.34% and 24% with 15% replacement ratio compared to control concrete results respectively.

Corn Cob Ash (CCA)

The corncob is the remainder of the corn ear after peeling the corn kernels and makes up about 75-85% of the corncob's weight. Corn cob ash (CCA) is an agricultural by-product and can be used by recycling it in concrete production as cement supplementary material [19]. Tiza [20] made a study covering the investigations on the usability of corn cob ash (CCA) as a partial cement substitute material in the production of concrete. In this scope, CCA was obtained and replaced with cement in various ratios of 5%, 10%, 15%, 20%, and 25%. The compressive strength of concrete obtained from cube specimens at the end of the 28 days of water curing decreased by 5.05%, 13.49%, 23.03%, 33.12%, and 42.82% for 5%, 10%, 15%, 20%, and 25% replacement ratios respectively. The decrease in flexural tensile strength also at the end of the 28-day water curing was 7.51%, 20.48%, 27.52%, 39.20% and 46.99% with replacement ratios of 5%, 10%, 15%, 20% and 25% respectively. Adesanya and Raheem [22] tested the effect of cement replacement with CCA in proportions of 0%, 2%, 4%, 6%, 8%, 10%, 15%, 20% and 25% by weight. They concluded that the optimum content for strength improvement comes into view as 8%.

Conclusion

This paper reviewed previous studies that investigated the effects of ESP, CWP, RHA, and CCA replacement with cement on the strength performance of concrete and it was aimed with this present study to arise an awareness for both researchers and concrete sector representatives to produce green concrete. The accumulation of these waste materials in landfills causes toxic gases and is a threat to the environment and public health. Hence, the utilization of these wastes as cement replacement material is a beneficial way to reduce environmental pollution and protect living health. Also, ensuring the minimize of cement usage by 10% in concrete production with this way is an effective way to reduce the greenhouse gas release into the ecosystem, which cement production is a big threat in the aspect of triggering global warming.

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