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EFFECT OF BORON CARBIDE ADDITION ON THE STRENGTH AND PHYSICAL PROPERTIES OF CONCRETE

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ABSTRACT

Concrete currently has become a conventional material in construction of nuclear reactor due to its properties such as safety, strength and economical in cost. Boron carbide (B_4C) was used as additives in concrete are characterized as a good neutron absorber for nuclear reactor applications. The effect of B_4C addition on physical and strength properties of concrete samples were investigated. The samples were prepared with three different weight percent (wt%) of B_4C powder. The concrete slump test of fresh concrete has been done to investigate the workability of mixtures. Free B_4C mixture shows the highest workability compare to 5 and 20 wt% B4C concrete mixture. The density of 0 wt% of B_4C is the lowest compared to 5 and 20 wt%. However, after 28 days curing time, the compressive strength test of 20 wt% B_4C shows the highest value compare to 5 and 0 wt% B_4C concrete respectively. It is obvious that up to 20 wt% B_4C can be added to concrete mixture and cause significant strength increased.

Keywords: strength; boron carbide; concrete; radiation shielding;

INTRODUCTION

Concrete is a mixture of water, cement, sand and coarse aggregate. It is widely used in building construction such as medical hospitals, particle accelerators and nuclear power stations [1]. Concrete is a cheap, effective and common material to shield neutron radiation. Different concrete mixes can have very different attenuation characteristics [2]. The flexibility and low price of concrete cause it as the main shield material for any construction design [3]. These concrete play roles to protect the surrounding from the high level radiations emitted from the reactor and supporting the reactor and its related equipments [4]. Recent development in variety of shield to protect the radiation is due to the fact that it could be hazardous to people and environment [5].

Nuclear reactors are usually surrounded by thick layers of concrete as biological shielding and this result in the decrease of the room size [6]. Therefore a special radiation shielding concrete become a very important component of nuclear reactor. The most significant types of radiation for which shielding is required in a nuclear reactor are primary neutrons and gamma-rays originating within the core itself and secondary gamma-rays produced by neutron interactions with materials external to the reactor core. Therefore, a study of the effect of concrete, on the neutron shielding properties of concrete materials is potentially useful in the development of radiation shielding design.

Concrete is widely used for neutron shielding due to both having a high level of hydrogen and its potential to serve as a high-strength load-bearing structural shield [7]. The elemental composition, hydrogen content and the concrete density play an important rule for neutrons and gamma-rays attenuation [1,8]. Material with suitable captured cross-section, like boron and cadmium can be use to capture the resultant slow or thermal neutron [3].

In this study, slump, density and compressive strength test has been used to investigate the effect of the addition of B_4C on the physical and mechanical properties of radiation shielding concrete. Boron carbide is frequently used as a shielding material, either alone or combined with other material for radiation shielding [9]. B_4C is used extensively in nuclear reactors as a neutron absorber [10] and as a constituent material of neutron shields because of its high absorption of neutrons [11]. Due to its many versatile properties such as high melting point, low density, low thermal conductivity and high neutron absorption efficiency, B_4C becomes an attractive absorber material [10,12,13].

MATERIALS AND METHODS

The samples were prepared according to the conventional methods of construction materials laboratory. The composition of all cube concretes were derived as specified in the Department of Environment, United Kingdom method [14] for concrete grade 40 in the laboratory. The cement used in this study was obtained from the Tasek Cement Company, and the aggregates with a maximum size of 10 mm were obtained from Lafarge Aggregates Sdn Bhd. In this study, B_4C has been used as an additive material in cube concrete. B_4C sized 15μm from Sigma-Aldrich Corporation was added in ratio of 5% and 20% by weight of the cement content.

Three mixtures have been prepared using water cement ratio 0.48, and using only two mixtures with B_4C addition. According to BSI (1983b) [15], the mixtures were poured to 15 cm × 15 cm × 15 cm molds and vibrated by a vibrator to settle down the concrete. Samples were left in the room temperature for 24 hours, and then the concrete samples were removed from the molds and placed in standard curing condition in a water tank for 28 days [16]. Concrete samples were prepared with three cubes for one mixture. The mix proportions and slump for the three mixtures containing different weight percentage of B_4C are provided in Table 1.

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Table 1: Mix proportions for the cube concrete

Mixtures	Slump (mm)	Cement (kg m^{-3})	Water (kg m^{-3})	Coarse Aggregate (kg m^{-3})	Sand (kg m^{-3})	Boron Carbide (kg m^{-3})
1 (0 wt % B_4C)	120	444.6	213.4	952.6	779.4	0
2 (5 wt % B_4C)	140	444.6	213.4	952.6	779.4	17.71
3 (20 wt % B_4C)	150	444.6	213.4	952.6	779.4	70.85

Concrete samples were obtained by adding the B_4C powder as mentioned in Table 1 in the ratios of 0, 5 and 20% by weight of the cement content in the fresh mixture, and finally, a total of nine cube concrete were obtained. Mixture 1 is a B_4C free mixture, which would be used for comparison purposes. Concrete slump test have been done to the fresh concrete mixture. This test is performed to check the consistency and the workability of the mixture [17]. Densities of the concrete cubes are obtained in accordance with BSI (1983d) [18].

After 28 days, the compressive strength for concrete was measured using a digital concrete compression machine [19]. The mechanical properties of different concrete mixtures have been investigated by a 5000 kN Autocon Concrete Compressive Strength Machine. In previous study, it is obvious that up to 20 wt% B_4C can be added to concrete mixture without affecting the strength significantly [20].

RESULTS AND DISCUSSION

The concrete slump test has been made to investigate the workability of the fresh mixture concrete. In previous study, the effect of carbon powder addition on the properties of hematite radiation shielding concrete has improved the workability and strength of concrete [21]. Table 1 show that Mixture 1 has the lowest slump followed by Mixture 2 and Mixture 3. It can be clarified that adding B_4C powder to concrete from 0 to 20% has worsened its slump. The experimental result shows that fresh concrete of Mixture 3 have poor workability compare to Mixture 2 and Mixture 1. Mixture 3 is presumed contained a smaller amount of water and become dry concrete mix, which is harder to manage but makes a stronger and more durable finished product. This statement has been proved by the compressive strength result in Figure 2.

According to Figure 1, 20 wt% of B_4C addition in the concrete sample recorded the highest density compared to 5 and 0 wt% B_4C addition in the other samples. This result clearly indicates that the high percentage of B_4C is denser than 5 and 0 wt% B_4C concrete.

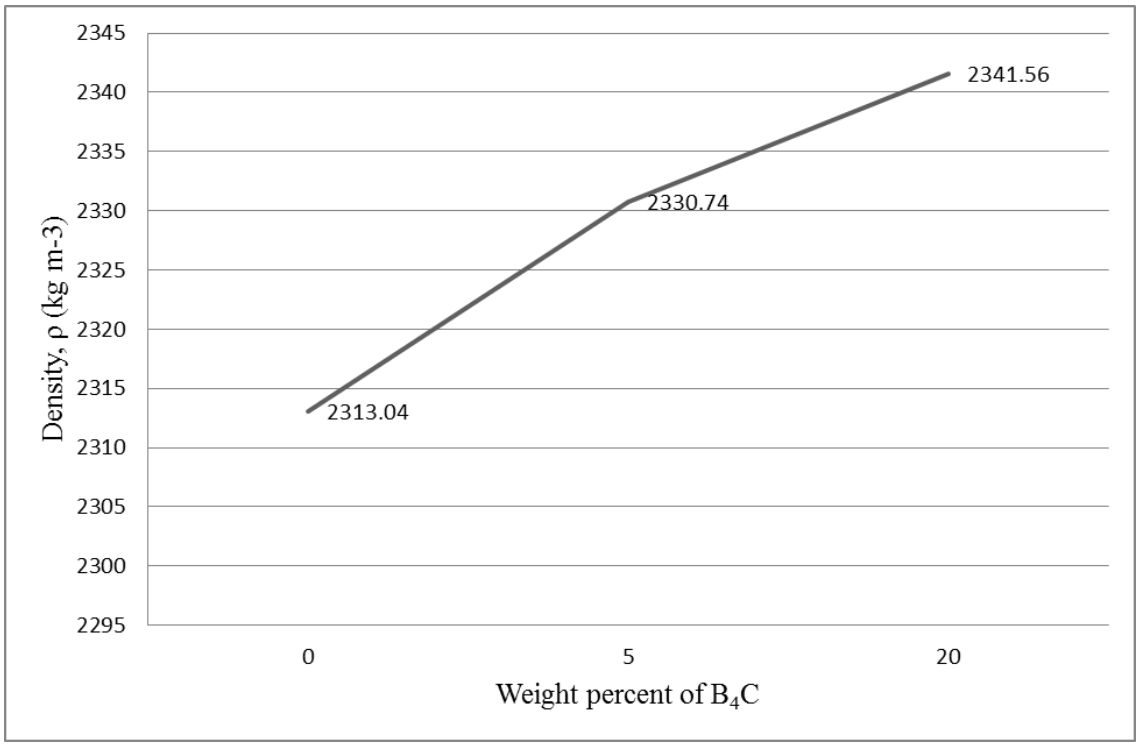

Figure 1: Effects of B_4C addition on the density of concrete

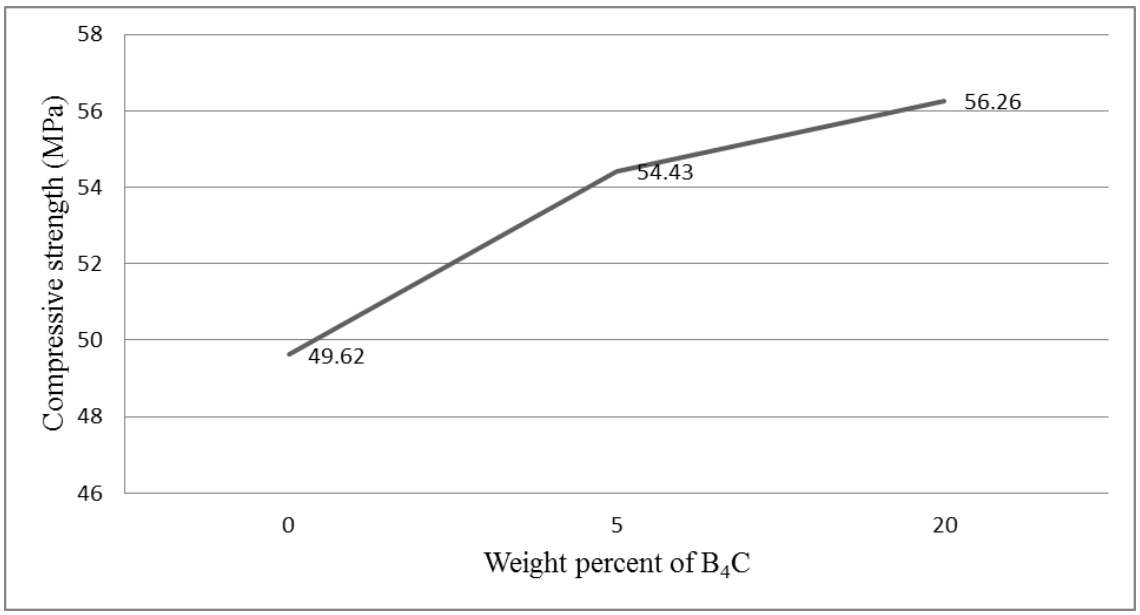

Figure 2: Effects of B_4C addition on the compressive strength of concrete

The compressive strength of the concrete with B_4C additives are shown in Figure 2. The result indicates that all type of mixtures is successfully passed the minimal compressive strength, 40 MPa, and it was found that the compressive strength increases with the increase in the added weight percent of B_4C. For 20 wt% B_4C, the compressive strength

is the highest with 56.26 MPa compare to 54.43 MPa and 49.62 MPa of 5 and 0 wt% B_4C. The actual strength increase is more than 13% compared with B4C free concrete. It is obvious that up to 20 wt% B_4C can be added to concrete mixture and cause significant strength increase.

CONCLUSION

It can be concluded that the compression strength of concrete increased as well as the increasing of B_4C weight percent up to 20% of the total weight of cement. Therefore, the concrete with B_4C additives can replace the conventional concrete of shielding reactor nuclear by reducing the thickness of concrete. The results indicated that the addition of B_4C has been improved the mechanical and physical properties of concrete. Further study on shielding properties of concrete with B_4C additives need to be investigated to analyses the potential of this concrete as a new radiation shielding material.

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