CEMENT-BORON CARBIDE CONCRETE AS RADIATION SHIELDING MATERIAL

Yusof Abdullah, Mohd Reusmaazran Yusof, Azali Muhamad, Zaifol Samsu and Nurhaslinda Ee Abdullah

Industrial Technology Division, Malaysian Nuclear Agency, Bangi,

43000 Kajang Selangor, Malaysia

yusofabd@nuclearmalaysia.gov.my

ABSTRACT

Boron carbide (B_4C) is a ceramic material which is effective to absorb thermal neutron due to wide neutron absorption cross section. In this work, B_4C is added into concrete as fine aggregates to test the attenuation properties by getting the attenuation coefficient of the concrete/B_4C. The samples of concrete/B_4C were exposing to the thermal neutron radiation source (241-Americium-Berylium) at the dos rate of 29.08 mR/h. The result show that the attenuation coefficient of the sample with 20wt% B_4C is 0.299cm^{-1} and the sample without B_4C is 0.238cm^{-1} and hence, concrete/B_4C is suitable as a shield for thermal neutron radiation.

ABSTRAK

Boron karbida adalah bahan seramik yang berkesan untuk menyerap neutron terma kerana ia mempunyai keratan rentas penyerapan neutron yang luas. Dalam kajian ini, B_4C ditambah dalam konkret dalam bentuk agregat halus bagi menguji sifat pelemahan menerusi penilaian pekali pelemahan konkret/B4C. Sampel konkret telah didedahkan kepada sumber sinaran neutron terma (241-Americium-Berylium) pada kadar dedahan 29.08 mR/h. Keputusan menunjukkan bahawa pekali pelemahan sampel 20% B_4C adalah 0.299cm^{-1} dan sampel tanpa kandungan B_4C adalah 0.238cm^{-1} dan oleh itu membuktikan bahawa konkret/B_4C adalah sesuai dijadikan sebagai pelindung sinaran neutron terma.

Keywords: Boron carbide, concrete, shielding, neutron, attenuation.

INTRODUCTION

Concrete is a multi user and it's commonly used as a radiation shielding material due to cheaper, easier moulded into complex shape, good structural and suitable as neutron and proton shielding materials compared to other shielding materials (Anon, 1981). Generally, concretes are composites material consist of aggregate, sand, water and cement. Furthermore, by the addition of B_4C in aggregate formulation could enhance the capability and quality of radiation resistance property (Abdo *et al*., 2002). Research for radiation shielding materials are cover wide area including radiation transform in shielding, radiation level in materials, thermal deposit, radioactivity, scattering of radiation, material selection, shielding design and interaction between radiation and materials (Chilton *et al*., 1984).

Hydrogen content in concrete is important factor for neutron shielding ability. Most of the hydrogen in concrete normally present in the form of water in which hydrated during cement curing and aggregate setting and free water flowing in the porosity structure of concrete. This water evaporated at high temperature and could reduce the concrete performance of radiation shielding. Water in concrete disappeared slowly by evaporation and diffusion and may almost 50% water will released after around 25 years. In nuclear reactor, for radiation shielding application, a special mixture of portland cement and sand was used, while boron carbide (B_4C) was doped with portland cement to form concrete as thermal neutron absorber and could reduced radioactivity by thermal neutron (Atsuhiko *et al*., 2004).

EXPERIMENTAL WORKS

The starting materials were consisting of sand, aggregate, portland cement, water and boron carbide powders. After mixing sand, aggregate, water, cement and boron carbide with specific portion then poured into mould, the sample was leaved setting within 28 days. Radiation test was performed by exposed to neutron source 241americium-beryllium for 15 hours with dose rate of 29.08 mR/h. The distance between source and sample was 63 cm and thermoluminasence (TLD) was used as detector. The attenuation coefficient was calculated using formula $I = I_o e^{-\mu x}$ (where, I= intensity after passing sample, I_o = incident radiation intensity, μ=attenuation coefficient and x= sample thickness). Compression strength has been measured according British Standard (BS 1881 - section 116: 1983) by using UNIT TEST machine (Autocon 2000).

RESULTS AND DISCUSSIONS

Figure 1 shows the concrete/B_4C samples after curing in air for 28 days. It clearly showed that concrete/20%B_4C darker that concrete/5%B_4C because colour of B_4C powder is dark blue.

Normally samples become fairly up to 28 days where supposedly concrete 100% set and fully strong. Meanwhile the density of concrete/B_4C was reduced by increasing of B_4C content as shown in Figure 2. The density of boron carbide is considering lower compared to the other concrete components. Therefore the higher composition of B_4C content in concrete could reduce the concrete/B_4C density as proven in these results.

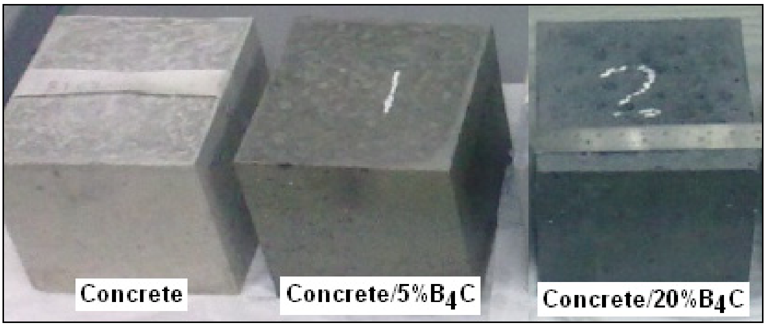

Fig. 1. Concretes after 28 days setting in air shows a variety of concrete/B_4C composition (0, 5 and 20% B_4C)

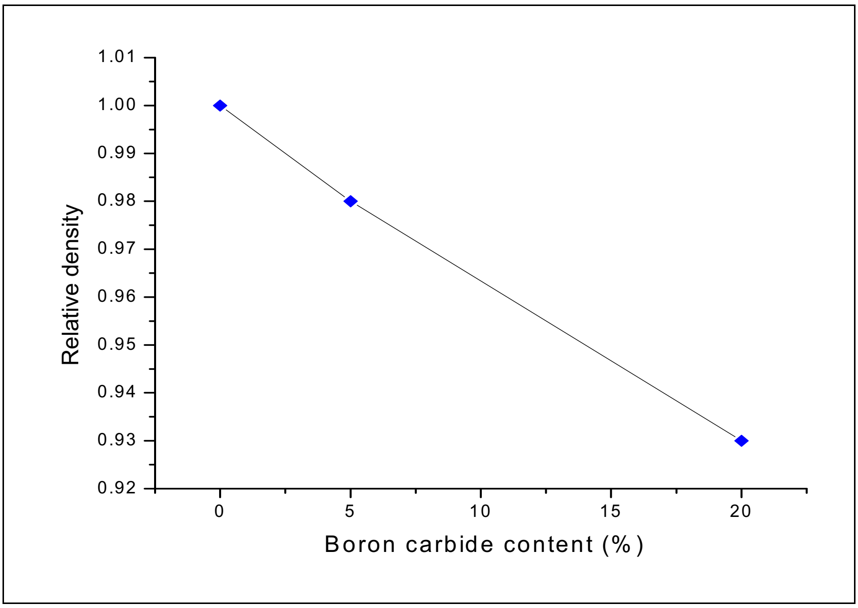

Fig. 2. The relative densities for concrete/B_4C with different B_4C content

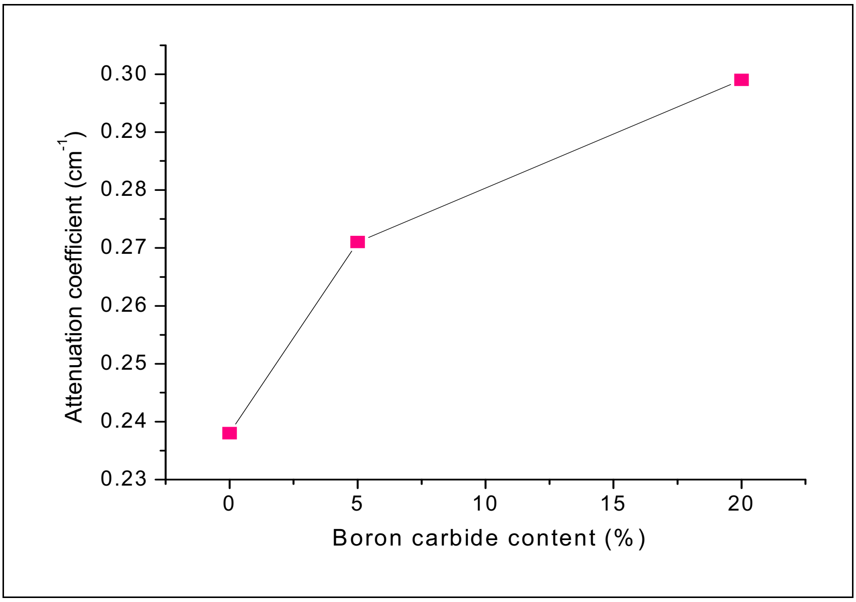

Fig. 3. Comparison between attenuation coefficient values of concrete/B_4C with different B_4C content

Figure 3 shows the attenuation coefficient values of concrete/B_4C samples. It clearly shows that attenuation coefficient of concrete/B_4C increased by the addition of B_4C particles. Attenuation coefficient of concrete/20%B_4C was higher that concrete/5%B_4C. Therefore concrete/20%B_4C absorbs more neutron than concrete/5%B_4C because the higher attenuation coefficient value could absorb more neutrons (Grossman *et al.*, 1999). It was indicated that concrete absorbs neutron because H_2O or water content in concrete as mentioned by Alexander & Mindess (2005). Therefore, using new concrete/B_4C to replace conventional concrete can reduced the thickness of conventional concrete shielding because new concrete/B_4C increased the neutron absorption about 23%. By the way, the space of control area also more spacious and can be used for other activity in reactor nuclear.

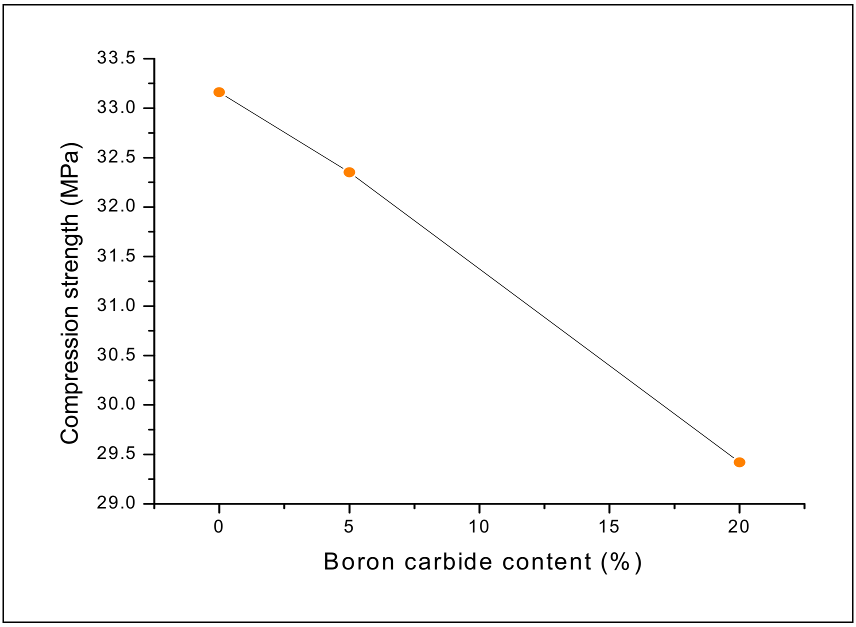

Fig. 4. The compression strength for the concrete/B_4C as a function of B_4C content

Figure 4 shows the comparison of compression strength between three compositions of boron carbide in concrete. The concretes strength was reduced by the increasing of boron carbide content in concretes. The fine particle of boron carbide around 15 µm size compared the other aggregate in concrete indicated that the cement bond couldn't enough strong to bond B_4C particles with other aggregates. This could be reduced interface bonding between aggregates.

CONCLUSIONS

The results show that the density of concrete was reduced by the addition of boron carbide in concretes. Attenuation coefficient of concrete/boron carbide increases as boron carbide content in concretes increased. This study shows that the addition of boron carbide particles to concretes able to increase the capability of neutron absorption compared to regular concrete. However concrete strength was reduced by the increasing of boron carbide in concretes. This showed the bonding strength between boron carbide particles and aggregates was not strong and could reduce the strength of concrete structure.

ACKNOWLEDGEMENT

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