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Full Length Research Paper

Effect of low-dose gamma-radiation on concrete during solidification

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Concrete containers have been used worldwide for its low price and good shielding performance for transporting and storing radioactive wastes. For this purpose, concrete must satisfy a certain property like density in particular. A series of 12 specimens were carried in this study to examine the effect of gamma radiation on compressive strength of concrete during solidification. Two types of cementitious mixes with a water-to-cement ratio of 0.4 were used to mold 5 cm cubes with and without sand. The results strength of gamma radiated concrete specimens have greatly been increased and confirmed by perceiving their microstructure using scanning electron microscope (SEM).

Key words: Radiation shielding, gamma ray, gamma effect, shielding material, nai detector, storing radioactive waste.

INTRODUCTION

Because of its low price and good shielding performance, concrete has been widely used in nuclear industries as a shielding material from nuclear radiations (Chang-Min et al., 2007). For example, concrete is used as a structural and shielding material for the storage and disposal of radioactive wastes (El-Hosiny and El-Faramawy, 2000). Therefore, it is necessary to study the effect of nuclear radiations on concrete. Two types of cementitious mixes with and without sand, were used to mold 5 cm cubes. The water-to-cement ratio for both types of concrete is 0.4 by weight.

Concrete is an inorganic material consisting of cement, water, and aggregates. Typical concrete contains large aggregate particles. By mixing water and cement, chemical reactions known as hydration take place. These reactions bind the different materials together.

It seems neutron, electron and gamma can affect on the resistance of concrete to radiation and its mechanical strength (Chichester and Blackburn, 2007).

In this paper, the effect of low dose gamma ray is investigated on resistance of concrete to radiation and its compressive strength. Concrete cubes with dimension of 5 cm are radiated during solidification by cesium (Cs-137) that emits gamma ray with 0.662 MeV energy. Then the resistance and strength of specimens are investigated.

METHODOLOGY

When gamma-ray photons strike a material, according to photons energies the thickness or density of the medium the intensity of the gamma ray is decreased after passing through it. Energy of Gamma-ray is the key factor when it interacts with medium. But in this research work we investigate only an unique energy (0.667 MeV). In the case of a concrete structure with how that the microscopic bubbles, because the density of air is different from that of the concrete, there is a difference in radiation intensity when the ray passes through concrete with air-filled bubbles and without that.

Water in concrete is distributed microscopically. By solidifying concrete, water is evaporated and cavities are formed in concrete. These cavities are gas pores that cannot rise to the surface of concrete and will be caught in the concrete. It is difficult to recognize pore, unless by using gamma ray to photograph concrete. Because of pore formation in the concrete its strength is considerably decreased.

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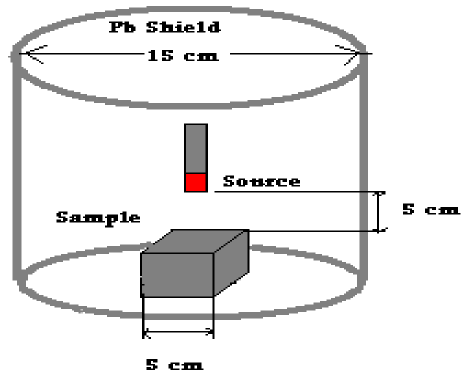


Figure 1. Experimental setup for radiating concrete specimen during solidification.

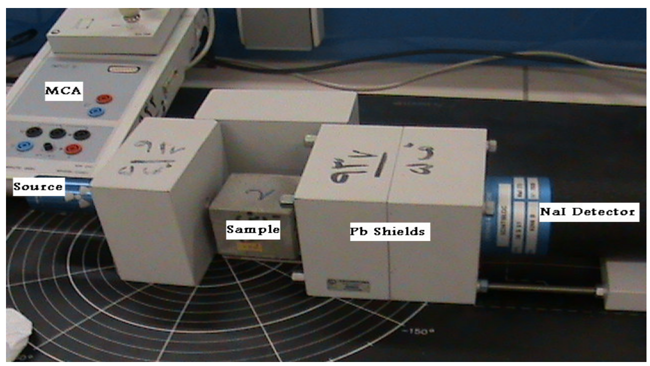


Figure 2. Photograph of experimental setup arranged to count transferred photons.

It is possible to minimize the macroscopic pore by vibration but it cannot affect on microscopic pore. Micro pores can be minimized by radiation of concrete during solidification. Because at the first micro pores have been filled by water. So, when gamma-ray interacts whit water molecules, they are analyzed to H and OH. The hydrogen (H) moves to surface of concrete and the OH participates on alkali-silica reaction (ASR). By this way, micro pores can be deleted. Therefore, if concrete is radiated during drying process, its strength will increase. This radiation can be gamma ray, neutron or electron beam.

In addition, ASR in concrete is one of the slow chemical reactions. This slow reaction causes severe deterioration of concrete. Nuclear radiations make the aggregate ASR- sensitive and the deterioration of concrete can emerge long after the irradiation (Ichikawa and Koizumi, 2002). It is therefore important to know the effect of nuclear radiation on the reactivity of aggregates to alkaline solution.

EXPERIMENTS

In order to investigate gamma effect on concrete cubes, two tests, using NaI detector and compressive strength test, were accomplished. At first, the resistances of cubes (irradiated and reference specimens) were measured against gamma radiation for two types of concretes (with and without sand), then compared with each other. The setup of experiment was arranged according to Figure 1. As seen in photograph, the gamma source and detector side were shielded by lead cubes. The concrete specimen was placed between source and detector. The applied gamma source and detector are Cs-137 and NaI scintillation detector (2"×2") respectively. NaI(Tl) detectors has been used in this work because all the scintillators existing in the market are the NaI crystal activated with thallium where NaI(Tl) is the most widely used for the detection of γ-rays. On the other hand, this detector has rather high efficiency and small decay time (Tsoulfanidis, 1995). Both source and detector that used in experiments have been made by Germany LYBOLD Co.

Two types of cementitious concrete cubes with dimension of 5×5×5 cm^3 were molded as specimens to test. Each type includes 6 specimens. The water-to-cement ratio for both types of concrete is 0.4 by weight. One type of them contains sand with sand-to-cement ratio of 0.43 by weight and the other type is without sand. A cube of each type was kept as reference specimen. For ripening the concrete, it is neccery to be protected in water for 28 days. But for out of water, one fourth of this time (7 days) is enough to ripen. Therefore the others specimens were irradiated for 7 days during solidification by Cs-137 as a gamma-radiation source, which has 100μCi activity. Gamma dose rate was 0.12114 Gy/day for each specimen. Photograph in Figure 2 schematically illustrates the setup of experiments. Cs-137 is employed as a gamma-radiation source in experiments. Because it is widely used for research experiments, it is relatively easy to secure and it is the only powerful gamma source in our laboratory (Shivaramu, 2006).

In addition, because it has remarkable penetration ability, it is estimated to be suitable for the present experiments where thick

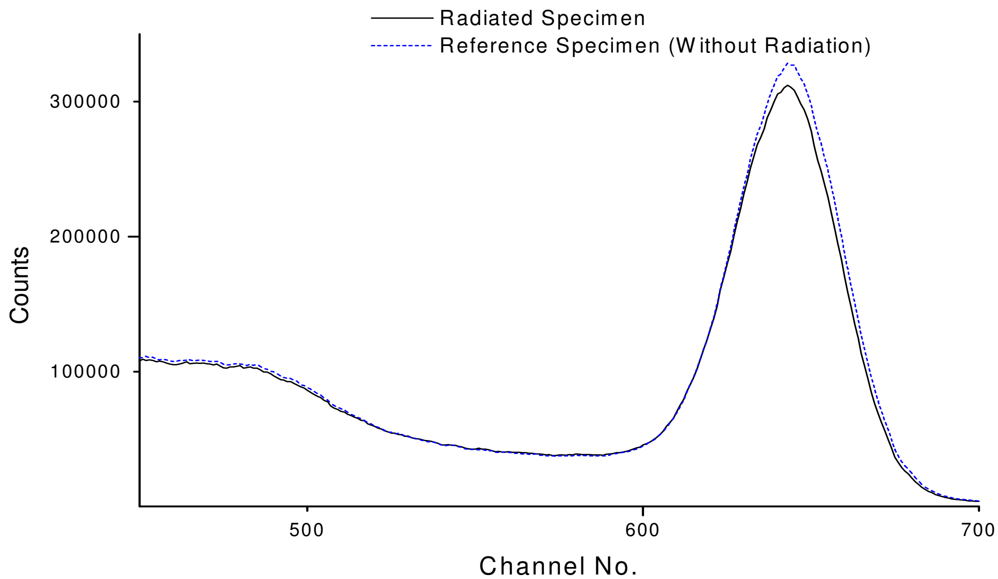


Figure 3. Comparison of photon counts transmitted through irradiated and non-irradiated concrete specimens with no sand.

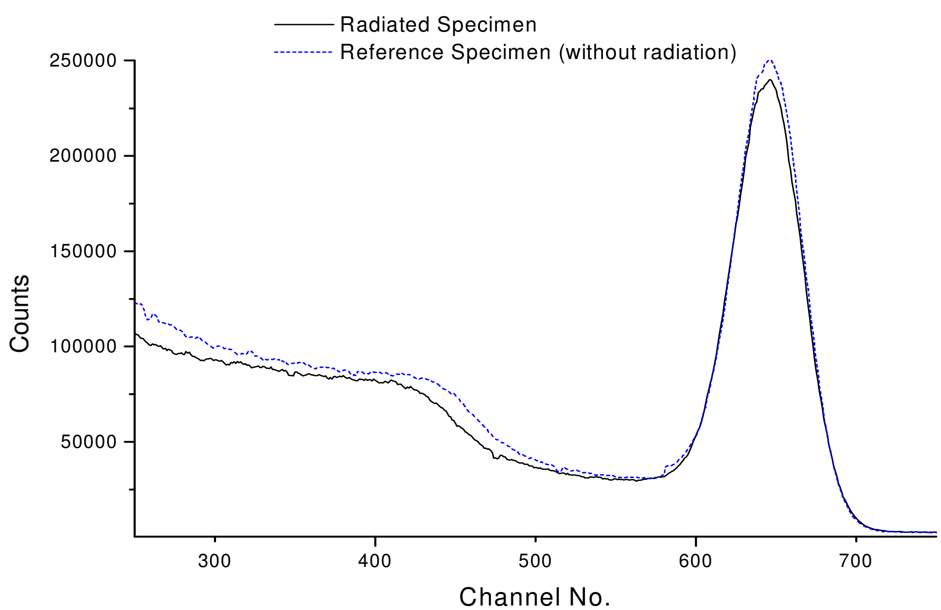


Figure 4. Comparison of photon counts transmitted through irradiated and non-irradiated concrete specimens that have 2.75 sand-to-cement ratio by weight.

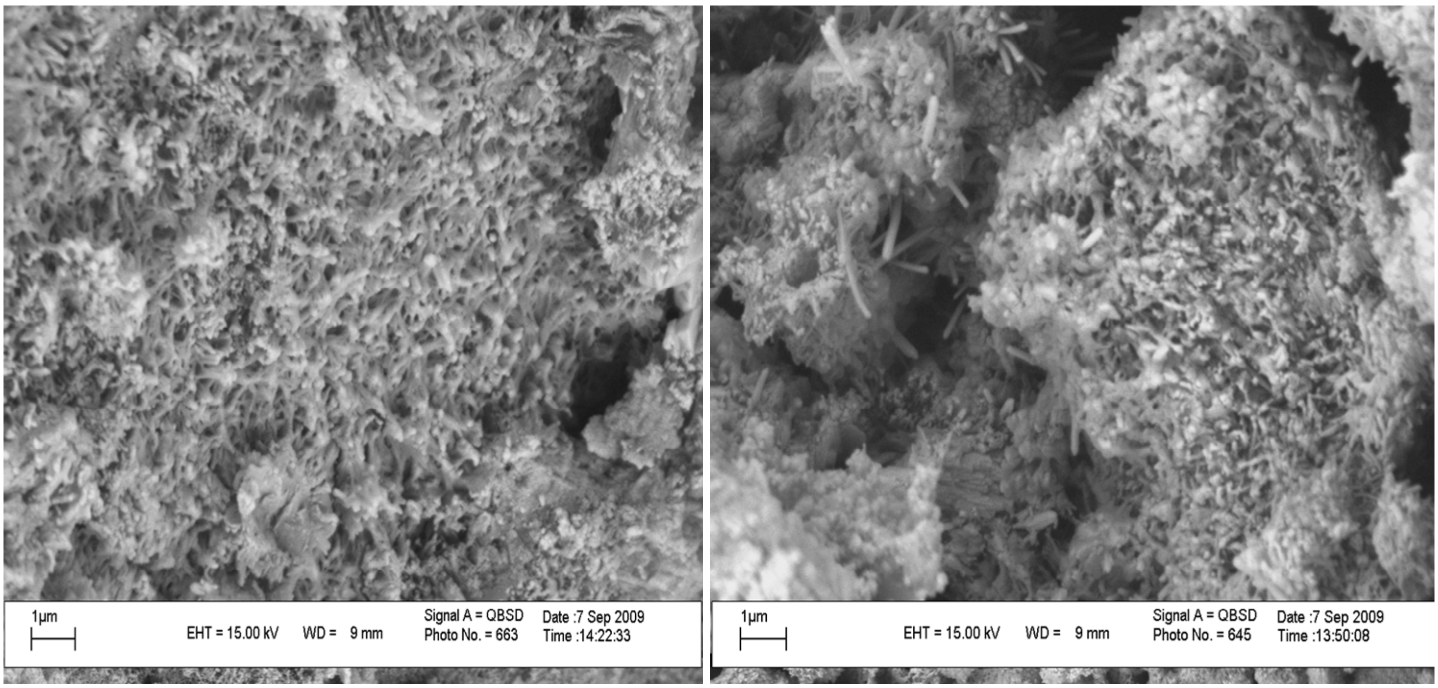
concrete is considered as a specimen. Moreover, as only one peak, 0.662 MeV, is detected in Cs-137, data handling is relatively straightforward (Knoll, 2000).

RESULTS AND DISCUSSION

The data obtained from experiments have been depicted in Figures 3 and 4. Figure 3 shows photon counts versus channel number for a specimen concrete that contains cement and water. The water-to-cement ratio is 0.4 by weight. As seen in Figure 3, the total number (under the photoelectric peak) of passed photons through irradiated specimen is less than the reference specimen. In other word, resistance of irradiated concrete against gamma radiation is more than non-irradiated concrete. Figure 4 shows the same variation for the type of concrete that has 2.75 sand-to-cement ratio by weight.

Table 1. Compressive strength (Kg/cm^2) test results for irradiated and non-irradiated concrete cubes.

Concrete with sand (sand-to-cement ratio 0.43)		Concrete without sand	
Non-irradiated	**irradiated**	**Non-irradiated**	**irradiated**
155	241	145	273



B A

Figure 5. SEM micrographs of irradiated and non-irradiated concrete specimens that have 2.75 sand-to-cement ratio by weight. B. Cement + Sand, irradiated; A. Cement + Sand, non-irradiated.

These Figures show gamma radiation affects on resistance of concrete. In other word, the strength of concrete will increase when it has been subjected to irradiation during solidification. It seems that gamma radiation eliminates the micro pores during solidification. Therefore, the capability of photon absorption of concrete is increased by gamma radiation.

Compressive strength test was used to determine the strength of concrete specimens. Table 1 which was based on average results of three specimens for each category shows compressive strength for irradiated and non-irradiated specimens. By comparing of table data it is obvious that strength of irradiated specimens have been increased due to gamma effect.

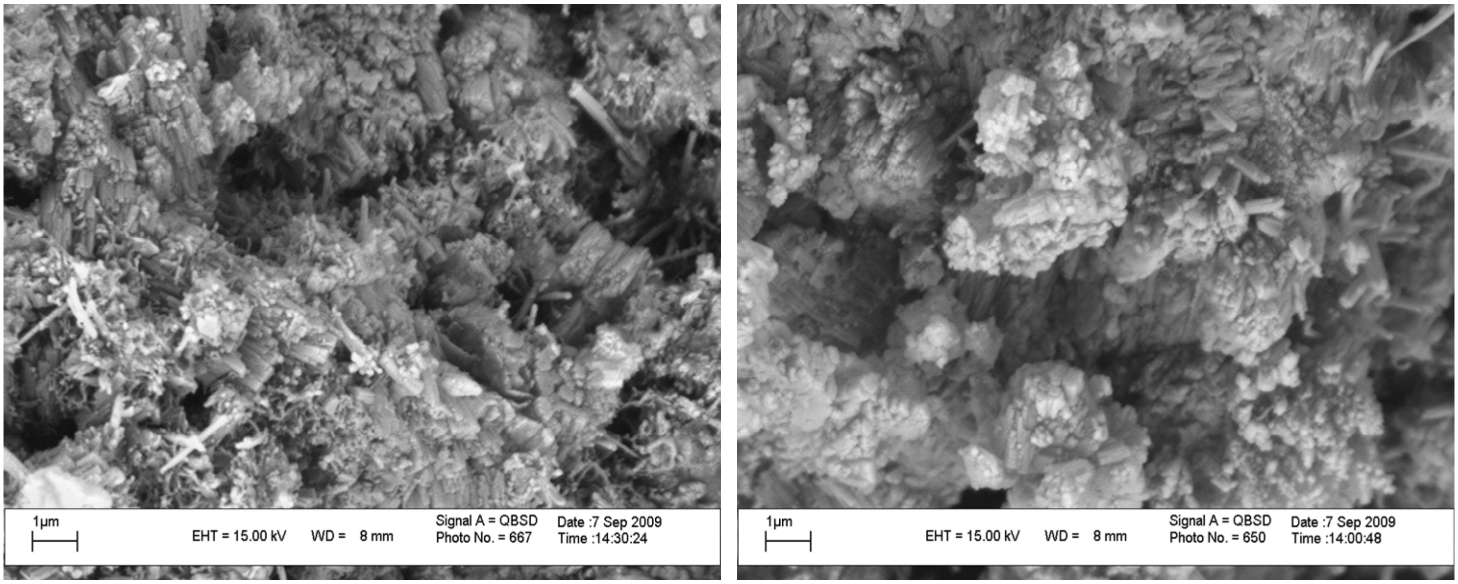
Morphology and microstructure of concrete specimens were examined by SEM, as shown in Figures 5 and 6. The SEM micrographs of concrete specimens indicated that its microstructure is changed by gamma radiating during solidification.

Conclusions

The results of this study demonstrate a potential application of gamma radiation for shielding practices. The photon counts that is transmitted through specimens with no sand is well below that of non-radiated reference specimens at channel No. of about 650 while this is different for the mixes with sand. In mixes with sand the photon counts is lower at channel No. between 0-500 and also about 650. This shows that gamma radiation positively affects on the total number of passed photons.

SEM micrographs for two types of cementitous mixes show that specimens with no sand are less dense than those with sand. Moreover, the radiated specimens are denser as compared to the non-radiated ones.

The compressive strength of both gamma radiated specimens is increased when compared to the reference ones with and without sand. The percentage increase in compressive strength of specimens with no sand is lower



B A

Figure 6. SEM micrographs of irradiated and non-irradiated concrete specimens (without sand). B: Cement without Sand, irradiated. A: Cement without Sand, Non-irradiated.

than that of specimens having sand to cement ratio of 2.75. This can be due to more air-entrainment in mixes with higher amounts of cement content.

This investigation draws attention for use of gamma ray study in designing concrete for shielding purposes, and requires further search.

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