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Comparison of Concrete Containing Barite and Graphite Powder against Gamma-ray and MCNP Code

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ABSTRACT: Concerning the development of nuclear technology in the world and the use of this technology in the industry and medical centers, the attention of countries to this topic and investment in this area has greatly increased. In this research, concrete was made in two series. In the first series, barite powder was replaced with 10, 25, 50, 75 and 100 percent as sand replacement, and in the second series, barite powder with the percentages as mentioned earlier and 10 percent graphite powder was prepared. In the present study, the amount of cement 400 kg/m3 and water to cement ratio of 0.4 and additives have been added to the concrete containing 10% micro-silica. The mechanical properties of these concrete were determined such as compressive strength and tensile strength. Their effect was also tested as a protection against gamma radiation using the CS-137 source and then examined by comparing the MCNP simulation code by Monte Carlo method. The results indicated that a sample containing 10% barite powder plus 10% graphite powder could be an optimal amount of protection against gamma rays. Also, the comparison of experimental results with the MCNP code showed a fairly good agreement, and the trend of its increasing and decreasing was almost the same.

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1. INTRODUCTION

Today in the world, including in our country, the use of nuclear technology in various fields of power plants, industry, agriculture and medicine is expanding. One of the most important issues in nuclear technology is nuclear radiation protection, to prevent harmful environmental effects, as well as the harmful effects on some precision measuring instruments. From the perspective of preservation, all the radiation and particles are not equally important in terms of their penetration and impact on different materials, including living tissue. In the discussion of protection, neutron and gamma radiation is of particular importance because of its unladen nature; they can pass relatively through large thicknesses of the shield and contribute to raising the dose rate outside the shield [1]. In addition to the many uses of radioactive waste, it should be noted that this radiation damages cells and living tissues and protection against it is essential and inevitable [2]. To protect against radiation, absorbent materials should possess high density,high-attenuation coefficient, and high-strength structural features with easy-to-make and inexpensive manufacturing. According to the above, the use of concrete is a suitable alternative for radiation protection [3]. Barite is widely used in the oil and gas drilling industry, coloring industry, pharmaceutical plastics (due to the absorption of radioactive wastes), chemicals, etc. due to its high specificity and low cost. So it can be a good option for gamma radiation protection.

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2. METHODOLOGY

In this study, the mix design procedure is based on the ACI 211 standard. The specimens were made in 12 series in varying percentages of 10, 25, 50, 75, and 100 percent of barite powder replacing sand without and with 10% graphite powder. Also, 10% of micro-silica was added to all mixes, except control specimens. The ratio of water to cement is 0.4 and the cement content of all mixtures is 400 kg/m^3. A super-plasticizer with a weight ratio of 0.3% was also used. To make concrete, the pre-soaked aggregate was first mixed with cement for 1 minute, then the rest of the water, along with the water-soluble super-lubricant, slowly was added and the mixing operation continued for one more minute. After assuring the proper slump of fresh concrete (3 to 5 cm), standard cubic samples of 10 cm for all tests and standard cylindrical specimens of 15 × 30 cm were prepared for tensile testing only. Afterward, the samples were stored in water after 24 hours of wet treatment. Radiographic experiments were performed on 28-day-old specimens exposed to gamma rays by CS-137 fountains with energy of 3.7 MBq. The detector used was sodium iodide NaI (Tl), 2×2, and a multichannel MCA analyzer and Cassy Lab software was also used to analyze the results. The voltage applied to the detector is 500 V. Concrete samples are placed at a distance of 2 centimeters from the detector and 1 cm from the fountain. To reduce background radiation, a protective shield was detected. Figure 1 shows the arrangement of the gamma-ray test.

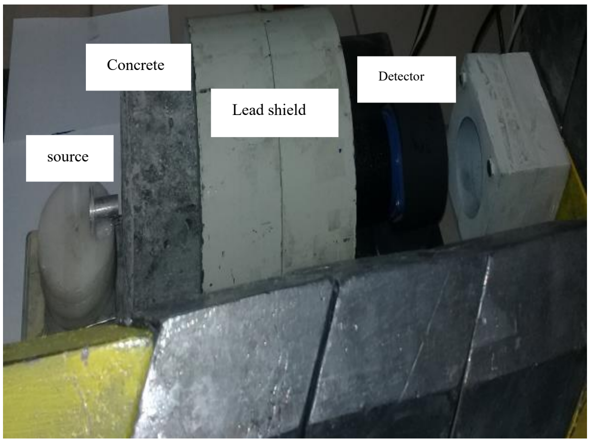

Fig. 1. Layout of irradiation experiments on concrete by gamma fountains and counting by NaI (Tl) detector.

3. RESULTS AND DISCUSSION

3.1.Water absorption and density

According to the results, it can be concluded that the presence of various percentages of barite powder and graphite powder decreases the water absorption of the samples. This is due to barium sulfate, which is the main source of barite powder, has low water absorption and reduces the adhesion of aggregates with cement paste. Moreover, the reduction in the presence of graphite powder is far higher. Also, increasing Barite powder, due to its higher density than sand, increases density in the first series of samples. But in the second series, which combines the percentages of barite powder with 10% graphite powder, due to the partial replacement of lower density (2.22 gr/cm^2) graphite powder with cement, density drops, but with increasing percentages of barite powder, the trend in accordance with the first series is incremental. As it is known, the presence of barite powder and graphite powder increases the density of concrete, especially for samples Ba75G10 and Ba100G10, and places them in the category of heavy concrete.

3.2. Compressive strength and tensile strength

Almost a decreasing compressive strength trend is observed among samples containing various percentages of barite powder and graphite powder, indicates that concrete containing barite powder reduces the compressive strength of concrete compared to control concrete. The reason for this phenomenon can be attributed to the low water absorption of barite powder, which reduces their adhesion to the cement paste. Also, this reduction will increase if graphite powder is present. Due to the low water absorption, their adhesion to cement materials is reduced and therefore, the compressive strength is reduced. The presence of barite powder and graphite powder, although increasing the density of concrete, reduces the compressive strength. The incremental and decreasing trend in the first and second series samples is almost the same and indicates that the compressive strength of the control concrete is lowered for the concrete containing barite powder. Also, the tensile strength is directly proportional to the compressive strength and is approximately 10 to 12% of the compressive strength. It can be concluded that the tensile strength depends only on the nature and size of the materials used in the manufacture of concrete, so that tensile strength can be attributed to the existing cement paste and the degree of adhesion of the paste compounds to aggregates. Since the percentage of water absorption of barite is very low, hence the adhesion of the paste to the barite powder also decreases. Also, this decrease is much higher with graphite powder, but the incremental or decreasing trend of both series of samples is almost the same.

3.3.Ultrasonic Pulse Rate Velocity and Linear Attenuation Coefficient

The ultrasonic pulse rate of the sample containing 10% micro-silica is higher than the rest of the designs, which suggests that this design has better paste quality due to the pozzolanic and filling properties of micro-silica than the other specimens. In addition, the process of pulse velocity changes is in line with compressive strength variations, which indicates the accuracy of the tests. In sum, all specimens have an ultrasonic pulse rate of more than 4500 m/s, which, according to the Whitehurst [4] classification, represents the excellent quality alone. Also, the mixture containing 100% barite powder plus 10% graphite powder with the lowest ultrasonic pulse rate suggests that this design is more resistant to ultrasonic wave velocities despite its highest density than other mix designs. Also the linear attenuation coefficients of concrete samples according to the result, show that the linear attenuation coefficient of the sample containing 10% of the barite powder plus 10% of the graphite powder is higher than the rest of the samples. It looks like this sample has the optimum amount of protection against gamma radiation.

A sharp decrease of the Linear attenuation coefficient of the sample containing 50% of the barite powder among other samples seems to be logical with regard to reduction in the speed of ultrasonic pulse rate, and this somehow indicates the accuracy of the experimental results.

3.4. Simulation results

In the MCNP code, the weight percentages of the elements obtained from the EDS test results are used. The results show a fairly good agreement between the two methods. Since geometric conditions are assumed ideal in the Monte Carlo simulation where the effect of concrete strength is not considered, so the amount of attenuation coefficients calculated by the MCNP code is slightly higher (about 5.44%) in comparison to the experimental results. It can be said that the increasing and decreasing trend for both methods is almost the same.

4. CONCLUSIONS

1. The presence of barite powder and graphite powder in samples, although increasing linearly, will reduce compressive strength.

2. The presence of graphite powder in concrete increases the linear attenuation coefficient of the samples.

3. The presence of the maximum linear gradient of gamma-ray results in the fact that a mixture containing 10% barite powder plus 10% graphite powder can be a good alternative to radiation protection. It is also possible to increase its compressive strength by increasing the percentage of micro-

silica and other additives.

4. The comparison between Monte Carlo simulation and experimental results showed a fairly good agreement, and the incremental and decreasing trend of the attenuation coefficients are in line for both methods.

REFERENCES

[1] A.B.Chilton, J.K. Shultis, and R.E. Faw, Principles of Radiation Shielding, *Prentice-Hall Englewood Cliffs*, 488 (1984).

[2] I.Akkurt, H.Akyıldırım , B.Mavi , S.Kilincarslan , C.Basyigit, Photon attenuation coefficients of concrete includes barite in different rate, *Annals of Nuclear Energy*, 37 (2010) 910-914.

[3] C. Basyigit, I.Akkurt, A.Akkas, S.Kilincarslan, B.Mavi, K.Gunoglu, Determination of Some Heavyweight Aggregate Half Value Layer Thickness Used for Radiation Shielding, *in Proceedings of the International Congress on Advances Applied Physics and Materials Science, in Antalya*, (2012).

[4] E.A.Whitehurst, Soniscope Tests Concrete Structures, *Journal of the American Concrete Institute*,47(1951)443-444.

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