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Research Article

Determination of Mass Attenuation Coefficients of High Strength Lightweight Concrete Which Producing Using Raw Perlite Aggregate

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Abstract
The development of technology increases the environmental pollution and radiological effects. In the present work, the radiation effects were determined experimentally, in the high strength lightweight concrete according to water /cement ratio. Also, the mass attenuation coefficients of the high strength lightweight concrete samples which producing with perlite aggregate were determined. The measurements were performed using a high-purity germanium detector. Ten different gamma rays energies were used. It is observed that the mass attenuation coefficients of the concrete samples are decreasing with the increasing photon energies. The concrete obtained with perlite aggregate can be used for protect from the radiation.

Keywords: Cement, Mass Attenuation Coefficient, Perlite, Concrete.

Ham Perlit Agrega Kullanılarak Üretilen Yüksek Mukavemetli Hafif Betonun Kütle Zayıflamasının Belirlenmesi

Öz
Teknolojinin gelişimi ile çevre kirliliği ve radyolojik etkiler artmıştır. Bu çalışmada, ham perlite agregası kullanılarak üretilen yüksek dayanımlı hafif betonda su-çimento oranının radyasyona etkisi deneysel olarak belirlenmiştir. Ayrıca, beton numunelerin perlit agregalı kütle zayıflama katsayıları belirlenmiştir. Ölçümler, yüksek saflıkta bir germanyum detektörü kullanılarak gerçekleştirilmiştir. Farklı gama ışın enerjileri kullanılarak beton örneklerinin kütle soğurma katsayılarının artan foton enerjileri ile azaldığı gözlenmiştir. Perlit agregası ile elde edilen betonun radyasyondan korunmak için kullanılabilir olduğu ortaya çıkmıştır.

Anahtar Kelimeler: Çimento, Kütle Soğurma Katsayısı, Perlit, Yüksek Dayanımlı Hafif Beton.

1. Introduction

The light weight concrete, which has been used since antique Roman times, has become popular due to its low unit weight, high durability and good heat insulation. Especially, volcanic origin lightweight aggregates cause increase in strength, durability and heat insulation properties of the concrete due to their pozzolanic activities that reacts with free and reactive agents comes out of the cement hydration. Light weight concrete shows quite different properties depending on the production and used materials. With the advance and wide use of the technology, various equipment and materials used for the benefit of the human being have become dangerous to human health due to emission of the radiation. Especialy; hospitals, industry, research centers, nuclear reactors, and some of devices and materials used in agricultural sector have negative effects even though they provide quite a bit of benefits for human beings. There are three major proposals to minimize effects of the radiation on society, employees, patients, and workers. These proposal are used to keep the residents away

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from these regions which radiation-emitting apparatus to minimize the time people spend in these regions, and to increase the protection precautions. The most efficient method among these proposals is considered to be use of protective materials. The most commonly materials used for protection are concrete and lime plates covered with lead. The reasons for the usage of concrete are ease and inexpensiveness of its production, and formation of protective layer for both for proton and neutron radioactivity by the concrete. To provide optimum protection from the radiation, the absorption properties of the protective materials need to be known. Concretes can have different properties, due to different mixtures and aggregates. So that there is very limited information on transmission of photons and neutrons by light, normal and heavy weight concrete. Kase et al. (2003) have shown that the radiation absorption or transmission of the concrete do not depend on density but neutron transmission varies with the hydrogen content. Also, the photon transmission varieswith the atomic structure. The perlite aggregate have open and closed porous. Also it has approximately ten percent due to too much variation water inside in pourus space due to perlite is formed by the cooling of the magma in water. This structure of perlite aggregate decreases the radiation transmission of the concrete which produced with this aggregate. Stankovic et al. (2010) demonstrated that the materials and theirratios cannot be determined the desired levels of radiation in concrete in the materials used for the production of the concrete. Common opinion is the radiation absorption of concrete which is directly proportional with its aggregate type and density. Akkurt and Akyıldırım (2012) obtained results supporting this common opinion. They have shown that the concrete obtained by the usage of pozzolanic aggregate do not provide ideal radiation absorption dueto its porous structure and low unit weight. Perlite aggregate shows pozzolanic activity due to its nature. So that increasing the strength and cement matrix density by reacting with the free lime released with the hydration of the cement. This increases the durability and lifetime of the concrete.

Table 1. Properties of concretes types.

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
Cement (kg/m^3)	600	600	550	550	450	450	400
Water (kg/m^3)	300	240	275	220	225	180	160
Super fluidizing agent	1%	1%	1%	1%	1%	1%	1%
Aggregate (kg)	100 % Perlite	100 % Perlite	100 % Perlite	100 % Perlite	100 % Perlite	100 % Perlite	100 % Perlite

2. Materials and methods

In the production of high strength light weight concrete (HSLWC), cement and Erzincan Molla köy raw perlite aggregate were used. Unit weight of perlite aggregate varies between 1020 and 1260 kg/m^3 depending on the aggregate's grading. The mixes grading was prepared due to standard specification for light aggregates for structural concrete (ASTM C330-04) and the relationship of Fuller $\left(P_i = \left(\sqrt{\left(di/D\max\right)}\right)^{1/n}\right)$.

The aggregate was mixed by water (pre-wetted), 5% of its weight before the mixing. This is the reason that the light weight aggregates cause a problem by absorbing the water of the concrete during mixing, transfer and placement (pouring/casting). To prevent this, the pre-wetting (adding water to) of the aggregates is needed before the mixture. During mixing, aggregates first put into the mixer. It was mixed about 3 minutes. In a Table 2. Chemical composition and physical properties of the cement used in concrete.separate cup water, plasticizer and cement were mixed to obtain a homogenous mix. The fluid mix was slowly poured into the aggregate in the mixer. This process was completed within about 3 minutes. After, the mixer was operated about 5 minutes to complete the concrete mixing. In the present work, it was determined the radiation effects of water to cement ratio. 7 different mixes were prepared with 4 different cements and 2 different waters to cement ratios, as seen from Table 1. These samples were cured in cure tank for 28 days. All concrete samples were tested according to TS 3114 and ASTM C39. The chemical and physical properties of the cement used in concrete are given in Table 2. The chemical composition of perlite aggregate is given in Table 3.

Table 2. Chemical composition and physical properties of the cement used in concrete.

Chemical composition	(%)
Silicon dioxide	74.6
Titanium dioxide	0.027
Aluminum oxide	13.20
Ferric oxide	0.480
Iron oxide	0.130
Manganese oxide	0.075
Magnesium Oxide	0.018
Calcium oxide	0.750
Sodium oxide	3.100
Potassium oxide	3.140
Phosphorus pentoxide	0.004
Furnace lost	2.370

Table 3. Chemical composition of perlite aggregate used in concrete.

Chemical composition	**% Weight**	
Calcium oxide	64.02	
Silicon dioxide	20.31	
Aluminum oxide	5.64	
Ferric oxide	3.27	
Magnesium oxide	2.09	
Sulfur trioxide	2.86	
Potassium oxide	0.93	
Sodium oxide	0.87	
Physical properties		
Density (g/cm^3)	3.11	
Specific surface (cm^2/g)	3489	
200 micrometer sieve coarser (%)	-	
90 micrometer sieve coarser (%)	0.3	
40 micrometer coarser (%)	8.4	
Volumetric expansion	2	
Loss on ignition	0.90	
Insoluble residue	0.31	
Compressive Strength	7 day	38.8 MPa
	28day	45.78 MPal

The experimental measurements were performed in Prof. Dr. Wolf Weyrich High Energy Spectroscopy Laboratories of Atatürk University, Erzurum, Turkey. The schematic view of the experimental setup is shown in Figure 1.

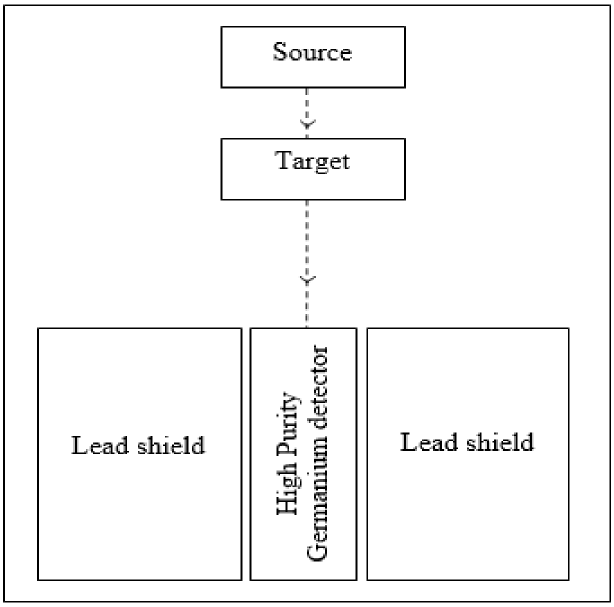

Figure 1. The detection geometry for the determination of mass attenuation coefficients of concrete types (Lead shields have thickness of 5 cm).

The mass attenuation coefficients of produced concretes were measured by using a high-purity germanium detector. The high-purity germanium detector has a beryllium window thick of 0.12 mm and active area of 200 mm^2 and a resolution of 182 eV at 5.9 keV. The spectra were recorded by using a Canberra (AccuSpec) PC-based multichannel analyzer card. Operating parameters of the system were governed and controlled by the computer program Genie-2000. The data were collected into 4096 channel of the multichannel analyzer. Data were analyzed by the Origin 7.5 software program. The concrete samples were irradiated at 59.54, 80.99, 121.78, 344.27, 356.02, 662.62, 778.20, 964.08, 1112.07 and 1408.01 keV energies emitted from 10 μCi ^{241}Am, ^{133}Ba, ^{137}Cs and ^{152}Eu point sources. The concrete samples were placed at a distance of 30 mm from the radioactive source. The measuring time for each target was 1800 s. The spectra were taken with and without the target in the primary incident beam.

Tablo 4. The experimental mass attenuation coefficients of the concrete types.

Energy (kilo electron volt)	Mass attenuation coefficient (cm^2/g) Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
59.54	0.5928±0.034	0.5869±0.019	0.5733±0.032	0.5596±0.023	0.5423±0.026	0.5322±0.021	0.5102±0.03
80.99	0.4153±0.024	0.4114±0.013	0.4056±0.022	0.3997±0.017	0.3822±0.018	0.3724±0.015	0.3651±0.02
121.78	0.3420±0.019	0.3121±0.009	0.3081±0.017	0.3061±0.013	0.2954±0.014	0.2854±0.011	0.2714±0.01
344.27	0.2308±0.030	0.2212±0.007	0.2125±0.012	0.2015±0.008	0.1908±0.009	0.1865±0.007	0.1752±0.01
356.02	0.1999±0.011	0.1845±0.006	0.1715±0.009	0.1666±0.007	0.1542±0.009	0.1425±0.006	0.1325±0.02
661.62	0.1523±0.009	0.1425±0.005	0.1356±0.007	0.1254±0.005	0.1125±0.005	0.1111±0.004	0.1025±0.01
778.20	0.1423±0.008	0.1411±0.005	0.1309±0.007	0.1169±0.005	0.1111±0.005	0.1023±0.004	0.1001±0.02
964.08	0.1279±0.007	0.1261±0.004	0.1254±0.007	0.1137±0.005	0.1107±0.005	0.1008±0.004	0.0945±0.03
1112.07	0.1199±0.006	0.1182±0.004	0.1173±0.006	0.1111±0.005	0.1100±0.005	0.1002±0.004	0.0922±0.05
1408.01	0.1155±0.006	0.1053±0.003	0.1021±0.006	0.1010±0.004	0.1005±0.005	0.0965±0.004	0.0912±0.02

Table 5. The theoretical mass attenuation.

Energy (kilo electronvolt)	Mass attenuation coefficient (cm^2/g) Cement	Perlite
59.54	0.501	0.269
80.99	0.290	0.197
121.78	0.181	0.154
344.27	0.103	0.101
356.02	0.101	0.100
661.62	0.0769	0.0741
778.20	0.0712	0.0704
964.08	0.0643	0.0641
1112.07	0.0599	0.0587
1408.01	0.0531	0.0523

The background count rate was subtracted from the measurements. The mass attenuation coefficients (cm^2/g) is obtained by;

$$\frac{\mu}{\rho} = \frac{1}{\rho x} \ln\left(\frac{I_0}{I}\right) \qquad (1)$$

where x is the material thickness, ρ is the material density, I and I0 are the background subtracted number of counts recorded in detector with and without concrete material between detector and source, respectively. The theoretical mass attenuation coefficients were obtained by using a computer program.

3. Results and Discussion

There is no consensus on what the mix of the concrete should be to protect from radiation. Şahin et al. (2011) showed that the mass attenuation coefficient increases with the increasing cement amount and the decreasing coefficients of cement and perlite water cement ratio in conventional concrete. Ogundare et al. (2012) showed that the mass attenuation coefficient does not depend only unit weight. The mass attenuation coefficient depends on the structure of the aggregate used in the concrete. Aminian et al. (2007) have investigated two concrete samples of different aggregate with unit weight 3.11 gr/cm^3 and 2.6 gr/cm^3.They have shown that both of samples can be used to protect from radiation. But the density (unit weight) is not an essential criterion. Akkurt and Akyıldırım have Perlite aggregate can be used to produce concrete for protect from the radiation. So it can be said that the mass attenuation coefficient varies significantly based on the structure of the aggregate used in the production of the concrete. The overall error in the experimental parameters is the sum of the uncertainties in different factors, namely, the evaluation of peak areas (2.3-4.7%), target mass thickness (1.5-4.2%) and statistical error (< 1.00%). Total errors affecting the experimental parameters are calculated between 2.9-6.4%. compared the mass attenuation coefficient of the conventional concrete and concrete with the pozzolanic aggregate. They obtained that the mass attenuation coefficient of the pozzolanic concrete is lower than the conventional concrete due to porous structure and low unit weight of pozzolanic aggregate. De Oliveira et al. showed that the mass attenuation coefficient of the concrete varies depending on the porosity and structure of the concrete. The theoretical mass attenuation coefficients of cement and perlite are given Table 5. Also, the experimental mass attenuation coefficients of the concrete samples are given Table 4. As seen from Table 4, the mass attenuation coefficients are decreasing with the increasing photon energies. Also, the mass attenuation coefficients decrease with the decreasing the cement amount. Şahin et al (2011) have shown that the mass attenuation coefficient of the conventional concrete increases with the increasing cement amount. Since the mass attenuation coefficient of the cement is higher than the aggregate used in the production of the concrete, the mass attenuation coefficient increases with the increasing cement amount.

4. Conclusions

In this work, the mass attenuation coefficients of the high strength lightweight concrete samples were determined. It can be concluded that perlite is an important aggregate. The addition of perlite as an aggregate in concrete is an alternative option to be used for the purpose of radiation shielding. Also, the mass attenuation coefficient varies with aggregate structure in the same unit weight

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