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Cement Paste as a Radiation Shielding Material

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Cement, mainly, natural limestone and clay mixture after being heated at high temperature is obtained by milling and it is defined as a hydraulic binder material. Especially, cement is used in production concrete. The photon attenuation coefficient (μ, cm^{-1}) for cement paste has been measured using gamma spectrometer containing NaI(Tl) detector and MCA at 835, 1173, and 1332 keV. Cement paste was prepared with types of Portland cement which is CEM I 52,5 R- and CEN reference sand has been used according to TS EN 196-1 standard. The mass attenuation coefficients have been calculated at photon energies of 1 keV to 100 GeV using XCOM and the obtained results were compared with the measurements at 835, 1173, and 1332 keV.

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1. Introduction

The cement industry is one of the basic industries that play an important role in the developing countries. Also, cement is one of the most common structural materials used in constructions such as home, office, hospital, etc. For this reason, investigation of radiation shielding properties of cement have been important.

The probability of a photon interacting in a particular way with a given material, per unit path length, is called the linear attenuation coefficient [1]. The linear attenuation coefficient per unit mass of the material is expressed as a mass attenuation coefficient to avoid the effects of variations in the density of a material for reference purposes [2].

There is a lot of studies in literature related with linear attenuation coefficients of different materials such as building materials, concrete, glass systems and steels [3–8]. These studies are based on experiment and theory. A significant number of studies related with attenuation coefficients of concretes which including different aggregates and having different percentages of water-cement have been realized.

In this study, for determination of radiation shielding properties of cement paste, photon attenuation coefficients have been measured at 835, 1173, and 1332 keV. The used results half value layer thickness (HVL) and tenth value layer thickness (TVL) have been calculated.

2. Materials and methods

Cement paste was prepared with type of Portland cement which is CEM I 52,5 R and CEN reference sand has been used according to TS EN 196-1 standard.

The photon attenuation coefficients of cement paste have been measured using the gamma spectrometer system containing NaI (Tl) detector coupled to a digital spectrum analyzer (DSPEC LF) which was a full featured 16 K multichannel analyzer on advanced digital signal processing techniques, were recorded on the MAESTRO-32 gamma spectroscopy software. The measurements have been carried out at 835, 1173, and 1332 keV which were obtained from ^{54}Mn and ^{60}Co radioactive sources. The schematic arrangement of the experimental setup used in the present study is shown in Fig. 1.

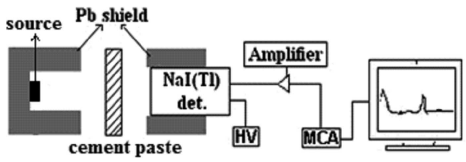

Fig. 1. Schematic view of the experimental setup.

The photon attenuation coefficients have been evaluated comparing I and I_0, which are the measured count rates in detector, respectively, with and without the absorber of thickness x (cm)

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

The effectiveness of γ-ray shielding is described in terms of the HVL or the TVL of a material. The HVL is the thicknesses of an absorber that will reduce the radiation to half, and the TVL is the thicknesses of an absorber that will reduce the γ-radiation to one tenth of its original intensity. Those are obtained as

$$\mathrm{HVL} = \frac{\ln 2}{\mu}, \tag{2}$$

$$\mathrm{TVL} = \frac{\ln 10}{\mu}. \tag{3}$$

The measured photon attenuation coefficients (μ) were compared with the calculation obtained using XCOM computer code. The XCOM is a data base and can run on a PC and it uses pre-existing data bases for coherent and incoherent scattering, photoelectric absorption, and pair production cross-sections to calculate mass attenuation coefficients at photon energies of 1 keV^{-1} [9]. In the XCOM code chemical contents are input and output is the mass attenuation coefficients (μ/ρ). The chemical compositions of cement paste is shown in Table.

TABLE

Chemical compositions of cement paste.

Chemical compositions [%]	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3
CEM I 52,5 R	20.09	3.87	4.84	64.02	1.15	2.83

3. Results and discussion

The linear attenuation coefficients (μ) for cement paste have been measured at the photon energies of 835, 1173, and 1332 keV. The obtained results are displayed in Fig. 2. It can be seen that the measured results decrease with increasing photon energy.

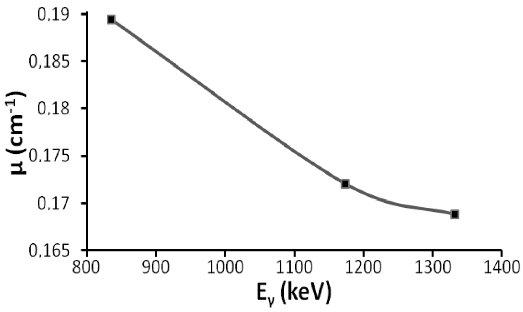

Fig. 2. Measured photon attenuation coefficients.

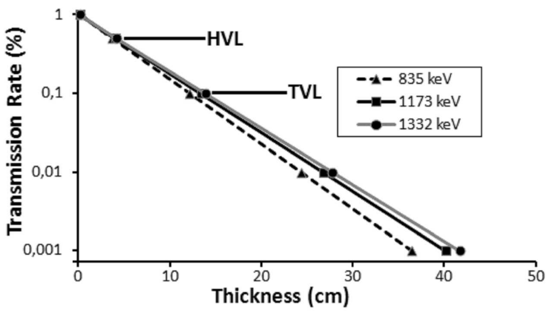

Fig. 3. Percentage transmission for composite samples as a function of thickness at different photon energies.

The transmission rate is an important parameter in order to test the radiation shielding properties of a material. This is shown in Fig. 3, where it was displayed as a function of cement paste thickness at three different photon energies. It is clear from this figure that larger thickness of materials is needed to stop higher energy photons.

The measured and calculated results are compared in Fig. 4. It can be seen from this figure that the linear attenuation coefficients of photon depends on the energy of the photon that interacts with the material. This is because of the different photon absorption mechanism which are photoelectric at low energy, Compton scattering low and mid-energy range and pair production after process (after 1022 keV) [5]. In Fig. 5 it can be seen that there is a good agreement between experimental and calculated results.

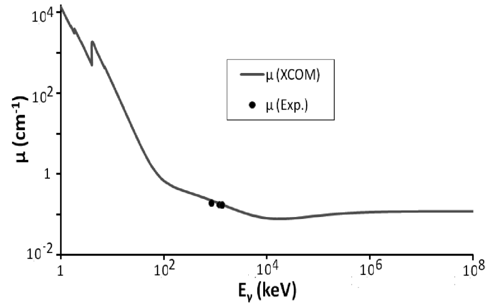

Fig. 4. The photon attenuation coefficient of cement paste as a function of photon energies.

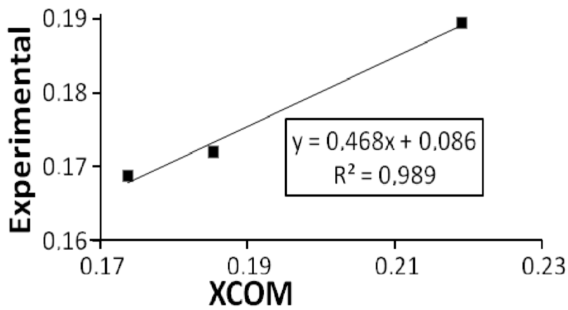

Fig. 5. Correlation between experimental and calculated results.

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