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Research Article

The Effect of Marble Powder Additive at Different Ratios on the Radiation Absorption Parameters of Barite Based Concretes

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Abstract:

This article contains the results of an experimental study to investigate the radiation shielding effect as a result of adding crushed marble powder at different rates to barite-based concretes. The mixtures of the produced concretes were calculated according to TS 802. In 1st group concretes formed by 9x9x9 cm sized cube samples, cement and aggregate ratio were kept constant and marble and barite ratios were changed. In the 2nd group concretes, the cement and barite ratio were kept constant and the marble and aggregate ratios were changed. The linear attenuation coefficients have been measured at 1773 and 1332 keV for samples using a gamma spectrometer that contains a 3"x3" NaI (Tl) detector and connected to Multi-Channel Analyzer (MCA). Also, the correlation between linear attenuation coefficients and marble doped % for the photon energies was calculated and R^2 was found to be 0.90 and above for all samples. In addition, these results have been used to calculate the half value layer (HVL) and mean free path (mfp) parameters. This study shows that the added of crushed marble powder contributes positively to the radiation absorption properties of barite added to concrete.

1. Introduction

With the use of natural stones as building and decoration materials, natural stone production has gained importance. Marble is also an important natural stones used for decoration purposes. Turkey possesses nearly 40 percent of the world's marble reserves, totalling 13.9 billion tons, with 5.2 billion tons [1]. The buildings are constructed mainly from concrete containing cement, water and aggregates. Two main factors have to be taken into account when constructing buildings: one is earthquake resistance, and the other is radiation resistance [2]. Therefore, the development of different shielding materials is important for radiation protection and concrete strength. In the production of concrete, different materials and methods are used in studies on the strength and durability of concrete. One of these materials is a marble powder. Marble powder fills the existing voids in the concrete by creating a filling effect in concrete mixtures, which positively affects the compressive strength of concrete [3, 4]. Marble powder consists of the smallest-sized marble granules formed during the cutting of blocks and slabs in marble processing plants. Due to the use of water in the marble cutting process, marble powders are transported to the settling pools together with water. Marble powder deposited in the pools is then taken to the waste sites. Marble powders are either precipitated using a sedimentation method or released directly into the field. It is a known fact that wastes that cannot be non-recycled cause problems for the environment. Therefore, in order to reduce environmental pollution, it will be useful to evaluate marble powders in different industrial areas [5].

In the studies on the use of marble wastes in concrete production [6-8]; it is stated that the pressure resistance will increase when the ratio of fine material in concrete production is changed with marble powder.

However, there are no come across studies investigating the radiation shielding properties of barite-based concretes produced using different amounts of waste marble powder in the literature.

For this reason, in this study, investigated radiation shielding properties of marble powder doped barite-based concretes. The shielding measurements have been performed via a gamma spectrometer in the Radioactive Research Laboratory of Amasya University, Sciences and Arts Faculty. The concretes have been produced in the Structural Material Laboratory of Vocational School of Technical Sciences at Amasya University.

2. Material and Methods

2.1. Sample Preparations

Mixing calculations of all concrete samples were made for minimum C30 / 37 class concrete design using TS 802 [9] standard. CEM IV B (P) 32.5N pozzolanic cement was used in various dosages in concrete samples due to its easy regional availability. The largest aggregate grain diameter was 16mm. The grain diameter distributions and specific weights of the aggregates used in the study are presented in Table 1. Also, the W/C ratios of all mixtures have kept as 0.54 and the consistency of the mixtures was adjusted by using super plasticizer additive (0.50-1.50% of cement weight). Within the scope of the study, the produced concrete samples, the amount of material in the mixture calculation of these samples and their proportions are presented in Table 2. Concrete mixtures were prepared in proportion given in Table 1 as 3 for each series of concrete. The samples have placed in 9x9x9 cm specially prepared concrete molds in two stages using a vibrator (Fig.1). Produced concretes have kept at least 28 days under the cure conditions pecified in EN 12390-2 [10] standard.

Figure 1. *Concrete molds*

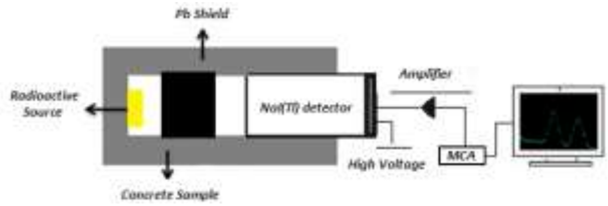

Figure 2. *The schematic view of gamma-ray spectroscopy system*

2.2. Experimental procedures

The LAC was determined by using marble powder doped concrete samples prepared as 9x9x9 cm size cubic for 1773 and 1332 keV energy values which were produced by Co-60 radioactive sources.The shielding measurements have been performed using a gamma-ray spectrometer with 3"x3" NaI (Tl) detector in the Radioactive Research Laboratory of Amasya University Science & Arts Faculty. The system contains a 3"x3" NaI (Tl) detector coupled to a digital spectrum analyzer (DSPEC LF) which was connected to the Multi-Channel Analyzer (MCA) provided by ORTEC hardware controlled by MAESTRO-32 software [11] (Fig. 2).

The LAC is calculated using the Beer-Lambert equation:

$$\mu = \frac{1}{x} In(\frac{N_0}{N})$$

Table 1. *Particle diameters distribution and physical properties in aggregates*

Sample Type	Sieve Analysis (% Passed)								Unit Volume Mass (kg/m^3)
	16	9.5	8	4	2	1	0.5	0.25	
Crushed Stone	100	67	37	0	0	0	0	0	2680
Crushing Sand	100	100	100	97	69	41	27	18	2680
Barite	98	69	47	1	1	1	1	0	4050
Thin Barite	100	100	100	83	44	14	6	3	4050
Marble Powder	100	100	100	100	100	100	100	100	2700

Table 2. *Amounts and ratios of material used in 1 m^3 concrete mixture*

		Aggregate (% volume) (kg)				
Sample Name	**Cement Dosage (kg)**	**Marble powder**	**Crushed stone Aggregate**	**Barite**	**Water (kg)**	**Unit Volume Mass (kg/m^3)**
16-CIV500-M0-A30-B70	500	0 (0)	30 (446)	70 (1572)	270	2790
16-CIV500-M4-A30-B66		4 (60)		66 (1482)	270	2762
16-CIV500-M8-A30-B62		8 (120)		62 (1392)	270	2735
16-CIV500-M12-A30-B58		12 (180)		58 (1302)	270	2705
16-CIV500-M0-A70-B30	500	0 (0)	70 (1040)	30 (674)	270	2486
16-CIV500-M4-A66-B30		4 (60)	66 (981)		270	2489
16-CIV500-M8-A62-B30		8 (120)	62 (921)		270	2492
16-CIV500-M12-A58-B30		12 (180)	58 (862)		270	2492

Table 3. *Amounts and ratios of Material Used in 1 m^3 Concrete Mixture for the 1^{st} group*

		Aggregate (% volume) (kg)				
Sample Name	Cement Dosage (kg)	Marble powder	Crushed stone Aggregate	Barite	Water (kg)	Unit Volume Mass (kg/m^3)
16	500	0 (0)	30 (446)	70 (1572)	270	2790
17		4 (60)		66 (1482)	270	2762
18		8 (120)		62 (1392)	270	2735
22		12 (180)		58 (1302)	270	2705

Table 4. *Amounts and ratios of Material Used in 1 m^3 Concrete Mixture for the 2^{nd} group*

		Aggregate (% volume) (kg)				
Sample Name	Cement Dosage (kg)	Marble powder	Crushed stone Aggregate	Barite	Water (kg)	Unit Volume Mass (kg/m^3)
19	500	0 (0)	70 (1040)	30 (674)	270	2486
20		4 (60)	66 (981)		270	2489
21		8 (120)	62 (921)		270	2492
23		12 (180)	58 (862)		270	2492

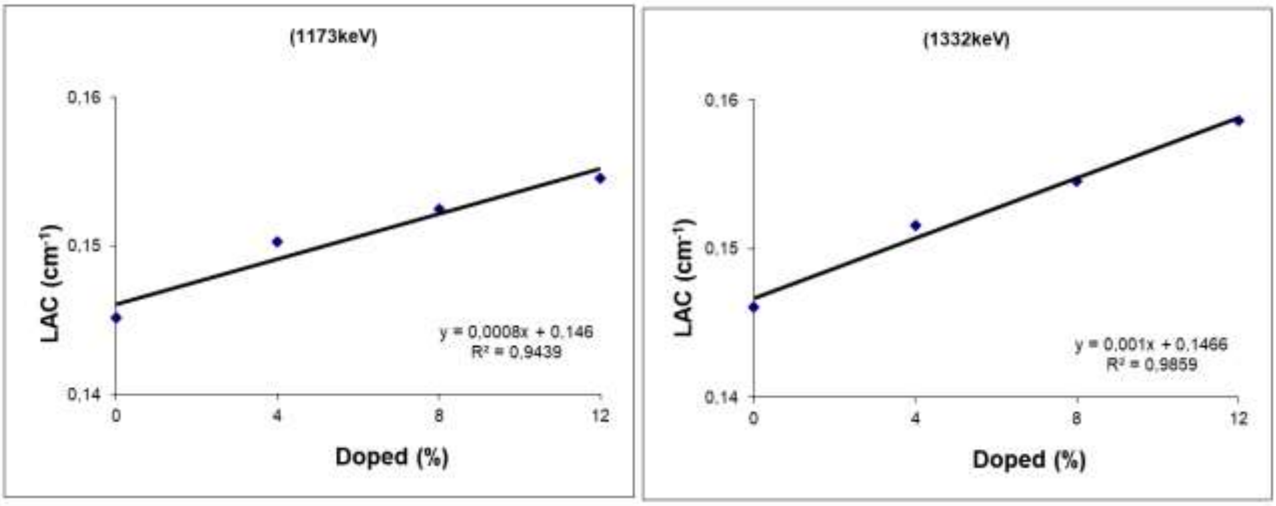

Figure 3. *Variation of linear attenuation coefficient with energy for 1^{st} group samples*

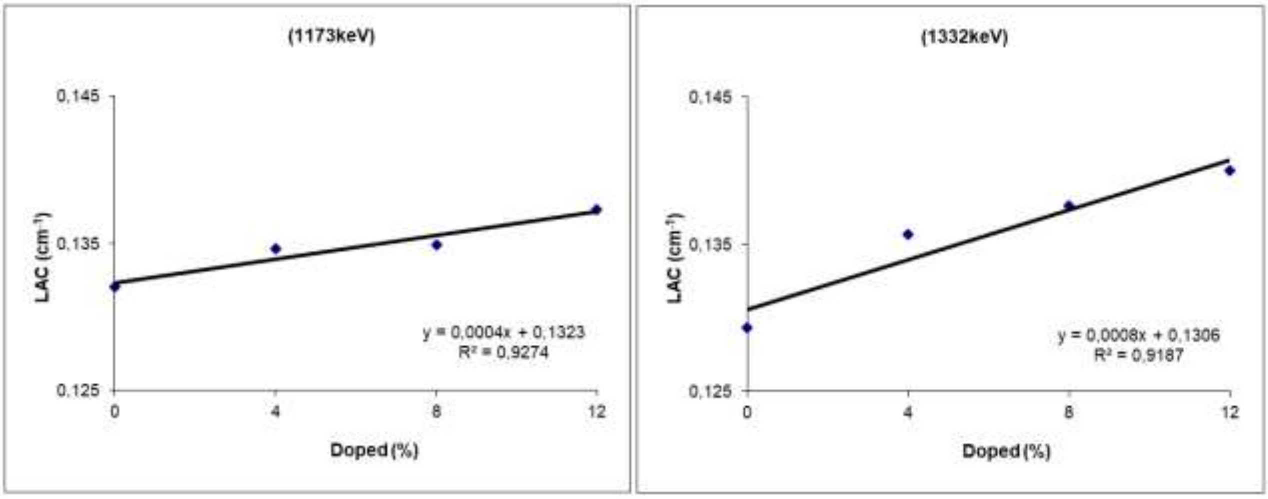

Figure 4. *Variation of LAC with energy for 2nd group samples*

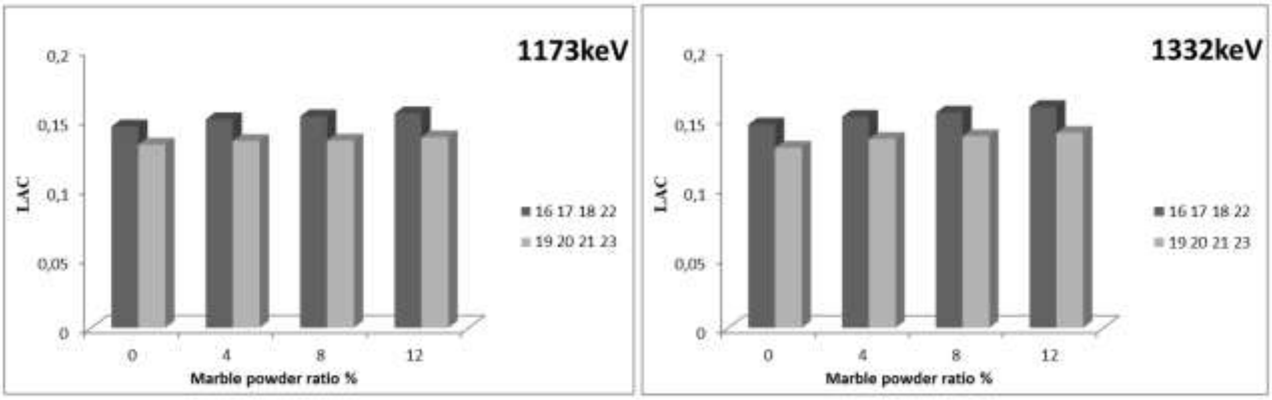

Figure 5. *Comparison of LAC with marble powder ratio for all samples*

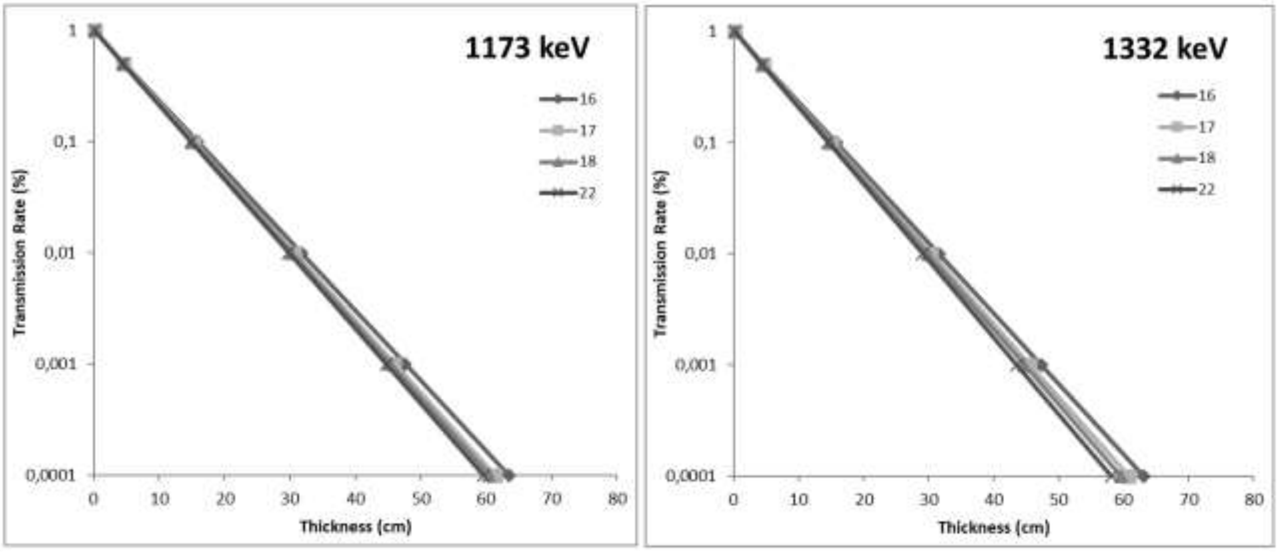

Figure 6. *The transmission rate of the samples as a function of concrete thickness for 1st group samples*

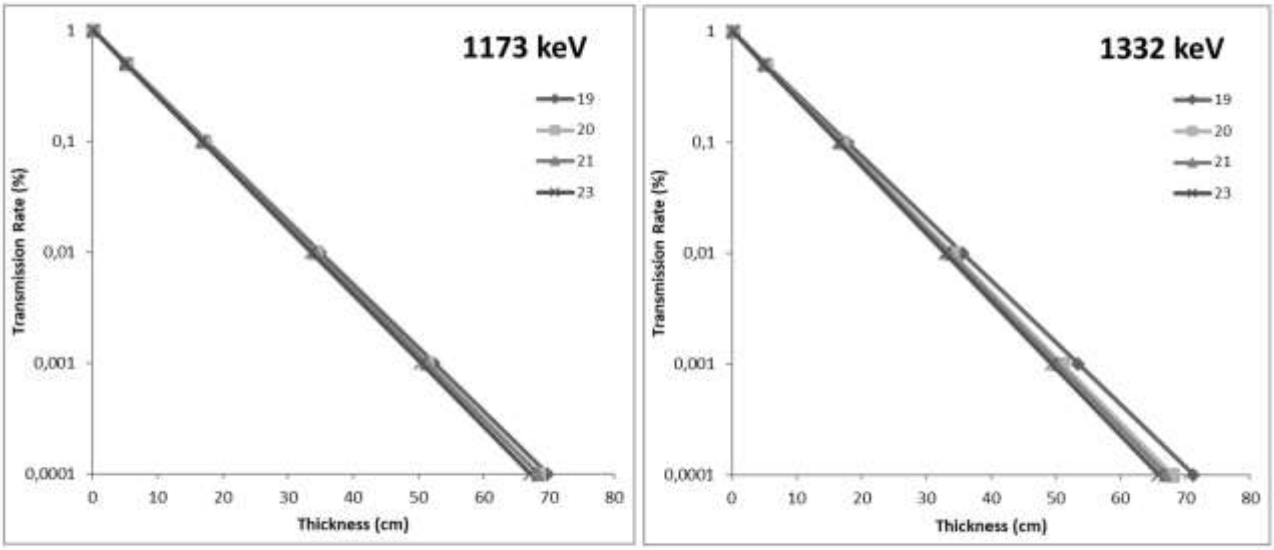

__Figure 7.__ The transmission rate of the samples as a function of concrete thickness for 2nd group samples

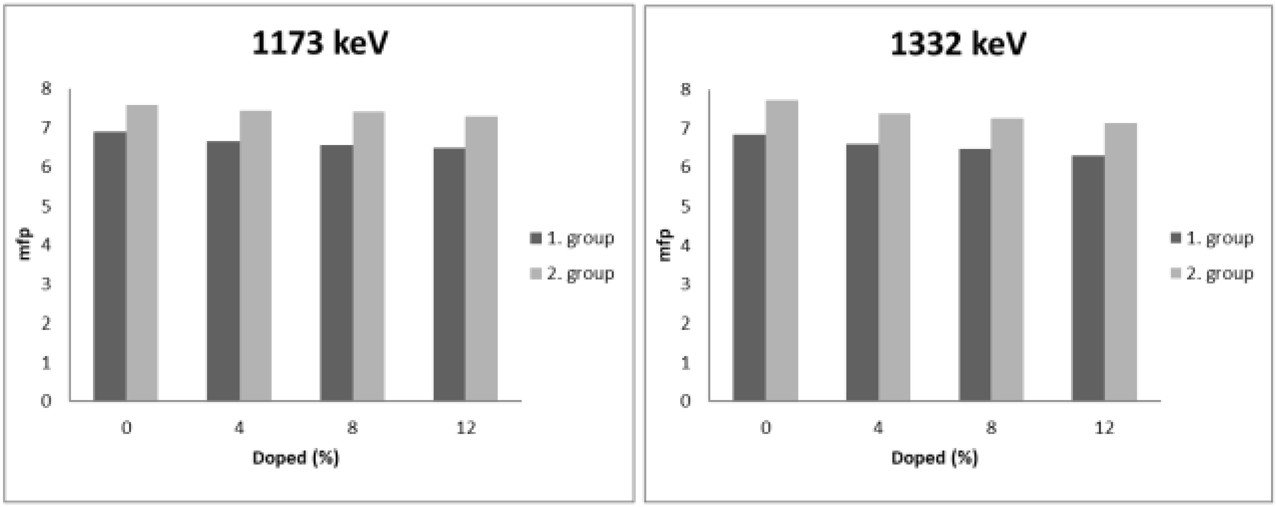

***Figure 8.** Mean free path- Marble powder ratio % changes measured for 1st and 2nd group samples*

where μ is the linear attenuation coefficient, x is the concrete samples thickness, N_0 and N are the net count before attenuation and after attenuation.

Eight groups of concrete were prepared to test the contribution of marble doped barite-based concretes to protect against gamma-rays. Each concrete was prepared with different amounts of marble powder, barite, cement and aggregates (Table 3 and Table 4).

3. Results and Discussions

Figure 3 and Figure 4 shows the LAC calculated for the concrete samples in the 1173 and 1332 keV gamma energies using ^{60}Co radioactive sources. The LAC values measured for *1st and 2nd group* are given in Figure 5 comparatively. The shielding properties of concrete which high ratio barite in marble powder doped concrete samples are higher than the high ratio aggregate. In high ratio barite doped samples, the increased shielding property against the decreasing barite rate is the result of increased marble powder.

The thickness of any given material with the half the incoming radiation intensity has been attenuated is referred to as the half-value layer (HVL). The HVL is defined as units of distance (cm). Similar to the attenuation coefficient depends on the photon energy [12, 13].
The following relations are given for the values of HVL.

$$HVL = \frac{In2}{\mu}$$

The calculated half value layer (HVL) values have been displayed in Fig. 6 and Figure 7.

It can be seen from this figure that larger thickness of materials is required to stop the photons of higher energy.

The mean free path is the average distance between two consecutive photon interactions in the sample and was obtained from the following equation:

$$mfp = \frac{1}{\mu}$$

The obtained results has been displayed in figure 8 where it is plotted mfp as a function of doped rate for gamma ray energies.

4. Conclusions

According to these results obtained in the study, the shielding properties of the concrete samples with high barite content in the marble powder added concrete samples are higher than the concrete samples with high aggregate content. In high ratio barite doped samples, the increased shielding property against the decreasing barite rate is the result of increased marble powder. As a result of this study shows that the added of marble powder contributes positively to the properties of barite and aggregate added to concrete.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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