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Determination of the effect of lead mine waste aggregate on some concrete properties and radiation shielding

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HIGHLIGHTS

- Concrete samples were prepared in C16, C25 and C35 classes.
- Mechanical and physical properties of the aggregate and concrete samples was determined.
- Linear attenuation coefficients were measured for 662 keV energy.
- Linear attenuation coefficients was increased as lead mine waste was mixed into limestone.
- However linear attenuation coefficients was decreased as lead mine waste was mixed into barite.

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ABSTRACT

The aim of this study is to determine the radiation absorption capacity of concretes produced from lead mine waste which cannot be processed economically as the lead content is low in the mines they are extracted. Lead mine waste (tallow) were exchanged at ratios of 25%, 50% and 75% respectively with barite and limestone aggregates and samples were prepared at C16, C25 and C35 classes. The compressive strength and the unit weight of the prepared samples were determined. The linear absorption coefficients of prepared concrete samples at 662 keV of energy were determined. In addition the relationship between the radiation absorption capacity and the compressive strength–unit weight was investigated. The experiments demonstrated that best absorption was in concrete samples with 100% barite content (100B). On the other hand in the concrete samples prepared from the mixture of limestone and lead mine waste aggregates, it was observed that radiation absorption capacity decreased due to decreasing amount of barite. In concrete samples prepared from the mixture of lead mine waste and limestone aggregates, it was observed that radiation absorption capacity increased due to increasing amount of mine waste aggregates in the concrete. As a result it was observed that lead mine waste aggregates do not absorb as much radiation as barite aggregates depending on the ratio increase of lead mine waste in the aggregate added to the concrete mixture. However the absorbed radiation amount was observed to be higher compared to limestone aggregates.

1. Introduction

Concrete is one of the most commonly used construction material. Aggregates play an essential role in concretes properties. Concrete shaving specific gravities higher than 2600 kg/m^3 are called heavy weight concrete and aggregates with specific gravities higher than 3000 kg/m^3 are called heavy weight aggregate. Barite or other heavy minerals are usually used within concrete as an aggregate [1–3] since they are in short supply.

One of the areas where heavy weight concretes used are nuclear power plants in order to reduce the radiation dose received by the power plant operator. Heavy weight concretes also find application areas in medical applications for shielding purpose. Due to the heavy metals in these concretes, they are suitable radiation shielding materials [4]. For a concrete to be a suitable material for radiation shielding, it must have high strength and high density. Such concrete that normally utilizes magnetite aggregates can have a density in the range 3.2–4 t/m^3, which is significantly higher than the density of concretes made with normal aggregates [5,6].

Due to its high cost and density, concrete is not frequently used on large scale as radiation shielding material although it is suitable

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Table 1
Chemical, physical and mechanical properties of CEM I 42.5 R.

Chemical properties (%)		Physical properties	
SiO_2	18.59	Setting time, Initial (min)	02:33
Al_2O_3	4.69	Setting time, final (min)	03:18
Fe_2O_3	3.04	Volume stability (mm)	0.7
CaO	60.34	Specific surface (blaine), (cm^2/g)	4145
MgO	1.92	Specific gravity (g/cm^3)	3.08
SO_3	2.89		
Na_2O	0.11	Mechanical properties	Comp. Strength (MPa)
K_2O	0.64	2. days	23.9
Loss on ignition	7.19	7. days	51.1
Insoluble residue	0.57	28. days	57.8
S.CaO	0.38		

for that purpose. Alternatively, various other materials have been searched for the purpose of radiation shielding. There are quite a number of experimental and theoretical studies in the literature on radiation shielding properties of materials (e.g. concrete, semi- conductor, polymer, Lipowitzalloy, colemanite, lead, solid waste containing lead, barite, magnetite and datolite etc.) [7–19].

The main objective of this study is to determine the compressive strength, unit weight and radiation absorption capacity of concrete samples prepared as limestone, barite, lead mine waste. Besides, the relationship between radiation absorption capacity and mechanical and physical properties are aimed to be investigated.

Fig. 1. Crushed aggregate in jaw broken and separated in classes.

2. Material and method

2.1. Materials

In order to prepare concrete sample, CEM I 42.5R Portland cement was used in the study. The chemical, physical and mechanical properties of the cement are presented in Table 1.

The lead mine waste, barite and limestone aggregates used in the study were crushed by jaw crusher so as to be suitable for concrete aggregate in terms of dimension. Aggregates were grouped in (0–4, 4–11.2, 11.2–22.4) classes in Fig. 1.

Table 2 shows the physical properties of aggregate classes. As seen from Table 2, the highest density was observed in barite aggregate as 3.84 g/cm^3 while the lowest value was observed as 2.52 g/cm^3 in limestone. Although, lead mine waste and limestone have the same formation, the differences between the density values are related to the presence of lead in lead mine waste. It is also seen that barite has the lowest absorption and porosity due to its massive structure.

Table 3 shows the chemical analysis of aggregate classes. The ratio of lead was found to be 0.98% as seen from Table 3.

2.2. Method

2.2.1. Preparation of concrete samples

The concrete samples on which radiation shielding test was applied were designed in three groups as: lead mine waste aggregates, limestone and barite aggregates and tallow-limestone, tallow-barite and barite-limestone. The aggregates were exchanged among each other at ratios of 25%, 50% and 75%

Table 2
Physical properties of aggregate.

Aggregate type	Aggregate class	Physical properties			
		Density (Oven-dry) (g/cm^3)	Density (SSD) saturated-surface-dry (g/cm^3)	Absorption (%)	Apparent porosity (%)
Lead mine waste	0–4 (Fine)	2.67	2.78	4.02	10.71
	4–32 (Coarse)	2.78	2.81	1.10	3.06
Barite	0–4 (Fine)	3.76	3.95	5.13	19.25
	4–32 (Coarse)	3.84	3.87	0.66	2.54
Limestone	0–4 (Fine)	2.52	2.63	4.21	10.62
	4–32 (Coarse)	2.54	2.59	1.93	4.89