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Study on Preparation and Shielding Effect of Lead-Zinc Tailings Sand Mortar

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Abstract. In order to study the shielding performance of lead-zinc tailings mortar, a lead-zinc tailings mortar with different contents of tailings sand (0%, 20%, 40%, 60%, 80%, 100%) was prepared. The mass attenuation coefficient in the energy range of 1keV-100GeV is calculated by XCOM theory. The test results show that with the increase of tailings sand content, the mass attenuation coefficient of mortar increases gradually, and the shielding performance is better. The simulated value and experimental value have Good consistency; the mortar strength prepared with lead-zinc tailings will decrease with the increase of tailings sand content, and the amplitude is larger.

1. Introduction

Although the development of nuclear power technology has brought a lot of convenience to people's lives in life, it has also brought us many radiation hazards directly or indirectly, such as α/β Particle radiation, γ /xRay electromagnetic radiation or neutron radiation, etc. α . β The ray penetration is low and easy to be absorbed. The γ -ray and neutron have strong penetrability, which will cause serious harm to people or equipment beside the ray. Therefore, the corresponding radiation protection is very important in the development of nuclear energy. Lead or a composite with a high atomic number is usually used. For example, Mehmet Erdem [1] and others use a lead-containing solid waste to mix with cement to prepare radiation-proof materials. Kh. REZAEI EBRAHIM SARAEE [2] and others use different proportions of lead-containing solid waste instead of cement, prepared concrete, γ -rays. The coefficient of attenuation increases significantly with increasing lead content in concrete and ceramic mixes. F. Akman [3] et al. used XCOM to study the shielding performance of iron, chromium and nickel ternary alloys at 81 keV–1333 keV. In low energy regions, the shielding performance of composites is better than that of ordinary concrete. Belgin EE [4] et al. used a composite of low-density polyethylene mixed with lead oxide and tungsten oxide to shield gamma rays. Mohamed Alwaeli [5-6] and others incorporated industrial waste into concrete and found it to meet the radiation characteristics of radiation-proof concrete. Radiation-shielded concrete prepared with composite materials and discarded cathode ray tubes also has good load-bearing, compressive and shielding capabilities [7-9]. He Zengqi, Guo Xizhi, Li Weiren [10] and others used lead and zinc tailings sand instead of ordinary sand to produce qualified concrete and its products.

At present, the use of lead-zinc tailings sand as raw material for the preparation of radiation-proof mortar is less. This experiment mainly uses the lead-zinc tailings sand from Shuikoushan, Changning



County, Hunan Province to prepare mortar, and studies the gamma-ray shielding performance test of lead-zinc tailings mortar. Research on compression and flexural strength.

2. Materials and method

2.1. materials

Fine aggregate: Considering the shielding performance of γ -rays, a lead-zinc tailing with an apparent density of 2730 kg/m^3 is used, with a fineness modulus of 0.78, which is an ultrafine sand; the ordinary sand fineness modulus is 2.0, the apparent density is 2554 kg/m^3 , which belongs to medium sand, cement: P.O 42.5 ordinary Portland cement.

2.2. Mix ratio

In order to explore the effect of the number of lead-zinc tailings on the shielding performance of the mortar and the effect on the mechanical properties of the mortar, the lead-zinc tailings are mixed in the mass volume of 0, 20%, 40%, 60%, 80%, 100% respectively. In the mortar, the mixing ratio of lead-zinc tailings mortar is shown in Table 1. The apparent density is shown in Table 2.

Table.1. Mortar mix ratio (kg/m^3)

Numbering	cement	water	Ordinary sand	Lead and zinc tailings
CZ1	298.35	295	1494	0
CZ2	298.35	295	1195.2	310
CZ3	298.35	295	896.4	620
CZ4	298.35	295	597.6	930
CZ5	298.35	295	298.8	1240
CZ6	298.35	295	0	1550

Table.2. Apparent density of mortar (kg/m^3)

Numbering	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6
density	1896	1896	1896	1896	1659	1659

3. Experimental results and discussion

3.1. compressive strength

According to JGJ/T70-2009 "Standards for Testing Basic Performance of Building Mortars", the results are shown in Table 3. Compared with ordinary mortar, when the number of lead-zinc tailings does not exceed 60%, the decrease is 9.20%, 19.07%. When the dosage exceeds 80%, the decrease is 55.84%. The main reason is that the lead-zinc tailings are compared with ordinary sand. The content of fine particles in the lead-zinc tailings is large, and the specific surface area is large, which reduces the wrapping ability of the cement and tailings sand, so the mortar strength is reduced.

Table.3. Compressive strength of mortar mortar (MPa)

Numbering	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6
strength	21.97	18.53	19.94	17.78	12.37	9.7

3.2. γ -ray shielding performance

The experimental instrument for radiation shielding performance uses the BH3216 nuclear technology application physics experiment platform jointly produced by the Nuclear Engineering Experimental Teaching Center of Nanhua University and the original China Nuclear (Beijing) Nuclear Instrument Factory (as shown in Fig 2). The platform used in this experiment mainly includes three parts: γ , β Two

kinds of radioactive lead chambers, NaI detectors, counting systems, And the radioactive resources of experimental platform are γ Radioactive source ^{137}Cs and β Radioactive source ^{90}Y - ^{90}Sr . In this experiment, lead-zinc tailings sand is used as fine aggregate, and the mortar test block with the size of $70.7\text{mm} \times 70.7\text{mm} \times 70.7\text{mm}$ is replaced by 20%, 40%, 60%, 80% and 100% respectively. Its influence on the shielding effect and mechanical properties of radiation-proof mortar.

The gamma ray shielding performance test is based on the attenuation principle of gamma ray in matter, and the attenuation law is:

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

$$\mu_m = \frac{\mu}{\rho} \quad (2)$$

Where: I --pulse reading after placing the test piece; I_0 -- initial reading of the ray (before placing the test piece); d - -thickness of the test piece; ρ --density. In addition, the shielding ability of gamma rays can also be reduced by thickness (HVL) of a half-decay layer, where $\text{HVL} = \ln 2 / \mu$.

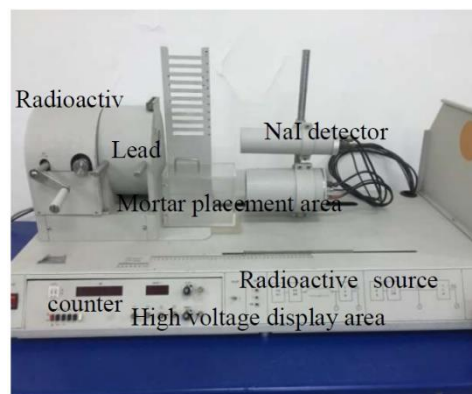


Fig.1. BH3216 nuclear technology application physics experiment platform

3.3. Mass attenuation coefficient

The XCOM program provides users with the ability to customize compound and mixture functions to automatically generate mass attenuation coefficients for compounds or mixtures. Calculate gamma rays at 1keV-100GeV for incoherent scatter, coherent scatter, photoabsorption, nucleus and atomic electron fields in the reaction process. Pairing and other photon sections and attenuation coefficients. Table 4 is used to calculate the mass attenuation coefficient of concrete under different dosages. The linear fit with the test is shown in Fig. 4. The change with photon energy is shown in Fig. 3. The simulation results are shown in Table 5.

It can be seen from Table 5. Fig4 that the mass attenuation coefficient of lead-zinc tailings increases with the increase of the amount of addition. After the tailings are added, the attenuation of γ -rays is faster, indicating that the lead-zinc tailings sand concrete has a shielding effect on γ -rays, and Increased as the amount of addition increases. The mass attenuation coefficient of lead-zinc tailings mortar in low-energy region is more obvious than that of ordinary concrete. The factors affecting the linear attenuation coefficient are mainly the density and atomic number of the material. When the secondary mortar content exceeds 80%, the concrete absorbs γ -rays. It is also reduced, but the linear attenuation coefficient is still higher than the linear attenuation coefficient of ordinary concrete. Under the same density condition, the shielding ability of tailings sand increases with the increase of the amount, the shielding of γ -rays by lead-zinc tailings increases with the increase of amount; the factors affecting the linear attenuation coefficient are mainly the density and atomic number of the material. When the mortar density is the lowest, the absorption of γ -rays by concrete is also reduced, indicating that the density is

proportional to the shielding effect of the material; The increase allows photons to escape without being absorbed after one or more scatterings inside the concrete. Comparing the ordinary concrete with the half-value layer of lead-zinc tailings sand concrete, with the increase of tailings sand content, the half-value layer of lead-zinc tailings sand is reduced, which can be reduced by up to 13%, as shown in Table 6.

Table.4. Composition table of lead-zinc tailings sand concrete

	LZC-0	LZC-20	LZC-40	LZC-60	LZC-80	LZC-100
Mg	0.3634	0.67902	0.9946	1.3102	1.6258	1.9415
Al	3.7774	3.7403	3.7033	3.6662	3.6292	3.5922
Si	84.7704	78.4345	72.332	65.1487	59.4268	53.0909
P	0.0982	0.1150	0.1318	0.1487	0.1655	0.1824
S	0.1044	0.1662	0.8280	1.1898	1.5516	1.9135
K	3.1792	2.8991	2.6180	2.3389	2.0588	1.7788
Ca	1.25	6.6602	12.0701	17.4806	22.8908	28.3011
Fe	4.7623	5.3642	5.9661	6.5680	7.1699	7.7719
Zn	-	0.0611	0.122	0.1833	0.2444	0.3055
Pb	0.7557	0.6406	0.5255	0.4104	0.2983	0.1803

Table.5. Linear attenuation coefficient μ analog value and experimental value (cm-1)

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6
Analog value	0.130	0.145	0.152	0.159	0.134	0.136
Experimental value	0.134	0.156	0.159	0.161	0.146	0.148

Table.6. Half-value layer thickness under different dosages

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6
Half value layer (cm)	4.95	4.44	4.35	4.30	4.74	4.68

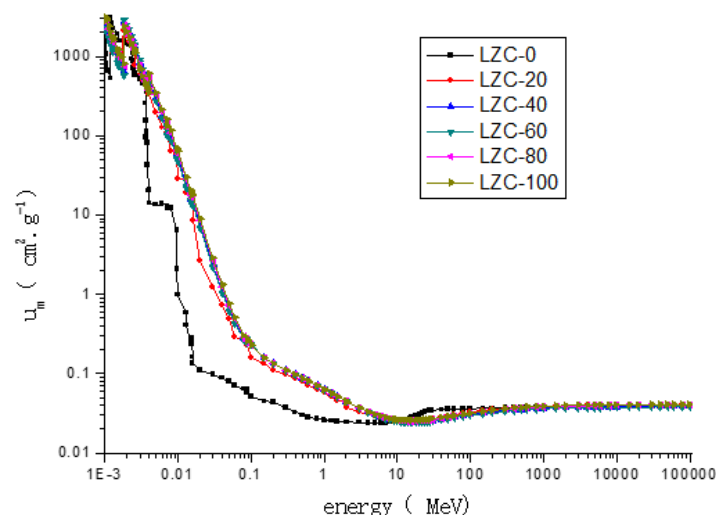


Fig.2. Variation of mass attenuation coefficient of different lead and zinc tailings sands

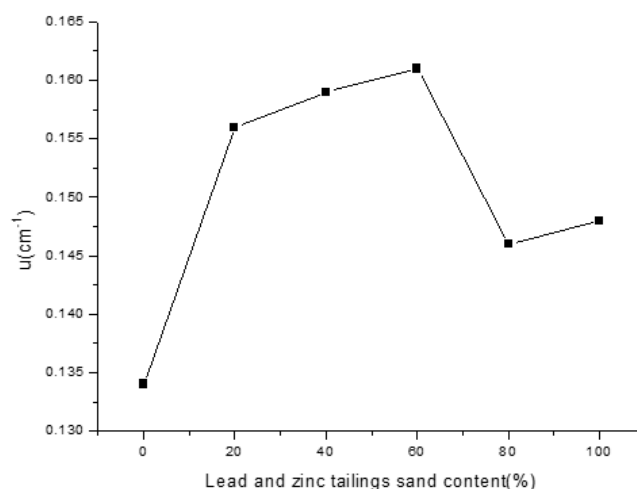


Fig.3. mortar linear attenuation coefficient u

4. Conclusion

- (1) According to XCOM simulation 1keV-100GeV photon energy, except for the high energy region, the larger the lead and zinc tailings sand content, the higher the mass attenuation coefficient, the better the shielding performance.
- (2) Under the low energy ^{137}Cs ray of 0.667 keV, the mass attenuation coefficient increases with the increase of lead and zinc tailings. When the dosage exceeds 80%, the mortar density is the lowest. At this time, the concrete has γ ray. Absorption is also reduced, indicating that density is directly proportional to the effect of material shielding.
- (3) The compressive strength of lead-zinc tailings sand concrete decreases with the increase of the amount of the concrete, and the drop is more than 80%. After the comprehensive compressive strength and shielding effect, the optimum blending range of lead-zinc tailings is 40%~60%.

Acknowledgments

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