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Preparation and properties of magnesite aggregate radiation - proof concrete

Bingquan Sun[1], Jiajia Sun[2]

[1]Department of Mechanical and Power Engineering, Yingkou Institute of Technology, Yingkou 115024, China
[2]Department of Electrical Engineering, Yingkou Institute of Technology, Yingkou 115024, China

Abstract. This paper, from the point of view of improving compactness of density and crystal water content of radiation-proof concrete, using magnesite with high crystal water content as aggregate and alkaline potential water as mixing water, prepared ordinary density radiation-proof concrete and studied its mechanical properties, resistivity and pore structure. The results show that, compared to base ordinary concrete, the prepared concrete has better 28d compressive strength and resistivity, overall porosity decreases by 17%, and pore gradation at all ages improves significantly. It is indicated that the prepared magnesite aggregate radiation concrete has good density and durability, improves concrete radiation protection performance.

1 Introduction

At present, the safety problems of nuclear technology mainly includes two aspects. First, how to improve the radiation shielding performance of protective materials; secondly, how to safely handle the increasing amount of nuclear waste. Cement concrete is currently the most widely used radiation protection material, which is both radiation shielding and of good structural mechanics performance. It has good shielding effect on γ ray and neutron ray, is at a low price, and is easy to form into different shapes and sizes for different structural requirements.

At present, the preparation of radiation-resistant concrete at home and abroad usually use heavy concrete technologies, among which the most widely used method is using magnetite ore, brown iron ore or barite as aggregate, adding enough amount of crystal water and Boron, Lithium compounds. However, due to the large aggregate density and large concrete capacity, this method has some shortcomings like being prone to segregation of concrete, has bad concrete construction performance and so on. The use of new aggregates that have good absorption and reflection properties for the rays is the future research direction and hot issues of radiation protection concrete [1]. The research of Sang Bum Hong and Alhajali S et al. shows that [2-3], concrete doped with Mg, Ti, ^{3}H, ^{14}C, ^{55}Fe can improve concrete radiation protection. Under certain radiation and temperature environment, radiation-resistant concrete must have good stability and durability, and good structural mechanical properties if used as a support structure. The research of Bingquan Sun and Lijiu Wang shows that [4], alkaline potential water helps to improve the durability and mechanical properties of concrete.

This paper takes into account of concrete density, MgO and crystal water content, uses magnesite with high crystal water content as aggregate and alkaline potential water as mixing water to prepare ordinary density radiation-proof concrete and study its mechanical properties, resistivity and pore structure and explored magnesium-based high performance radiation protection concrete preparation method.

2 Raw material selection

(1) Cement: Ordinary Portland cement is easy to access and could meet the general requirements of neutron radiation protection due to the fact that its crystalline water is about 13% ~ 15% at room temperature and has less dehydration at high temperature (above 100 ℃). Taking into account factors like strength development and the impact of setting time on construction, we used P.042.5R ordinary Portland cement produced by Dalian Cement Factory, related physical properties is shown in Table 1.

(2) Fine aggregate: We used natural sand in Dalian, with the properties of apparent density 2650kg / m^3, fineness modulus 2.6, clay content 2%.

(3) Coarse aggregate: Coarse aggregate is made from manually breaking high-quality magnesite of Liaoning China. The main chemical components of selected crystalline magnesite are magnesium oxide; the minor components are calcium oxide, silicon oxide, ferric oxide, aluminum oxide. Hardness 4.2, apparent density 2870 kg/ m3,

Table 1. Cement physical properties

Stability	Initial setting time (min)	Final setting time (min)	Compressive strength (MPa)		Flexural strength (MPa)		Specific surface area (m^2/kg)
			3d	28d	3d	28d	
qualified	190	292	26.7	46.8	5.2	7.1	357

particle size 5 ~ 25mm, continuous grading, the apparent density of ordinary stones 2760 kg / m^3, the largest particle size 25mm, continuous grading, from limestone mine around Dalian.

(4) Water: Mixing water is alkaline potential water, electrolytically obtained from an electrolyzer consisting of a self-made small diaphragm cell. The electrolysis parameters used in the experiment were electric field strength of 320 V / m, flow rate of 80 ml / s, the pH value of obtained alkaline potential water is 9.0.

The baseline mix ratio of the C40 concrete used in the experiments is shown in Table 2.

Table 2. Baseline mix ratio (W/C=0.42)

Composition	Amount per cubic meter (kg)
Cement	438
Water	185
Sand	624
Gravel	1186
Slump	5-7cm

3 Concrete performance test

3.1 Concrete resistivity and compressive strength test

Resistivity can comprehensively reflect the parameters of concrete capillary pore water content, concrete pore structure, porosity, pore fluid ion concentration and other parameters, is an important parameter for evaluating concrete performance. The conductive phenomenon of hardened concrete is due to the electrolysis process that occurs as the ions flow in the pores of the cement paste, so concrete resistivity reflects the potential corrosion rate of the steel in concrete [5]. Resistivity has many advantages for characterization of concrete properties [6]: (1) Resistivity measurement method is relatively simple and fast; (2) Measurement of resistivity does not require damage to the concrete structure, is non-destructive testing; (3) For some structural parts in need, measurements can be conducted repeatedly, which to some extent, improve the accuracy and validity of the test, and also easy to compare with the previous results to determine the occurrence of unexpected conditions; (4) Compared with other commonly used non-destructive testing methods, the measurement of resistivity does not require the use of large-scale instruments, and the measurement cost is relatively low.

Since concrete is a conductive material whose internal ion is unevenly distributed, it has a slight potential difference in itself, which makes curing concrete have a certain piezoelectric property, producing a certain piezoelectric potential under pressure, which is a dozen to nearly 100 millivolts when the pressure is kept low. The presence of residual potential leads to the inability to measure with a DC bridge. Voltammetry can not eliminate the residual potential and piezoelectric potential, resulting in poor data accuracy, repeatability. Voltammetry also has practical troubles like too many equipments and wiring. The existence of residual potential makes DC test methods poor in accuracy and repeatability. So, the key to accurately measure concrete resistivity is eliminating the impact of residual potential effectively during measurement. In this paper, concrete resistivity is measured in a method invented by the author that could eliminate the impact of residual potential and provides accurate measurement. Table 3 lists test results of concrete resistivity and compressive strength.

Table 3. Compressive strength and resistivity of concrete specimens

Sample name	Compressive strength (MPa)			Resistivity (kΩ.cm)		
	7d	14d	28d	7d	14d	28d
P-40	31.2	35.6	41.8	10.5	11.6	12.8
L-40	34.0	38.6	43.5	12.8	13.2	13.6
Pd-40	36.5	39.3	45.1	11.8	12.7	13.6
Ld-40	38.5	42.5	49.2	12.5	13.6	14.2

In Table 3, P-40 stands for common gravel coarse aggregate and tap water mixed concrete which serves as comparing reference, L-40 stands for magnesite coarse aggregate and tap water mixed concrete, Pd-40 stands for common gravel coarse aggregate and alkaline potential water mixed concrete and Ld-40 stands for magnesite coarse aggregate and alkaline potential water mixed concrete. Results in Table 3 show that, at curing age

Table 4. Concrete pore structure test results

Sample	Porosity	Pore volume (mL/g)	Pore diameter (nm)		Pore specific surface area (m^2/g)	Density (g/m^3)	
			Median	Average		Bulk	Apparent
P-40	22.25%	0.1073	40.77	15.83	27.82	2.042	2.612
Ld-40	17.28%	0.0786	35.52	14.67	21.65	2.168	2.637

longer than 7 days, compressive strength of all four samples meets design value, among them, the compressive strength of magnesia concrete is higher than that of ordinary stone concrete, in particular, the compressive strength of magnesite aggregate and alkaline potential water concrete increased by about 20%, mainly due to high activity of alkaline potential water and greater density of magnesia aggregate; the resistivity of all concrete samples goes above 10kΩ · cm, indicating that internal steel corrosion is very unlikely. It can also be seen from Table 3 that, concrete resistivity and compressive strength have an approximately proportional relationship, indicating that the homogeneity, compactness and porosity of magnesite aggregate alkaline potential water concrete are obviously better than ordinary concrete, and have better durability and radiation protection performance.

3.2 Pore size distribution and porosity of concrete

Pore size distribution and porosity test is conducted using Micromeritics Instrument 9420 mercury porosimeter, using the testing parameters of initial pressure 1.03MPa and max pressure 30MPa at low pressure stage, initial pressure 30MPa and max pressure 55000MPa at high pressure stage, which corresponds to a pore size measuring range of 3.3～175000 nm. The pore structure of concrete of curing age 28d is shown in Table 4. As can be seen from Table 4, compared with ordinary concrete, the total porosity of magnesite aggregate alkaline potential water radiation-proof concrete decreased by 21.8%, the median pore diameter decreased by 12.3% and the average pore diameter decreased by 7.8%, also, due to the increase of the density, both the bulk density and the apparent density have increased. In terms of pore size distribution, the coarse pores and the pores of radiation-resistant concrete prepared from alkaline potential water of magnesite aggregate decreased at each age, and the gel pores also decreased slightly. Alkaline potential water increases the strength and impermeability of concrete, which can have beneficial effects on the concrete shrinkage and creep.

4 Conclusion

(1) The new concrete resistivity measurement method used in this paper realizes the accurate measurement of concrete resistivity measurement, avoids the trouble of voltammetry equipment and wiring, and realizes convenience, simplicity, speed and stability of concrete resistivity testing process.

(2) Alkaline potential water can improve the uniformity and compactness of concrete, effectively inhibit the activity of CO2, slow down the rate of concrete carbonization and improve the durability of concrete, making it good mixing water for making radiation-proof concrete.

(3) The magnesite aggregate radiation protection concrete made has a density of 2.43kg/m3 and high content of magnesium oxide and crystal water, has good anti-neutron beam ability and also meets the protection requirements of nuclear waste. By appropriately increasing density (such as the use of magnesia and barite mixed aggregate) or thickness, it can also meet the purpose of protection of γ-rays.

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