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Study of the volume stability of slag cement mortar applied to desulfurization slag during high temperature operation

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HIGHLIGHTS

- The slump flow of the mix proportion with the slag powder is higher than the slump flow of the mix proportion without addition by 11.5–39%.
- The compressive strength and the ultrasonic pulse velocity decrease as the replacement of desulfurization slag increases, and both increase with age.
- After high temperature catalysis, the expansion response increases as the curing time and desulfurization slag replacement increase and the slag powder decreases.

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ABSTRACT

In recent years, upon increasingly exploiting natural sandstone, the natural ecology has been damaged severely. To reduce the impact of market demand on natural resources, replacing natural resources with recycled materials, such as desulfurization slag and slag powder, is a very important topic at present. This study used desulfurization slag that had been passed through #4 sieves and slag at a fineness of approximately 4000 cm^2/g to replace fine aggregates (0, 10, 20 and 40%) and cement (0, 10, 20 and 40%), respectively, via a volumetric method to make cement mortar for testing its fresh properties. The hard properties and volume stability were tested at different ages in order to discuss the variance in the material volume stability under different mix proportions.

The results show that the slump flow of the mix proportion with the slag powder is higher than the slump flow of the mix proportion without addition by 11.5–39%. The addition of desulfurization slag and slag powder increases the setting time. The compressive strength and the ultrasonic pulse velocity decrease as the replacement of desulfurization slag increases, and both increase with age. Under the influence of high temperature, a high compressive strength can be reached at an early age. When the addition level of desulfurization slag is the maximum, 40%, the weight loss is higher than observed at the other addition levels. The autoclave expansion increases as the desulfurization slag replacement increases and the amount of slag decreases. After high temperature catalysis, the expansion response increases as the curing time and desulfurization slag replacement increase and the slag powder decreases. The high temperature has an apparent effect on the volume stability of slag powder cement mortar with desulfurization slag, and the expansion response of all mix proportions is within safe specifications (0.06%).

1. Introduction

As engineering construction increases, the demand for natural resources grows greatly; however, these natural resources are not inexhaustible. The sustainable development of resources in Taiwan can be implemented only by cherishing resources and establishing a colorful mental life [1]. Desulfurization waste slag (hereafter abbreviated as desulfurization slag) is solid waste generated from the desulfurization process of molten iron in a blast furnace with the help of a desulfurization agent in an integrated steel company that uses iron ore as its main raw material. Currently, the steel companies in Taiwan have an annual production capacity of approximately 300,000 tons of desulfurization slag [2]. Desulfurization slag (DS), a solid waste resulting from desulfurizing blast furnace molten iron with a desulfurizer, is derived from integrated steel plants using iron sand as their main raw material [2].

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Table 1
Desulfurization slag component analysis. Unit: %.

Materials	Cement	Slag	Desulfurization slag
Physical properties			
Specific gravity	3.15	2.89	2.38
Chemical content (%)			
Al_2O_3	4.96	13.71	4.22
CaO	64.51	41.00	69.08
SiO_2	20.22	35.47	9.93
Cr_2O_3	–	–	0.08
MgO	2.33	6.60	2.33
P_2O_5	–	–	0.17
SO_3	2.46	–	4.3
K_2O	–	–	0.06
Na_2O	–	–	0.14
f-CaO	–	–	0.95
Fe_2O_3	2.83	0.33	8.23
MnO	–	–	0.6
LOI	24	–	–

Table 2
Materials physics basic properties.

Properties	Specific gravity	Unit Weight (kg/m^3)	Water Absorption (%)
Fine aggregate	2.68	1865	1.6
Desulfurization slag	2.38	1009	34

Although there are many ways to recycle desulfurization slag, only the metallic iron derived from the early magnetic separation has high reproducibility and value, while the pH (12.5) of the other purified desulfurization slag is close to the corrosive industrial waste standard [3]. The molten iron from blast furnace steelmaking contains sulfur; when the molten iron is discharged to the torpedo car, its sulfur should be removed by a desulfurizer. The obtained slag is discharged out of the torpedo car and cooled to form fine particles, called "desulfurization slag" [4]. Using an appropriate portion of desulfurization slags in the replacement of natural fine aggregates can reduce the construction time, improve the efficiency and shorten the pending time for a testing run [5].

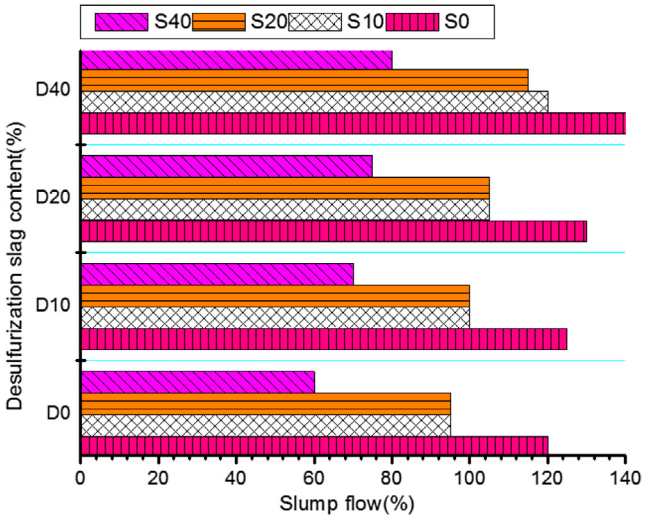

Fig. 1. Slump flow of slag cement mortar with desulfurization slag.

The desulfurization slag is a product of high melt, it is resistant to high temperature and free from the effects of climate change, and it is free of organic matter, polychlorinated biphenyl, peroxide, cyanide, inflammables and halogen solvents. Since there is little heavy metal dissolved out of it, desulfurization slag is highly safe. Since the desulfurization slag contains a part of slag, after the magnetic separation, crushing and grinding processes, the slag can be recovered, and the purity and utility value of desulfurization slag are increased. In terms of the desulfurization slag recycling in Taiwan at present, the metal of the desulfurization slag component is recovered as steelmaking material, as an agricultural soil amendment, an earthwork backfill material and for replacing limestone [6]. A study of the replacement of desulphurization slag for sand to ready-mixed soil materials (RMSM) [7].

Current applications using recycled DS include ground improvement, soil modification, earth backfill, and the substituent of $CaCO_3$ for cement clinker manufacturing [8]. In recent years, desulfuriza-

Table 3
The Toxic Chemical Leaching Procedure (TCLP) of Desulfurization slag Unit: mg/L.

Properties	Cr	Cu	Cd	Pb	Ba	As	Hg
Desulfurization slag	0.021083	0.007759	ND	0.045056	0.403827	ND	0.004795

Table 4
Mixing proportions Unit: kg/m^3.

Specimens		W/B	Cement	Slag	Desulfurization slag	Fine aggregate	Water
OPC		0.5	541	–	-	1488	271
S0	D10				135	1353	
	D20				269	1219	
	D40				539	950	
S10	D0		487	50	–	1476	268
	D10				134	1328	
	D20				267	1180	
	D40				533	943	
S20	D0		433	99	–	1463	266
	D10				146	1317	
	D20				293	1171	
	D40				585	878	
S40	D0		330	202	–	1463	266
	D10				132	1316	
	D20				265	1170	
	D40				529	943	