Department of Civil Engineering, I-Shou University

DRMS 2023 Conference on Durability, Repair and Maintenance of Structures
March 16 and 17, 2023 – Porto, Portugal
Paper number: P168

A Study of Engineering Properties of Cement Mortar with Electric Arc Furnace Slag

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ABSTRACT

The electric arc furnace slag produced by the electric arc furnace during the steelmaking process has a swelling property due to the content of free-CaO. Swelling due to CaO leads to the obstruction of the reuse path of electric arc furnace slag. This study will investigate the basic properties and differences between the electric arc furnace slag which is before carbonation (EAFS1). This study's analyses include basic property tests, SEM-EDS tests to determine the effects of EAFS1 and EAFS2 on the macroscopic and microscopic properties of cement mortar in terms of compressive strength test, tensile strength, and autoclave expansion. The test results showed that CaO of EAFS1 primarily existed as $CaCO_3$, while CaO od EAFS2 still existed. When cement mortar contains both EAFS1 and EAFS2 and the water-cement ratio is 0.6, the compressive strength of the cement mortar will increase with the increase of EAFS1 substitution when the water-cement ratio is 0.6, while the compressive strength will decrease with the increase of EAFS2. The cement mortar containing EAFS2 will have a phenomenon of structural collapse after conducting the hot compression expansion test. Still there will be no structural collapse if only EAFS1 is used in the cement mortar. Thus, it means that the carbonation technology helps to suppress the swelling properties of electric arc furnace slag and helps to improve the engineering properties of cement mortar.

INTRODUCTION

In recent years, with the gradual maturity of steelmaking technology, the demand for iron and steel products has increased rapidly, resulting in a large amount of steelmaking slag. The final disposal method of steelmaking slag is not landfill or sea reclamation, but rather a resource recovery and reuse. Therefore, this study investigates the effect of electric arc furnace slag before carbonization (EAFS 1) and electric arc furnace carbide slag (EAFS 2) on the engineering properties of cement mortar. After applying EAFS 1 and EAFS 2 to cement mortar, we will analyze the compressive strength, tensile strength, flow rate, and autoclave expansion to determine the effect of different electric arc furnace slags on the engineering properties of cement mortar.

RAW MATERIAL

Basic properties

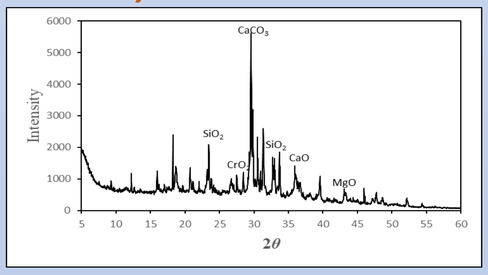
▼ Basic properties of the raw material of cement mortar specimens.

	Cement	Natural Sand	EAFS1	EAFS2
Specific Gravity	2.91	2.67	3.42	3.13
Water Absorption, %	-	1.47	1.73	9.73
Sand Equivalent, %	-	97.3	94.0	67.4

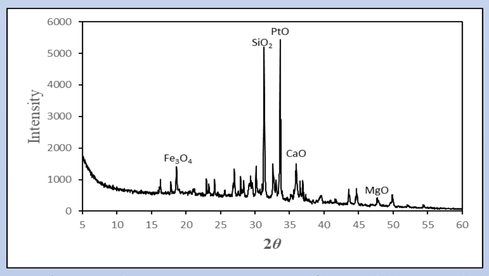
▼ Heavy metal dissolution results of EAFS1 and EAFS2

Element	Cu	Ba	Cd	As	Pb	Cr	Hg	Cr^{6+}	Se
EAFS1, mg/L	ND	0.694	ND	<0.001	ND	0.060	ND	0.01	ND
EAFS2, mg/L	ND	0.553	ND	<0.001	ND	0.331	ND	0.14	0.041
Standard	≦12.0	≦10.0	≦4.0	≦0.4	≦4.0	≦0.8	≦0.016	≦0.2	≦0.8

XRD analysis

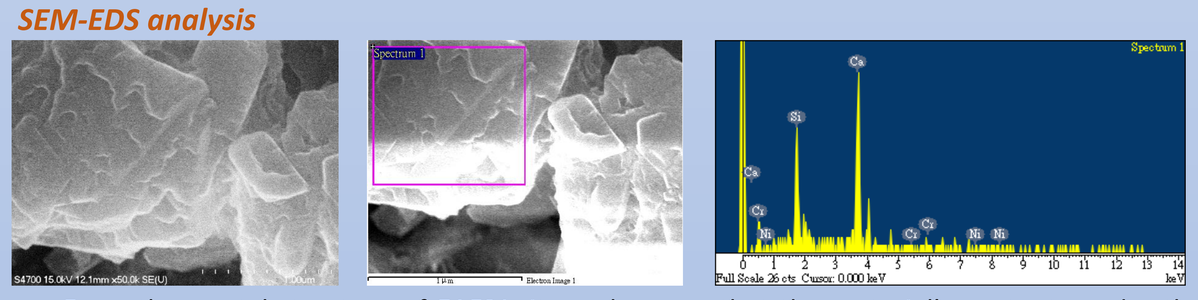


▲ The main components of EAFS1 are $CaCO_3$ and SiO_2, while Ca exists in the form of calcium carbonate due to carbonation treatment.

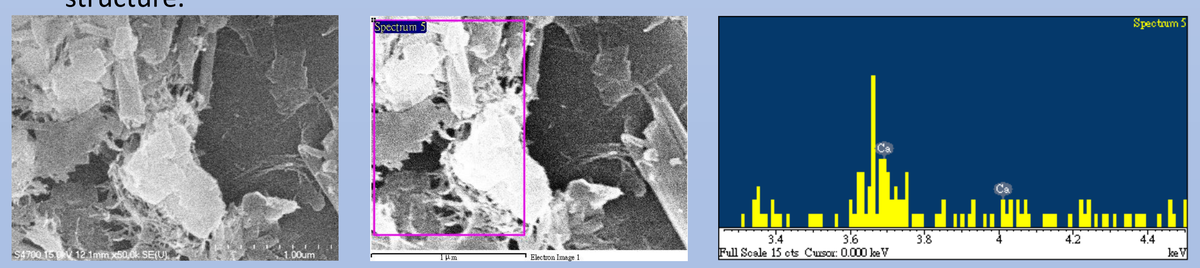


▲ The main components of EAFS2 are CaO, SiO_2, and Fe_3O_4, with Ca existing in the form of calcium oxide.

SEM-EDS analysis



▲ From the crystal structure of EAFS1, it can be seen that the material's contents under the microscope are very pure, with its internal crystals tightly stacked together in a layered structure.



▲ The internal structure of EAFS2 is more irregular and loose, with more pores, resulting in a higher water absorption rate.

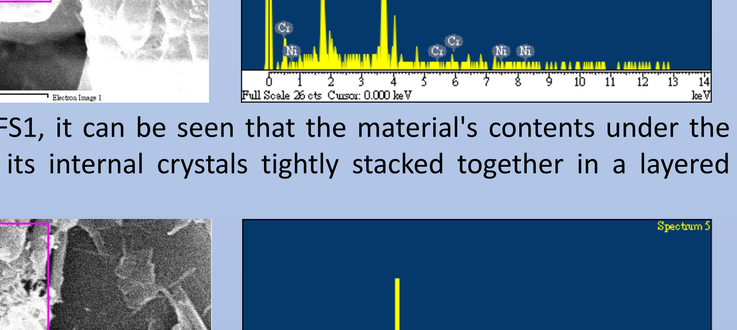
RESULTS AND DISCUSSION

Mix Design

- The mix designs of the cement mortar specimens.
- The ratio of cement to aggregate was set at 1:2.75.
- The water-cement ratios (W/C) used were 0.485, 0.6, and 0.8, respectively.
- The amount of EAFS1 and EAFS2 replacements was varied from 0% to 100% in increments of 10%.
- The mixture was processed to form specimens for the compressive strength test and unit weight test, with a size of 50x50x50mm, and for the autoclave expansion test, with a size of 25x25x160mm.

Unit Weight

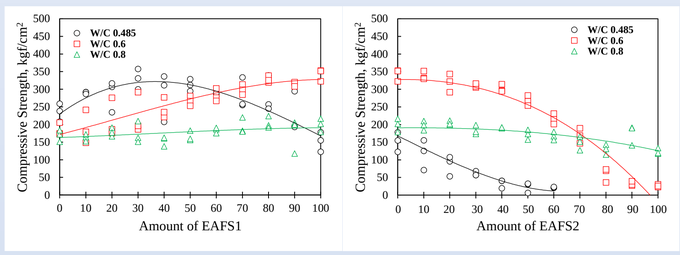
- The unit weight of cement mortar increases with the use of EAFS1.
- Using EAFS2 leads to a decrease in the unit weight of cement.



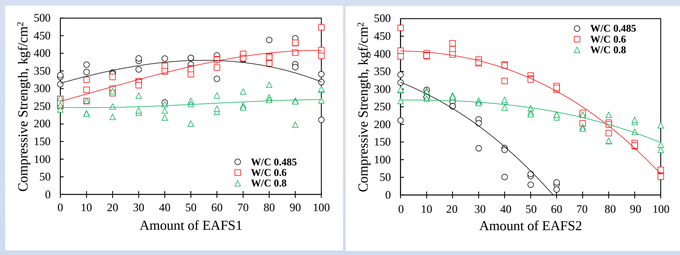
▲ The results of the unit weight test for cement mortar specimens

Compressive strength

- The water-to-cement ratio directly affects compressive strength. When the EAFS1 concentration is less than 60%, the optimal performance is achieved with a water-to-cement ratio of 0.485. When the usage of EAFS1 is greater than 60%, the optimal performance is achieved with a water-to-cement ratio of 0.6. When the EAFS2 concentration exceeds 70%, the mixture achieves optimal performance with a water-to-cement ratio of 0.8.
- In the case of sufficient water use, using EAFS1 helps to increase the cement mortar's compressive strength, while EAFS2 decreases the compressive strength.



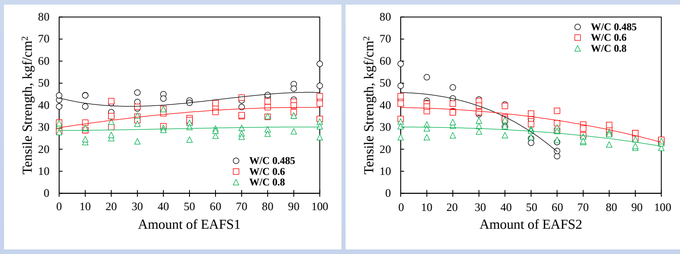
▲ The compressive strength of cement mortar in 7 days



▲ The compressive strength of cement mortar in 28 days

Tensile strength

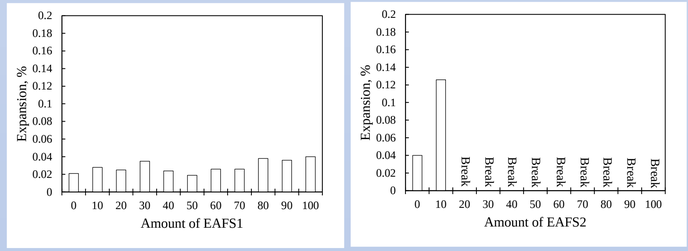
- EAFS1 has no significant effect on the tensile strength of cement mortar, but EAFS2 will lead to a significant decrease in tensile strength.



▲ The tensile strength of cement mortar in 28 days

Autoclave expansion

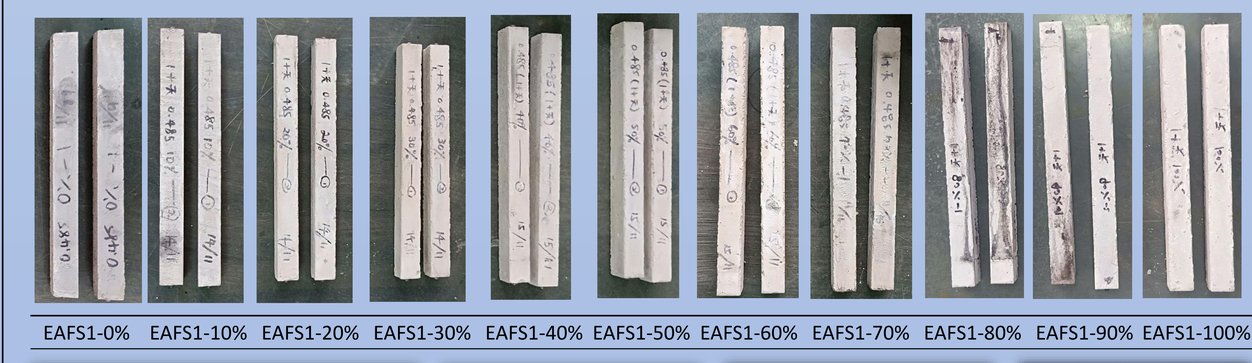
- The expansion behavior of cement mortar shows no significant changes with an increasing replacement of EAFS1.
- EAFS2 will significantly increase the expansion of cement mortar. When the replacement level of EAFS2 exceeds 10%, the cement mortar structure will experience breakage.



▲ Expansion of cement mortar after autoclave expansion

Cement mortar after autoclave expansion test

▼ When the EAFS1 concentration is 0%, there will be no damage to the cement mortar structure. When the EAFS1 concentration is between 20-60%, partial spalling will appear on the surface of the cement mortar. When the EAFS1 concentration exceeds 70%, partial spalling and cracking will occur on the surface of the cement mortar.



▲ The use of EAFS2 will lead to the collapse of the cement mortar structure.

CONCLUSIONS

- EAFS1, which stabilizes via carbonization technology, contains CaO mainly in the form of $CaCO^3$. EAFS2, which does not stabilize via carbonization technology, still contains a high quantity of CaO..
- When the water-cement ratio of the cement mortar is 0.6, the compressive strength will increase with the increase of EAFS1 substitution. When the water-cement ratio is 0.485, the compressive strength will rise and fall due to insufficient water. Lastly, when the water-cement ratio is 0.8, the EAFS1 does not significantly affect the compressive load.
- The increase in EAFS2 in cement mortar regardless of the cement-water ratio, will cause the compressive strength to decrease.
- The structure of cement mortar containing EAFS2 will crumble after the hot-pressure expansion test. Alternatively, structures are unlikely to crumble if only EAFS1 is used.