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COLD-PRESSING TECHNIQUE - A NEW APPROACH TO RECYCLE STAINLESS STEEL REDUCTIVE SLAG AS COARSE AGGREGATE

Chih-Ta TSAI[1], Wei-Sheng CHEN[2], Juu-En CHANG[3]

[1] Sustainable Environment Research Laboratories, NCKU, 70955 Tainan, Taiwan
[2] Department of Resources Engineering, NCKU, 70101 Tainan, Taiwan
[3] Department of Environmental Engineering, NCKU, 70101 Tainan, Taiwan

chihta.tsai@gmail.com, kenchen@mail.ncku.edu.tw, juuen@mail.ncku.edu.tw

Introduction

Every year there was approximately 160,000 to 200,000 tons of stainless steel reductive slag generated in Taiwan. Due to the fact that stainless steel reductive slag has the characteristic of poor volume stability (i.e. stainless steel reductive slag is liable to react with H_2O and CO_2 to result in expansion), the Industrial Development Bureau, Ministry of Economic Affairs announced that stainless steel reductive slag should only be recycled or reused in raw cement materials and concrete products in Taiwan. Many research studies indicate that the sintering technique has been successfully applied to recycle a lot of resources as light weight aggregates[1]. However, the energy consumption and CO_2 emission from this sintering process are too high to be extensively adopted[2]. A new approach, the cold-pressing technique[2] which incorporates the principles of the cement chemistry[3,4] and composite material[5] was developed to recycle these resources as coarse aggregates. Consequently, the main difference between cold-pressing and the sintering technique is the reduction of energy consumption and the CO_2 footprint. This paper aims to show that using cold-pressing technique to recycle stainless steel reductive slag as coarse aggregate.

Experimental

Materials

The following were used as cementitious materials in this study: Type I Portland Cement produced by Taiwan Cement Company, blast-furnace slag (BF slag) provided by CHC Resources Corporation, and class F fly ash supplied by Taiwan Power Station. A carboxylate-based type G superplasticizer was purchased from a local factory. The cementitious materials and superplasticizer conform to the related ASTM standards. The stainless steel reductive slag was provided from Ming Hsiang Hsin Co., Ltd. in Tainan, Taiwan. The glass fibers were recycled from printed circuit board (PCB)

wastes by Much Fortune Technology Co., Ltd. The TCLP results of stainless steel reductive slag were below the criteria of general enterprise wastes and green building materials in Taiwan as shown in Table 1.

Table 1: TCLP results of stainless steel reductive slag

	TCLP results of stainless steel reductive slag (mg/L)									
	Cr	Ba	Se	Cd	Pb	Cu	As	Hg	Ag	Cr^{+6}
Stainless steel reductive slag	0.07	0.543	ND	ND	ND	ND	ND	ND	ND	ND
Criteria of general enterprise wastes	5.0	100.0	1.0	1.0	5.0	15.0	5.0	0.2	5.0	2.5
Criteria of green building material	-	-	-	0.3	0.3	0.15	0.3	0.005	0.05	1.5

Mixture proportioning

In this study a local mixture proportion method in Taiwan, densified mixture design algorithm (DMDA), is adopted to design and prepare the cement-based composites for making the recycling coarse aggregate. Herein the cement-based composite is regarded as concrete. The water-to-cementitious ratio (w/cm) of mixture proportion is 0.2 and a total of 39.4 kg glass fibers (the volume = 0.02 m^3) was added to the cement-based composites. Specifically, the mixture proportions with a low cement amount of 100 kg/m^3 was designed as shown in Table 2. Also Table 2 shows that the cement-based composite contains approximate 75 % (by weight) of stainless steel reductive slag.

Table 2: Mixtures of cement-based composites (kg/m^3)

Cement	Pozzolanic materials	Stainless steel reductive slag	Glass fiber	SP+Water
100 (5.00)*	365 (18.22)	1499 (74.81)	39.4 (1.97)	93

Pozzolanic materials: BF slag + Fly ash

*: The percentage by weight of solid composition materials.

Method of granulation

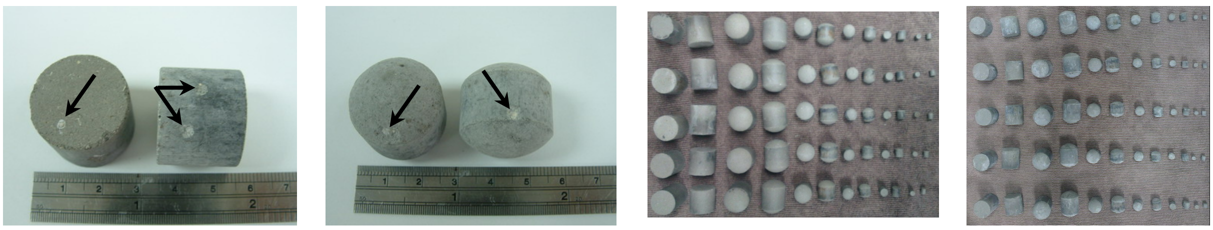
The press ingot method was developed to successfully granulate the cold-pressing recycling coarse aggregates with five various diameters[2]. Properties of stainless steel reductive slag are quite different from primitive aggregates (e.g. particle shape,

gradation, absorption, and so on). The purpose of exploring the optimum moisture of stainless steel reductive slag under granulating aggregate is to avoid two issues: 1) with lower moisture: the recycling coarse aggregate can not be adequately granulated; 2) with higher moisture: the redundant water may drain out during the process of forming recycling aggregate (like consolidation in geotechnical engineering[6]) to result in the excessively high water-to-cement ratio (w/c) or water-to-cementitious materials (w/cm) around the surface of the recycling aggregate. The excessively high w/c or w/cm will be harmful to the strength, hardness, abrasion resistance, soundness, permeability, etc[3]. The optimum moisture for granulating recycling coarse aggregate of stainless steel reductive slag was 14.0 % while the stress of granulation by using press ingot method is 35.0 to 42.0 MPa.

Results and Discussion

Observation of volume stability

The results of volume stability show that the surface of recycling aggregate had slight splits due to expansive reaction of f-CaO within stainless steel reductive slag before the age of 7 days. So far, recycling coarse aggregates with stainless steel reductive slag has not generate further expansion, splits, or even rupture for more than four years. There was a significantly white particle existing in the expansions, splits, or spalls of recycling coarse aggregate as shown in Figure 1a. Also Figure 1a shows that the diameter of the white particle is more than 1.0 mm. While the diameter of stainless steel reductive slag was controlled to less than 0.297 mm (below No. 50 sieve), the expansions, splits, or spalls of recycling coarse aggregate were completely improved as shown in Figure 1b.



(a) Unscreened (b) below No. 50 sieve

Figure 1: The results of volume stability observation of recycling coarse aggregate

Single particle compressive strength

Figure 2 shows that recycling coarse aggregates with stainless steel reductive slag using the cold-pressing technique results in the growth of single particle compressive strength. The result indicates that the single particle compressive strength increases

with the increase of curing age due to the contribution of hydration of cement and pozzolanic reaction.

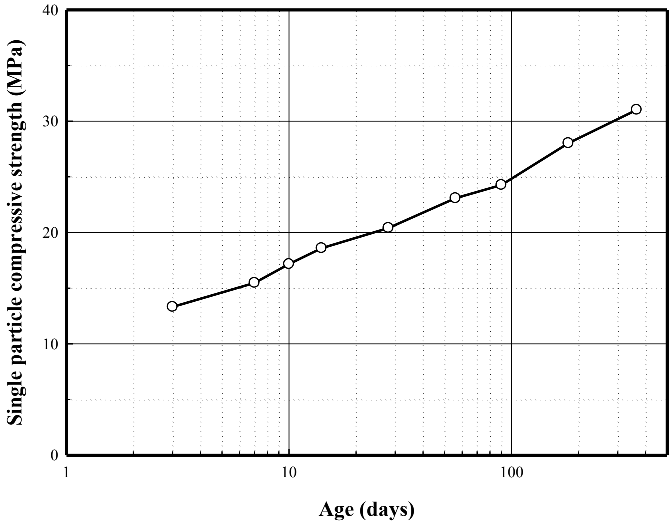


Figure 2: The single particle compressive strength growth of recycling aggregate

Basic characteristics of recycling coarse aggregate

After granulating, these recycling aggregates are cured in saturated limewater at the temperature of 23 ± 2.0 °C according to ASTM C192. Basic characteristic tests were conducted at the age of 28 days. The results show that the specific gravity of cold-pressing recycling coarse aggregate is in the range of 1.70 to 1.73 in the OD state; the absorption capacity is 14.0 to 14.5 %; the dry loose density (i.e. unit weight) is 1,200 to 1,250 kg/m^3; and other characteristics conform to ASTM C33.

Conclusions

According to the above-mentioned test results, the recycling coarse aggregates produced by using the cold-pressing technique can reduce about 65 % CO_2 footprint when compared to using the sintering technique. And the prime cost of cold-pressing recycling aggregate is 5 to 6 times lower than sintering recycling aggregate. Therefore the cold-pressing technique is a new and practicable approach to recycling stainless steel reductive slag in future.

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