STUDY ON UTILIZATION OF AIR COOLED SLAG AGGREGATE FOR PRECAST CONCRETE

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1. INTRODUCTION

Blast furnace slag is an industrial by-product obtained from the iron making process. The final form of blast furnace slag depends on the method of cooling. If the liquid slag is air cooled under ambient conditions, a crystalline material is formed and a hard piece is produced that can then be crushed and separated as a blast furnace slag aggregate[1)]; which is a porous crystalline material that absorbs a great amount of water. At present, air cooled blast furnace slag is not considered for use as a concrete coarse aggregate, and is only utilized as a roadbed-filling material. However, a special type of slag aggregate has been recently produced (herein after referred to as"SBFS") through an air cooling method, in which the rate of water absorption is less than 1% or almost equal to that of natural aggregate[2)].

This study focused on the SBFS aggregate by comparing its drying shrinkage with that of limestone aggregate and sandstone aggregate. The study also compared a number of fresh and mechanical properties of concrete produced with SBFS aggregate, limestone aggregate and sandstone aggregate, which then subjected to steam curing for the first 24 hours, in order to evaluate the suitability of SBFS aggregate for use in precast concrete.

2. MATERIALS AND EXPERIMENTAL DETAILS

2.1 Materials Used and Mix Proportions

The materials used in this study are listed in **Table 1**. Concrete mix proportions are shown in **Table 2**. Ordinary Portland cement (herein after “N”), blast furnace slag powder (herein after “BB”), mountain sand as fine aggregate, special blast furnace slag (SBFS) aggregate, limestone aggregate, sandstone aggregate and air-entraining chemical admixture (herein after “AE”) were used throughout the investigation in order to evaluate the fresh and mechanical properties of each concrete mixture.

Table 1. Materials Used

Material		Properties
Cement	N	Ordinary Portland Cement, Density*: 3.16 gr/cm^3
	BB	Blast Furnace Slag Powder (Esumento 4,000), Density*: 2.89 gr/cm^3
Coarse Aggregate	A	Special Blast-furnace Slag Aggregate (SBFS), density*: 2.81 gr/cm^3
	B	Limestone Aggregate (from Yamagochi Prefecture), Density*: 2.69 gr/cm^3
	C	Sandstone Aggregate (from Sagamihara-shi), Density*: 2.65 gr/cm^3
Sand	S	Mountain Sand (from Chiba Prefecture), Density*: 2.62 gr/cm^3
Admixture	Ad	HPWRA, type AE (Polycarboxylic acid-based ether)
* : In saturated surface-dry condition		

2.2 Mixing Method

A pan-type mixer with a maximum capacity of 50 liters was used. The blending process started by mixing sand, cement and blast furnace powder for 30 seconds. Subsequently, water plus admixture were added, and further blended for 60 seconds. Finally, coarse aggregate was introduced, and the whole mixture was kneaded for 90 seconds and then discharged.

2.3 Curing Conditions

All the specimens were pre-cured in a steam curing chamber for the first 24 hours. The run-up time for the steam curing chamber was 1-hour with a temperature of 20℃. Subsequently, the chamber’s temperature climbed up to 65℃, rising by 45℃/h. The chamber has maintained 65℃ temperature for a period of 3-hour and then started to go down to 20℃, falling at 45℃/h.

Table 2. Mix Proportion Conditions

Aggregate	W/C (%)	W (kg/m^3)	C (kg/m^3)	BB (kg/m^3)	S (kg/m^3)	G (kg/m^3)	Ad (Cx%)
SBFS	33.6	168	250	250	838	917	1.0
Limestone						878	
Sandstone						865	

3. RESULTS ANALYSIS AND DISCUSSION

3.1 Aggregate Drying Shrinkage

The drying shrinkage test was performed in accordance with (JIS A 1129-2:2010), using wire-strain gauge method[3)]. As a result of the investigation, SBFS aggregate has revealed to be the fastest water absorbing material as compared to those of other coarse aggregate. Similarly, a small drying shrinkage was also observed in limestone aggregate, which is said to be effective regarding drying shrinkage reduction[4)] in concrete. In contrast, larger drying shrinkage was observed in sandstone aggregate. The results of the experiment are shown in **fig. 1**. As seen , the average amount of strain for SBFS aggregate, limestone aggregate and sandstone aggregate was measured as 93μm, 43μm and 300μm, respectively.

Keywords: air cooled slag aggregate, drying shrinkage, compressive strength, splitting-tensile strength, flexural strength,
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3.2 Concrete Fresh Properties

The fresh properties of concrete produced with three diverse source of coarse aggregate have been given in **Table 3**. Looking at the table, it's evident that concrete created with SBFS aggregate has shown almost identical fresh properties as those of limestone made concrete.

3.3 Compressive Strength

The characteristic compressive strength of concrete was determined by casting and testing cylinder-shaped specimens, size (100× 200) mm at the age of 1-day, 14 days and 28 days. The test was performed in accordance with (JIS A 1108:2006). The maximum load sustained was noted, and the average compressive strength for three specimens has been determined for each blend; the results are graphically represented in **fig. 2**. Judging by the figure, it can be said that, all specimens have almost equal amounts of compressive strength at the age of 1-day. However, SBFS utilized concrete specimens displayed greater strength at the ages of 14 days and 28 days.

3.4 Split-Tensile Strength

The splitting tensile strength of concrete was checked by casting and testing of (150x150) mm size cylinders at the age of 28 days, as specified in (JIS A 1113:2006). The maximum load sustained was recorded and the average splitting strength for three specimens was measured for each mixture. The results of the test have been illustrated in **fig. 3**. As seen from the figure, concrete specimens produced with SBFS aggregate showed the highest splitting strength, greater than the samples prepared of limestone aggregate and sandstone aggregate.

3.5 Flexural Strength

The flexural strength of concrete was determined by casting and testing of beams, size (100x100x400) mm at the age of 28 days, as mentioned in (JIS A 1106). The maximum load sustained was recorded and the average flexural strength for three specimens has been determined for each blend. Experimental observations and results have been represented in **fig. 3**. From the figure, it's obvious that, concrete specimens produced with SBFS aggregate exhibited greater flexural strength, whereas concrete comprised of sandstone aggregate and limestone aggregate are in the second and third place respectively.

4. CONCLUSION

The drying shrinkage was observed to be smaller in limestone aggregate and SBFS aggregate, and considerably larger in sandstone aggregate. Similarly, SBFS aggregate can be used in concrete under the same conditions as those employed for limestone aggregate since their fresh properties match up. Moreover, experiment results demonstrated that SBFS-utilized concrete carries greater mechanical properties than those of limestone and sandstone utilized concrete. Therefore, it can be concluded that utilization of SBFS aggregate would not adversely affect the short-term performance of precast concrete.

Table 3. Fresh Properties of Concrete

Material	W/C (%)	Slump (cm)	Air Content (%)	Concrete Temperature (℃)
SBFS	33.6	22.0	4.0	20.0
Limestone		19.5	4.0	20.0
Sandstone		21.0	2.5	20.0

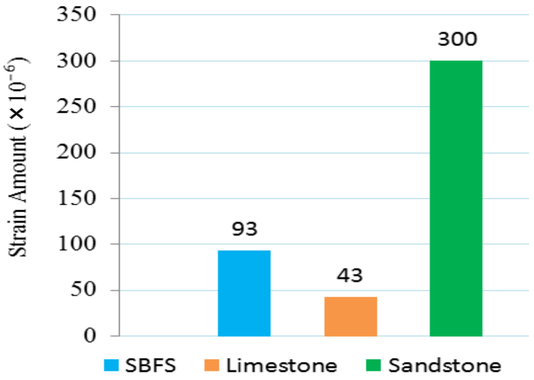

Fig. 1. Aggregate Average Drying Shrinkage

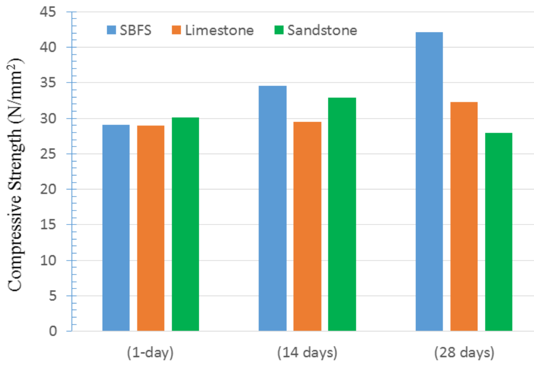

Fig. 2. Compressive Strength Exhibition

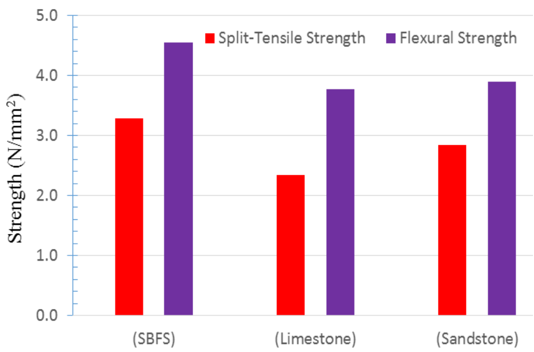

Fig. 3. Splitting Strength and Flexural Strength

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