INVESTIGATION OF FRESH BEHAVIOR AND PHYSICAL AND MECHANICAL PROPERTIES OF PAVEMENT CONCRETE CASTED USING EAF SLAG FINE AGGREGATE

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1. INTRODUCTION

Electric Arc Furnace oxidizing slag (EAF slag) is the by-product of steel manufacturing process. EAF slag is produced when scrap iron is melted in the electric furnace and refined. Around 3 million tons of EAF slag is produced annually in Japan [1]. One of the characteristic property of EAF slag is high density. It has been revealed by Vidha that incorporation of high density aggregate in concrete increases the compressive, tensile and bending strength of concrete significantly [2]. Hence, these results can be utilized with the use of EAF slag fine aggregate in pavement concrete where one of the desirable criteria is that the concrete should have sufficient flexural strength to transmit the wheel load to a wider base/subbase. This study aims to investigate the fresh behavior and physical and mechanical properties of EAF slag fine aggregate concrete to be used in pavement.

Fig. 1: EAF slag fine aggregate

2. EXPERIMENTAL OVERVIEW

In this experiment, 4 different types of concrete were casted by using EAF slag fine aggregate as mix proportion were shown in Table 1. Ordinary Portland cement was used and mix proportion was computed for a w/c, s/a, slump and air content of 0.4, 40%, 5cm and 5% respectively. Design flexural strength target for pavement concrete for the current study is 4.5MPa at early age. In this study, sand was replaced by slag with a volume ratio of 0.0, 0.3, 0.5 and 1.0. Slag used for this study were spherical in shape. The fineness of the slag was found as 3.40%, which is higher than natural sand (2.80%) to be replaced. Gradation curve provided in Fig. 2 indicates the more presence of larger particles in slag and it is controlled in production factory. The density of slag was measured as 3.60 g/cc which is very high in comparison to natural sand (2.55 g/cc) and gravel (2.60 g/cc). Water absorption capacity of slag was found as 0.53% which is low in comparison to normal sand (1.57%) and gravel (1.16%). Moisture content of slag was an important experimental parameter, which was generally controlled before casting. Measured moisture content of slag and sand before casting was found as 0.42% and 5.75% respectively.

Table 1: Mix proportion (for 1m^3 of concrete)

Slag ratio	s/a (%)	W/C	Water (kg)	Cement (kg)	Gravel (kg)	Sand (kg)	Slag (kg)
0.00	40	0.4	164.5	411.3	1045.0	665.5	0.00
0.30	40	0.4	164.0	410.0	1029.6	464.1	280.8
0.50	40	0.4	160.0	400.0	1005.1	331.5	464.4
1.00	40	0.4	155.0	387.5	1005.1	0.0	928.8

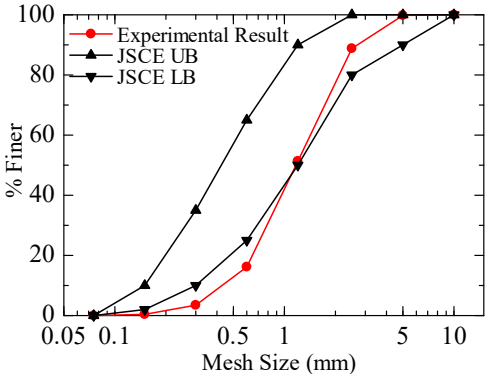

Fig. 2: Gradation curve of EAF Slag

In order to investigate the characteristics of EAF slag fine aggregate concrete, experiments related to fresh behavior like slump, air content, fresh density and bleeding, physical property like density distribution, and mechanical properties like compressive, bending and split tensile strength were conducted. For this reason, cylinders of Φ100 x 200 mm were used for density distribution, compressive and split tensile tests whereas, cubes of 100 x 100 x 400mm were used for bending test. For each experiment category, 36 specimens were used and each experiment was conducted after a curing age of 3, 7 and 28 days.

Table 2: Fresh behavior of concrete

Slag ratio	Slump (cm)	Air Content (%)	Fresh Density (kg/m^3)
0.00	6.8	4.2	2345
0.30	6.6	5.2	2428
0.50	3.5	5.6	2487
1.00	3.4	5.8	2665

3. EXPERIMENTAL RESULTS

3.1 Fresh Behavior

The results related to fresh behavior of concrete are shown in Table 2. The value of slump and air content were closer to the target value. Fresh density of concrete was found to be increasing linearly with the increase in slag ratio. The results related to the bleeding of concrete is depicted in Figs.

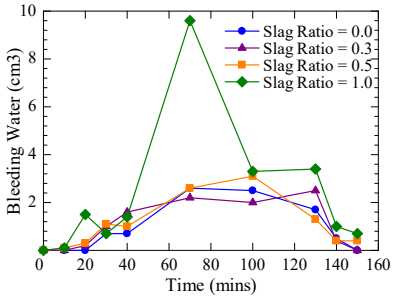

Fig. 3: Bleeding of concrete with time

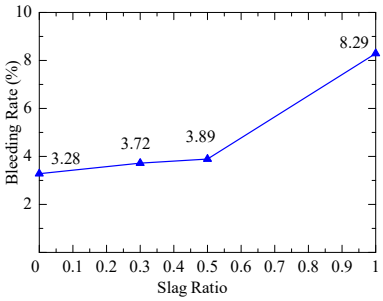

Fig. 4: Bleeding rate with slag ratio

Keywords: EAF slag fine aggregate, pavement concrete, fresh behavior, physical property, mechanical property
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3 and 4. It can be seen from Fig. 3 that, bleeding of concrete occurs gradually in between 40-140 mins and shows similar trend as normal concrete up to 50% replacement of sand by slag. However, for 100% replacement by slag, high bleeding is observed at 70 mins. As shown in Fig. 4, rate of bleeding is found to be increasing steadily up to slag ratio of 0.5. Whereas, for the slag ratio of 1.0, bleeding rate is found to be as high as 2.5 times of normal concrete.

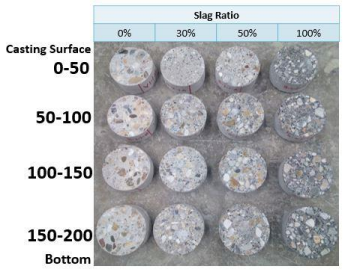


Fig. 5: Sliced specimen

3.2 Physical Properties

Due to high density of slag, possibility of sedimentation of slag in the specimen were checked because of material segregation. This experiment was conducted at curing age of 14 days. Each cylinder specimen was sliced at length of 50mm horizontally along specimen length in 4 distinct parts as shown in Fig. 5 and then oven dried at a temperature of 105°C for 24 hours. Dimension and weight of each sliced part were measured and density was computed. The density distribution is shown in Fig. 6. For each case, the average density is also provided in Fig. 6. It is clearly observed that the density increase along with increment of slag ratio. The differences of density from top and bottom in case of 0-50, 50-100, 100-150 and 150-200 sample are 0.07, 0.62, 1.63 and 1.66%, respectively. This indicates the settlement of slag from concrete mix with the increase in slag ratio but these differences are very small.

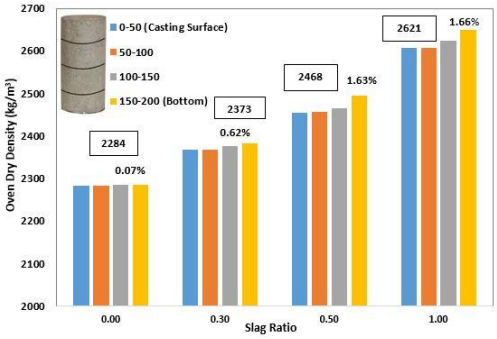
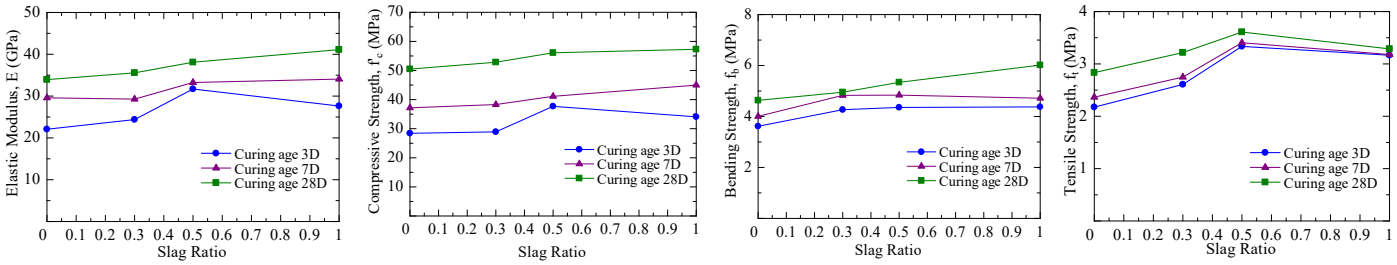


Fig. 6: Density distribution

3.3 Mechanical Properties

Results related to the mechanical properties of concrete tested after 3, 7 and 28 days of curing are depicted in Figs. 7 (a)-(d). Increase in mechanical behavior with the increment of slag ratio in comparison to normal concrete are noted for all cases. In addition, 28 days bending strength is observed more than the target design strength for pavement concrete and the highest strength is observed for the slag ratio of 1.0. For the curing age of 3 days, increase in elastic modulus, compressive, bending and tensile strength is observed up to a slag ratio of 0.5, while reduction of behaviors than 0.5 case is observed when the slag ratio is 1.0. After 28 days curing, elastic modulus, compressive and bending strength increase in association with the increase in slag ratio. However, the tendency of tensile strength is still similar to that of 3days curing. It can be noted that tensile strength in case of 1.0 slag ratio after 28 days curing is higher than normal concrete case although it is lower than that of 0.5 slag ratio. Hence, all mechanical behaviors of EAF slag fine aggregate after 28days are higher than normal concrete even if all sand were replaced by slag. This indicates that EAF slag fine aggregate seems to be good for pavement concrete.



(a) Elastic Modulus (b) Compressive Strength (c) Bending Strength (d) Tensile Strength

Fig. 7: Relationship between slag ratio and mechanical properties of concrete

4. DISCUSSION

From the results as shown above, it is evident that replacement of sand by slag in concrete is advantageous as it increases the elastic modulus, compressive, bending and tensile strength of concrete in comparison to normal concrete. However, for the slag ratio of 1.0, tensile strength shows a decreasing trend than that of slag ratio 0.5. Moreover, slag ratio of 1.0 causes excessive bleeding. In addition to bleeding a very small slag settlement was observed for slag ratio 1.0. These results indicate a little segregation of slag particle when slag ratio is more than 0.5. Therefore, possibility of bleeding and material segregation requires to be considered when very high slag content other than this experiment is used.

5. CONCLUSION

From the present study, it can be concluded that EAF slag fine aggregate concrete possess the merit of improved mechanical behaviors than normal aggregate concrete with the increase in slag ratio. It can be effectively utilized in pavement concrete since high bending strength is observed with the increase in slag ratio.

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