Mechanical and Water Absorption Properties of Cement Mortar Incorporating Basic Oxygen Furnace Slag as Fine Aggregate

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ABSTRACT: The steel industries produce much waste called steel slag (SS) which can be classified into three broad classification namely basic oxygen furnace slag (BOFS), electric arc furnace slag (EAFS) and ladle furnace slag (LFS). The disposal of these SS resulted in land occupation, water pollution and other environmental issues. The aim of this research is to study the performance of cement mortar by using BOFS as partial sand replacement. The properties of both fresh and hardened mortar containing 10%, 20% and 30% of BOFS with particle size <0.15mm were examined. The mechanical properties of BOFS mortars were tested at 1, 7, 28 and 60 days. While for water absorption, it was conducted only at 28 days. Results show that the increase of BOFS causes reduction in workability and water absorption which indicates good improvement in the water tightness of mortar. From the perspective of compressive strength, the replacement of BOFS increases the strength up to 14% compared to the reference specimen at 28 days. The compressive strength and flexural strength development in the mortar with 20% BOFS content yielded the highest strength gains compared to all specimens at later age.

Keywords: *compressive strength, natural sand, steel slag*

1. INTRODUCTION

The development of industry produce various solid waste which can be alternatives used in construction [1,2]. Steel slag is one of the industrial wastes generated from the process of refining pig iron or recycled steel to make crude steel. The statistics from the World Steel Associated shows and increase approximately 3.6% global steel production from 1621Mt in 2015 to 1869Mt in 2019 annually [3]. Studies have shown that replacing fine aggregates with BOFS up to 20% could increase the strength in concrete but decrease gradually when the BOFS content is further increased. The improvement of strength with the particle size of BOFS <0.50mm had also been observed. Herein, in this study, BOFS with <0.15mm particle size was used as natural sand replacement in cement mortar. The results from the laboratory test namely workability, mechanical properties and water absorption are recorded and analysed.

2. MATERIALS AND METHODS

2.1 Materials

Portland cement with the strength grade 42.5MPa which conformed to MS EN 197-1:2014 CEM II/B-L 42.5N standards was used throughout the research. The river sand and BOFS are use as the fine aggregate. The maximum particle size of river sand and BOFS used as fine aggregate was 2mm and 0.015mm, respectively. The mix design of cement mortars was of cement/aggregate 1:2.75 and w/c mass ratio of 0.50. BOFS were used as a replacement for 10, 20 and 30% of fine aggregate. The flow table value is measured for the fresh mortar mixture after mixing well. All the mixtures were then cast into plastic cubes and cured in water with temperature 24±5°C. 12 cubes with the size of 50 x 50 x 50 mm^3 and 9 prisms with size 50 x 50 x160 mm^3 were cast for each mortar mix.

2.2 Test Methods

The mechanical properties of mortar were conducted by using BS EN 1015-11: 2019 at 7 days, 28 days and 90 days curing. The mortar cubes were used in the compressive strength test while mortar prisms were tested to evaluate the flexural strength. Besides that, water absorption test complying with BS EN 1015-18: 2002 was carried out to evaluate the quality of mortar from the perspective of density and imperviousness.

3. RESULTS AND DISCUSSION

3.1 Workability

Figure 1 shows the flow table value of fresh mortar with BOFS as fine aggregate replacement. The decreasing trend of the flow value from CM0 (control), 10 to 30% replacement namely CM10, CM20 and CM30, respectively, is observed. It is found that the lowest flow table value is examined at CM30. The result shows that

the increase of BOFS content reduces the workability of fresh mortar. The reduction of workability is affected by the increase of specific surface area and angular shape of BOFS.

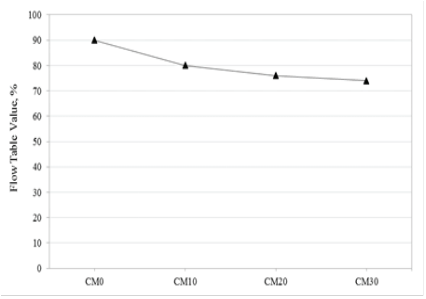

Figure 1 Workability for all mortar specimens

3.2 Compressive Strength

From the results, three of the BOFS mortars had a comparable strength (~35.2-39.6MPa) to control specimen at 28 days. The increase of strength can be explained that the finer particle size of BOFS acts as filler that fills the voids in mortar [4]. The angular shape of BOFS also contributed to a higher compressive strength which can effectively improve the interaction between BOFS and binder [5]. However, when the BOFS content is high, the water absorption increased during the mixing process and more water is required for the hydration of cementitious materials.

Flexural Strength

Figure 2 shows the effect of cement mortar on flexural strength containing different BOFS percentages. From the result, the decreasing and fluctuating trend were observed at early and later strength of different mortars, respectively. At 7 days, CM20 obtained the lowest flexural strength (8.09 MPa) compared to the other specimens. However, it yielded the optimum which is higher than CM0, CM10 and CM30 at 28 days and above strength. It is observed that that the flexural strength of CM10 and CM20 is comparable (~9.24-9.52 MPa) with control specimen at 28 days.

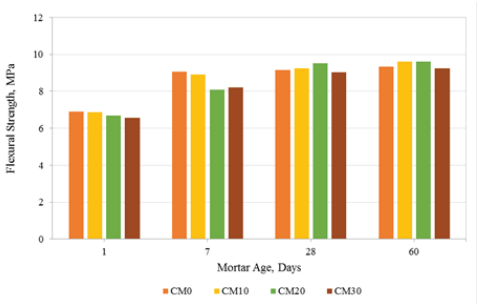

Figure 2 Flexural strength of all mortar specimens at different ages

3.4 Water Absorption

Figure 3 shows the water absorption rate of cement mortar containing different percentages of BOFS at 28 days. From the results, a decreasing exponential trend was observed with increasing BOFS contents. The result shows that the increase of BOFS content reduces the water absorption of mortar. The reduction of water absorption rate is affected by the particle size of BOFS. The smaller particle size of BOFS fills the voids and refining the pores in the mortar and thus reduced the water absorption of hardened mortar.

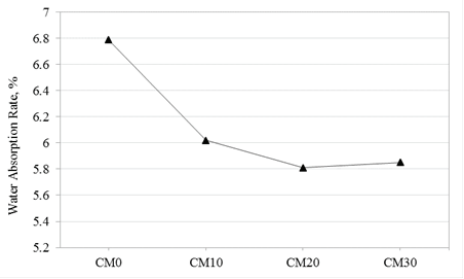

Figure 3 Water absorption of all mortar specimens

4. CONCLUSION

The incorporation of BOFS in mortar reduces the workability of the mortar. It also yielded an adverse effect in flexural strength at early age but showed positive improvements at later age. The optimum water absorption was observed at 20% BOFS replacement which reduces the water absorption up to 14.4%. From the study, 20% BOFS replacement gives the optimum compressive and flexural strength as compared to the other specimens.

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