Investigation on the effect of steel slag as cement replacement material on mechanical properties of mortar

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ABSTRACT: The use of SS to replace cement in mortar production can reduce the consumption of cement while improving the efficiency of the resource utilization. This study is to investigate the influence of SS as cement replacement material on the properties of fresh and hardened mortar. A series of mixes by varying the contents of SS from 0-40% with increment of 10% replacement ratio was prepared. Flow table test, compressive strength test and flexural strength test have been conducted. While for the compressive strength, it reduces from 19.7 to 4.2 MPa, 34.1 to 10.4 MPa, 41.5 to 13 MPa with the increase of SS replacement ratio for 1-day, 7-day and 28-day curing age mortar, respectively. Flexural strength value decrease from 5.7 to 2.5 MPa, 7.5 to 4.3 MPa and 8.2 to 5.6 MPa with the increase of SS replacement ratio for 1-day, 7-day and 28-day curing age mortar, respectively. The optimum mix design of SS mortar is 10% replacement ratio.

Keywords: *Steel Slag; Compressive Strength; Flexural Strength*

1. INTRODUCTION

Previous researches show that SS could be an alternative material for replacing cement [1-3]. The replacement of cement with SS improves the workability of mortar [2]. Most of studies shows that with the increasing replacement ratio of SS, the strength of mortar shows decreasing trend despites of different types of SS and is lower than that of control specimen. Saly et al. [4] used two types of SSs which were BOFS and EAFS to study the effect of SS on the properties of mortar. Cement was replaced with SS with replacement ratio of 15%, 30% and 45% and the strength of mortar was determined at the curing age of 7-day, 28-day and 90-day. Results showed that the strength of mortar decreases with the increase of replacement ratio of SS at every curing age and all of the SS mortars have lower strength than control specimen at the same curing age. The objective of this study is to investigate the effect of SS on the properties of fresh and hardened mortar. Cement was replaced with SS of 10%,20%,30%,40% for making mortar. Compressive strength test and flexural strength test were conducted to determine the properties of hardened mortar.

2. METHODOLOGY

2.1 Raw materials

The binder consists of cement and SS. Cement used is type CEM I 52.5 Portland cement (PC) conforming to British standard BS EN 197-1-2011 [5]. SS shown in Fig. 1 were obtained from Baifeng Mineral Materials Co. Ltd, China. SS passes 0.075mm sieve with the chemical composite content shows in Table 1.

The fine aggregate in this study were from local river. The particle size of fine aggregate is below 2.00 mm with fineness modulus of 2.4. The sand was oven-dried before mixing. Tap water supply in the lab was used to produce all the mortar mixtures and for specimens curing.

Figure 1 The steel slag powder

Table 1 Chemical compositions of SS

SiO_2 (%)	CaO (%)	SO_3 (%)	Fe_2O_3 (%)	MgO (%)	Al_2O_3 (%)
11.9	42.3	0.18	20.3	3.77	1.4

2.2 Specimen preparation

In this study, the mortar without addition of SS were regard as control specimen. Water to binder ratio of 0.5 is used for control mortar and SS mortar; the ratio of binder to sand is 1:2.75. SS was used to replace cement with the percentage of 10%, 20%, 30% and 40%. Each mix proportion consists of 3 specimens with the size of 50×50×50mm for compressive strength, and with the size of 40×40×160mm for flexural strength testing, respectively.

3. RESULTS AND DISCUSSION

3.1 Compressive strength

Fig. 2 shows the influence of SS on the compressive strength of mortar. Results indicated that the replacement

of SS has a negative influence on the compressive strength of mortar specimens [4]. With the increase of replacement of SS, the strength of mortar shows a decrease trend at 1d, 7d and 28d curing age. This is due to the component characteristics of SS. Although the SS is a kind of cementitious material which can generate C-S-H gel through hydration, the content of cementitious component in SS is lower than in cement [6]. In comparison with the control specimen, the decrease in compressive strength of BM10, BM20, BM30 and BM40 are 26%, 62%, 61% and 79% for 1d curing age, respectively, are 16%, 41%, 42% and 70% for 7d curing age, respectively, and are 6%, 26%, 34% and 52% for 28d curing age, respectively.

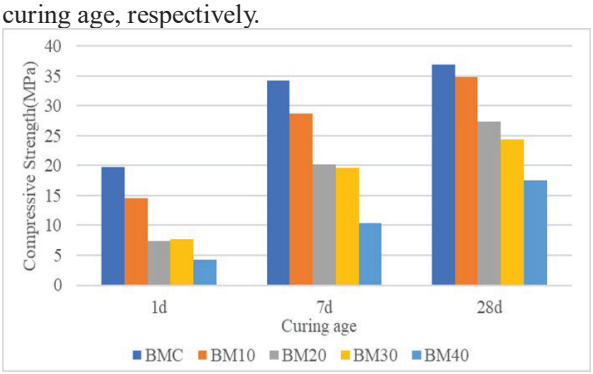

Figure 2 The compressive strength of SS Specimens

3.4 Flexural strength

The flexural strength of mortar with and without replacement of SS are shown in Fig. 3. Result indicated that the SS has a negative influence on the flexural strength of mortar at 1d, 7d and 28d curing age. The trend of flexural strength at all of 3 curing age are similar with the trend of compressive strength. In comparison with the control specimen, the decrease in flexural strength of BM10, BM20, BM30 and BM40 are 11%, 23%, 23% and 55% for 1d curing age, respectively, are 10%, 22%, 28% and 43% for 7d curing age, respectively, and are 4%, 15%, 28% and 37% for 28d curing age, respectively. Besides, the strength loss of all specimens at 28d curing age is lower than at 1d and 7d. It means the lower hydration activity of SS at early strength has same influence on both of compressive strength and flexural strength [7].

4. CONCLUSION

SS is an industrial solid waste from steel-making industry and could be an alternative material used to replacement for making mortar. It can support green sustainable development in the global scale. The conclusions based on this study can be drawn as follow:

a. The replacement of SS can improve the fluidity of mortar. The flow table value of SS mortar is higher than control mortar when SS replacement ratio is lower than 30%.
b. The SS has a negative influence on the compressive strength of mortar. The strength value of mortar shows a decreasing trend at all of curing age in this study. The strength of SS mortar is close to control specimen at 28d curing age compared with that at early age. There is a slight difference between strength of SS mortar with the replacement ratio of 20% and 30%.

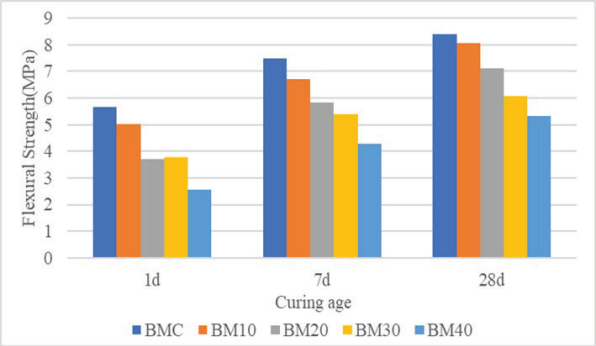

Figure 2 The flexural strength of SS Specimens

ACKNOWLEDGEMENT

The authors would like to thank the Ministry of Higher Education for providing financial support under Fundamental Research Grant Scheme (FRGS) No. FRGS/1/2018/TK06/UMP/02/5 (University Reference RDU190151) and Universiti Malaysia Pahang for laboratory facilities as well as additional financial support under Postgraduate Research Scheme PGRS200376

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