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EFFECTS OF ACTIVATOR PROPERTIES ON IMPACT BEHAVIOUR OF ALKALI ACTIVATED SLAG MORTAR

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Abstract: Alkali activated systems are considered the third generation of binding systems. Alkali Activated systems are characterized by low carbon dioxide emission and superior mechanical and durability performance compared to cement-based systems. This study will focus on characterizing the performance of alkali activated slag (AAS) mortar. Sodium hydroxide and sodium silicate were used in as the activator for all mixtures. Effects of activator dosage and properties including sodium oxide (Na_2O%) and silicate modulus (Ms), water to solid ratio and slag content on fresh properties, hardened properties and Impact resistance of AAS mortar will be evaluated. Sodium hydroxide and sodium silicate were used in a mix as an activator to be able to control both dosage and modulus. Increasing the dosage up to 8 % was found to be beneficial to the mechanical properties in the hardened state. Also increasing the modulus up to 2 was found to improve the strength for a fixed dosage, while, after certain range of modulus (1.5 to 2) the workability of fresh mortar was significantly decreased as a result of higher viscosity obtained.

1 INTRODUCTION

After lime and OPC, geopolymer is considered as the third generation cement. The term ‘geopolymer’ is generically used to describe the amorphous to crystalline reaction products synthesised by aluminosilicates reacted with alkali solution. Different terms such as ‘‘Inorganic polymers’’, ‘‘Alkali-activated cements’’, ‘‘Geocements’’..’ etc., describe materials synthesized utilizing the same chemistry [1].

Concrete structures are required to withstand various types of loading such as static loads and dynamic loads. Standards are always there for most types of static loading, while dynamic loads are usually a field of study in order to characterize the material behavior towards such type of loads. This include impact loads.

Moreover, damages due to an impact load are also varying depending on a lot of variables such as impact velocity, projectile geometric properties, the material properties of both projectile and structure and the geometric properties of the target like thickness [2]. For AAMs, as a new generation of binders, a lot of studies have been investigating their properties and behavior under different exposure conditions. Few studies hit the point of impact resistance behavior and the ways to improve impact resistance of AAMs. Fiber incorporation was suggested and tested as possible method to enhance AAMs impact resistance[3, 4]. Also, there are many variables need to be studied in order to evaluate their effects on AAMSs behavior under impact loads such as aggregate types and aggregate size distribution.

Loading type and material properties are the most important information needed by engineers to be capable to design a structure. These loads can be broadly classified into static and dynamic loadings. Dynamic loads itself can be subdivided into single cycle and multicycle. As an example for single cycle dynamic load is a mass impact against a structural element. The impact resistance of a structural system might be defined in terms of the system ability to absorb the impact energy before failure.

2 MAIN FACTORS AFFECTING ALKALI ACTIVATOR

Different types of alkaline activators were used in alkali activated systems such as sodium hydroxide, potassium hydroxide, sodium silicate, sodium carbonates, and etc. [5-7].The most commonly used activator is sodium hydroxide or a mixture of sodium silicate and sodium hydroxide. The selection of the alkaline activator properties is dominated by the activated material characteristics. Hydration products of alkali activated systems are mostly dependent on activator type and pH value which is the negative log of the hydrogen ion concentration.

2.1 Dosage of alkali activator

Dosage of activator is the amount of sodium oxide Na_2O as a ratio of the binder weight. Generally, the higher the dosage, the better the strength as it improves the dissolution rate of Si and Si–Al phases of precursor material, leading to high Si and Al contents in the aqueous phase. For slag as a precursor, there is a threshold for Na_2O% dosage of the activator depending on slag chemical properties, activator type and curing condition, after which no further significant increase in strength is achieved. Moreover, detrimental properties such as brittleness may increase at higher Na_2O% dosage as a result of more free alkalis in the product. Trying to increase the strength by increasing the alkali dosage is not recommended from both economic and property points of view [8-10].

2.2 Modulus of alkali activator (M_s)

Activator modulus (MS) is the ratio of SiO2 to Na2O in the activator In alkali activated systems, soluble silicate species are necessary as it enriches the aqueous phase of the system with soluble silicate species. The relative concentration of silicate anions is presented as a function of weight ratio of SiO2 to Na2O in the aqueous solution. Addition of soluble sodium silicates in the aqueous phase of the system increases SiO2 to Na2O ratio. This gradually contribution to form silica gel providing higher strength within a certain range of silica content which in turn will result in good mechanical properties [11]. Although high sodium silicates have positive effect on the mechanical properties of alkali activated materials, viscosity should be taken in consideration. Viscosity of the aqueous phase was found to increase substantially at high SiO2 to Na2O ratios. This would result in a low workability affecting the hardened mechanical properties [12].

3 IMPACT LOADS

In some cases, concrete structures are required to withstand impact loads such as projectiles. Impact may cause local and global damages [13-16]. This local damage can be classified into concrete fragmentation from the front face, scabbing of concrete from the back face or perforation which is total penetration of the projectile. In order to protect concrete structures against impact loads, different methods can be applied to improve the concrete resistance [17, 18]. A well-known approach is increasing concrete strength. High strength concrete showed lower penetration depth and crater diameter [19]. However, other studies [16] showed that high strength concrete exhibits larger crater area which means lower fracture energy under impact.

4 EXPERIMENTAL STUDIES

The aim of his experimental study is to investigate the effect of different factors of the alkali activator on the behavior against impact load. Dosage (Na_2O %) and modulus (M_S) of the activator as the most influencing factors of the activator were studied to understand their effect on the behavior with impact loads. Three modulus values and three dosage ratios were chosen according to previous work recommendations.

4.1 Material

Slag of specific gravity 2.9 is the aluminosilicate precursor material utilized in this investigation. Fine aggregate (natural sand) of specific gravity 2.65 was used in the mortar samples. Solid sodium hydroxide of specific gravity 2.1 and sodium silicate of specific gravity of 1.41 and were used to prepare the activator solution for different mixes.

4.2 Mix proportions

Mortar samples were prepared using water/solid ratio of 44%. Ten mixtures were prepared and casted (Table 1). One OPC control mixture and nine alkali activated slag samples were casted using the same binder content. Three values for modulus (M_S) of 1.0, 1.5 and 2 were used and three Na_2O ratios of 4%, 6% and 8% were used for each modulus value.

Table 1: Mix proportions

mixture	Binder (Kg)	Sand (Kg)	NaOH (Kg)	Na2SiO3 (Kg)	Added water (L)
control	548.7	1508.8	0.00	0.00	241.4
1 - 4	530	1457.5	18.8	73.6	206
1 - 6	521	1433	27.7	108.6	189.2
1 - 8	525	1443	37.2	145.9	152.8
1.5 - 4	526.9	1449	14.4	109.8	186.7
1.5 - 6	516.7	1421	21.2	161.6	160.9
1.6 - 8	506.8	1394	27.7	211.4	136.1
2 - 4	523.9	1440.7	10.11	145.6	167.6
2 - 6	512.3	1408.9	14.8	213.6	133.1
2 - 8	501.2	1378.5	19.3	278.7	100.1

5 TESTING PROGRAM

In this experimental study, compressive strength and impact resistance under drop weight of mortar samples were evaluated.

5.1 Compressive strength

Compressive strength of alkali activated slag samples and the control sample was measured using compression test machine. All samples were 50 mm mortar cubes (three of each mix). Cubes were tested at 3, 7 and 28 days after casting.

5.2 Impact test

ACI committee 544 (50) has recommended the drop weight test. In this test, a steel ball (4.5 kg) is dropped repeatedly from a height of 18 inches (457 mm) on a cylindrical sample of diameter 6 inches (152.4 mm) and height of 2.5 inches (63.2 m). These recommended values were simulated in the drop weight impact machine shown in (Fig. 1). A hammer with a substantial mass (i.e 4.5 kg) is raised to 18 inches (457 mm) height above the specimen. When the hammer is allowed to drop from its position, the potential energy of the mass will be converted to kinetic energy as the hammer falls with acceleration (g) neglecting any kind of resistance from air.

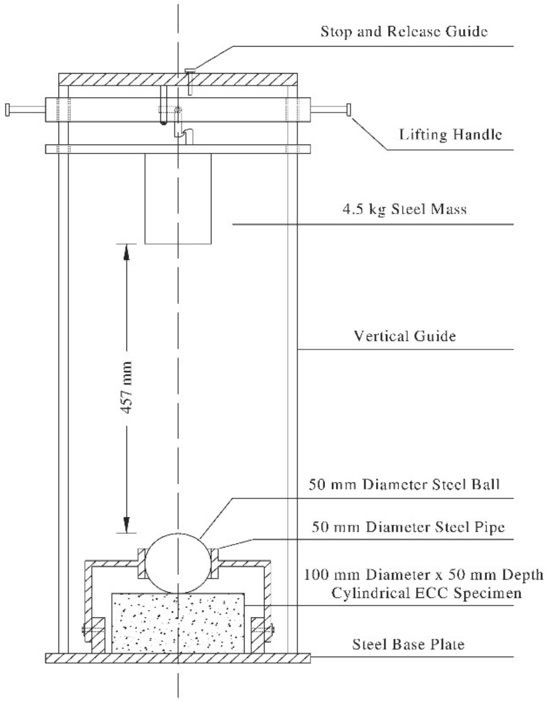

Fig. 1. Schematic drawing for the drop weight impact test machine

Just before the hammer strikes the steel ball, it is supposed to have velocity (v) given by “Eqn. 1”:

$$v = \surd 2gh \tag{1}$$

At this velocity, the hammer has kinetic energy given by “Eqn. 2, 3”:

$$ke = \frac{1}{2} m\, v^2 \tag{2}$$

Then,

$$ke = mgh \tag{3}$$

The number of blows that leads to failure is then counted and multiplied by the amount of energy transferred per blow to know the total adsorbed energy causing failure due to impact.

6 RESULTS AND DISCUSSION

6.1 Compressive strength

Three samples were tested for compressive strength every age. The results presented in (Fig. 2) in the study are the average of three values. Compressive strength is presented in MPa.

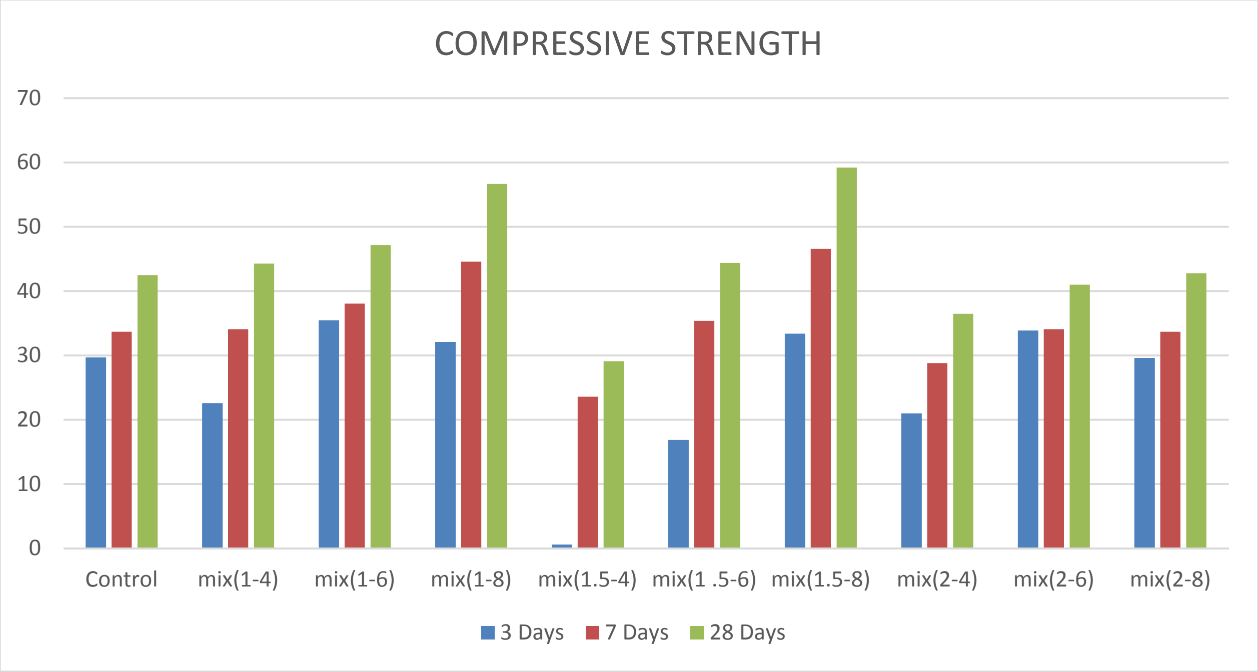

Fig. 2. Compressive strength results for 3, 7 and 28 days.

Results are showing that the most important factor in strength gaining is the dosage, such that for every different modulus, the more the dosage the more the compressive strength. On the other hand, for the same dosage in each modulus, modulus of 1.5 exhibited the highest value for compressive strength (Fig.3).

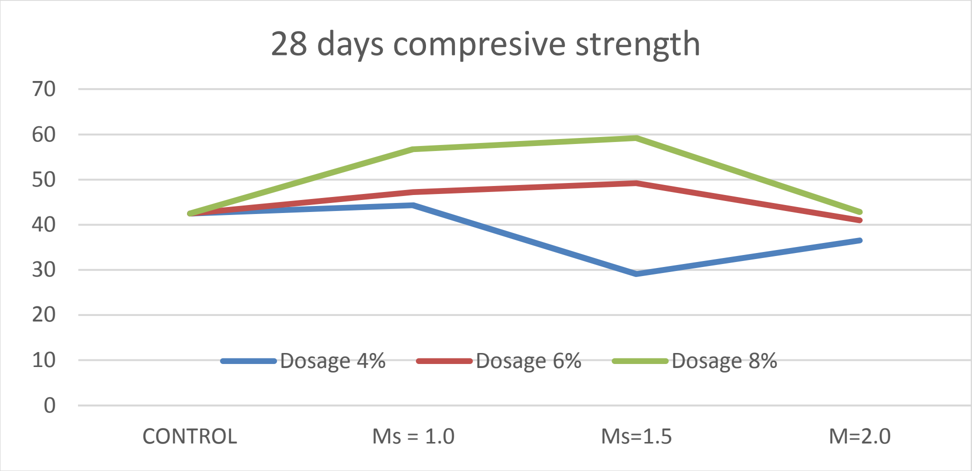

Fig. 3. Compressive strength results for 28 days.

6.2 Impact absorption

Impact test results have shown that Na_2O % is the most important factor to enhance the impact energy absorption of alkali activated slag. According to the failure number of blows for each mix, dosage of (8%) and modulus of (1.5) exhibited the highest impact energy absorption.

7 CONCLUSION

As for compressive strength, impact energy absorption of alkali activated slag is greatly affected by the activator properties in terms of modulus (M_s) and dosage (Na_2O %). According to results, modulus of (1.5) had shown the highest mechanical properties in terms of compressive strength and impact energy absorption. Also, for the dosage of the activator, dosage of 8% gives the highest compressive strength for each modulus and the highest impact energy absorption in terms of number of blows until failure.

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