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CHEMICAL RESISTANCE OF BOTTOM ASH – METAKAOLIN BLENDED GEOPOLYMER MORTAR

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ABSTRACT

The present study examined the chemical resistance properties of bottom ash – metakaolin (BA-MK) geopolymer binder under various chemical environments. The chemical environment such as sulphate attack salt attack and acid attack for geopolymer mixes were taken. Sodium based alkaline activators were proposed for this work. Steam and ambient curing were chosen to study the chemical resistance properties. Acid resistance test was performed with HCl, sulphate resistance test was performed with $MgSO_4$ and salt resistance was performed with NaCl solution. The percentage of mass change and compressive strength were determined after the immersion period. Based on the results, it was found that the mass retention and strength retention of BA-MK geopolymer mortar against chemical resistance was exceptional.

Keywords: Alkaline Activators, Bottom Ash, Curing Mode, Metakaolin .

I. INTRODUCTION

Portland cement concrete has long been considered as an excellent material for its effectiveness in binding the aggregates. Nevertheless, it is energy intensive product which consumes huge amount of ingredients for its production. It releases one ton of CO_2 into the atmosphere for manufacturing one ton of cement. It has great impact in the environment and causes global warming. Additionally, the long term performance under various durability issues is not convinced by conventional binder OPC. Under these circumstances, the use of pozzolanic materials like fly ash, silica fume, GGBS, metkaoline, rice husk ash takes the advantage to address the durability issues associated with OPC. The pozzolana materials can replace the cement partly and reduces the problem associated with durability issues. The life of the concrete structures is not only paying attention on the strength aspect it equally gives weight age to the durability under different environment. Henceforth, in view of all the above mentioned points, several researches have undertaken to give an alternate binder material. In this way, geopolymer binder is emerged as an alternate superb material for cement.

Geopolymer concrete compliances with performance base standard are comparable to that of most other high-strength concrete. Particular attention is paid to the role of free alkali and silicate in poorly- formulated systems and its deleterious effect on concrete performance with necessitates a more complete understanding of the chemistry of geopolymerisation for the technology to be successfully applied. Revathi.V et al (2014) carried out exhaustive study on BA-GP for its prospective applications. Logesh Kumar.M et al (2015) reported that weathering resistance of BA-MK should have the excellence performance. Vanchai Sata et al (2012) investigated the durability of lignite bottom ash geopolymer mortars in 3% sulfuric acid and 5% sodium sulfate solutions. It was found that the fine bottom ash was more reactive and gave geopolymer mortars with higher compressive strengths than those of the coarser fly ashes. All bottom ash geopolymer mortars were less susceptible to the attack by sodium sulfate and sulfuric acid solutions than the traditional Portland cement mortars. Davidovits (1991) found that metakaoline based Geopolymer has very low mass loss when samples were immersed in 5% sulphuric acid solutions for 4 weeks. Bakharev, 2005, studied the resistance of geopolymer materials prepared from fly ash against 5% sulfuric acid up to 5 months exposure and concluded that geopolymer materials have better resistance than ordinary cement counterparts. Song et al (2005) conducted an accelerated test to assess the durability of geopolymer concrete in a 10% sulfuric acid solution for 56 days and reported its good durability. Wallah and his associate (2006) have shown that geopolymer composites possesses excellent durability properties in a study conducted to evaluate the long term properties of fly ash based geopolymers. Caijun and Stegemann (2000) found the formation of a protective layer around specimen which acted as a barrier for further corrosion.

Besides, the presents work aims to carry out chemical resistance of bottom ash – metakaolin (BA-MK) geopolymer binder under various chemical environments.

II. MATERIALS

The materials used in the geopolymer mortar are bottom ash (BA), metakaolin (MK), sodium based alkaline activators and river sand. Bottom ash, a byproduct was collected from thermal power plant, Mettur, Salem. The properties of bottom ash are given in Table 2.1. Metakaolin was used as another source material in this study. for. The properties of metakaolin are presented in Table 2.2 River sand was used as fine aggregate in the study. It was properly graded to give the minimum voids ratio and shall be free from deleterious materials like clay, silt content and chloride contamination. The property of river sand is presented in Table 2.3.

Sodium hydroxide and sodium silicate was used as an activator. The sodium silicate solution (Na_2=13.7%, SiO_2=29.4% and water = 55.9% by mass) and sodium hydroxide (NaOH) in flakes 97% to 98% purity was purchased from local supplier in bulk. In preparation of NaOH solution, NaOH pellets were dissolved in water in volumetric flask for concentration of NaOH. Alkaline activator with the combination of NaOH and Na_2SiO_3 was prepared just before the mixing with the source materials. The addition of sodium silicate is to enhance the process of geopolymerization.

Table 2.1 Properties of Bottom Ash

Chemical Compositions	Percentage by weight
SiO_2	51.5
Al_2O_3	32.58
SO_3	5.19
CaO	0.50
MgO	0.21
Na_2O	1.35

Table 2.2 Properties of Metakaolin

Chemical Compositions	Percentage by weight
SiO_2	53.18
Al_2O_3	42.72
K_2O	0.41
CaO	0.28
MgO	0.0
Na_2O	0.09
LOI	0.34
Fe_2O_3	0.97

Table 2.3 Properties of Fine Aggregate

S.No	Test for Fine Aggregate	Relevant Code	Result
1	Specific Gravity	IS:2386 -1963 (Part I)	2.65
2	Bulk density	IS:2386 -1963 (Part III)	1721.32 kg/m^3
3	Fineness Modulus	IS:383-1970	3.42

III. EXPERIMENTAL PROGRAM

In this work, BA- MK blended geopolymer mix was selected for studying chemical resistance. The molarity of sodium hydroxide was selected as 8. The liquid to binder ratio was kept as 0.5. The ratio of Na_2O to SiO_2 in sodium silicate solution was considered as 2.0 in the present work. In the blended source material, equal proportions of bottom ash and metakaolin were chosen to study the chemical resistance of BA-MK blend geopolymer.

Cubes of 70.6 x 70.6 x 70.6 mm size were casted to find the acid resistance, sulphate resistance, and salt resistance for the proposed combinations of geopolymer mortar. The acid test was performed with 3% HCl solution, sulphate resistance test was performed with 5% $MgSO_4$ solution and the salt resistance was performed with 5% NaCl solution. The casted specimens were kept immediately in steam curing chamber at 60°C and ambient for 24 hours. After 24 hours, the steam cured (SC) and ambient cured (AC) specimens were stored in room temperature up to 28 days prior to the exposure to the solutions. In case of specimens cured under room temperature continued to keep in the same condition up to 28 days. At the age of 28 days, the specimens were weighed and immersed completely in the solutions. After 28 days immersion, specimens were taken out, surface dried and weighed. The percentage loss in weight was calculated. Then the specimens were tested for compressive strength.

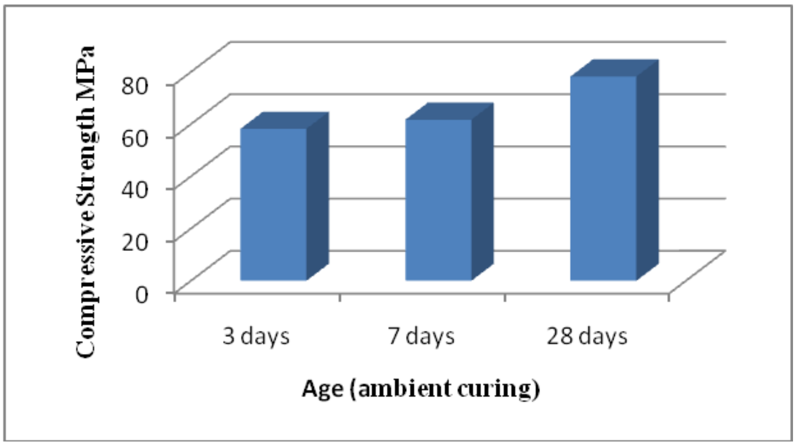
IV. RESULTS AND DISCUSSIONS

4.1 Compressive Strength of BA-MK GP Mortar

The compressive strength of BA-MK GP mix is given in Table 4.1. At the age of 3 days the BA-MK GP mix achieved 58.2 MPa under ambient temperature. At the age of 7 days ambient cured attained 61.7 MPa and 68.15 MPa. Similarly, compressive strength of steam cured BA-MK GP mix reached 66.74 MPa at 3 days, 68.15 MPa at 7 days and 82.24 MPa at 28 days (Fig 4.1 & 4.2). Compressive strength of steam cured BA-MK GP mix was higher than ambient cured specimens.

Table 4.1 Compressive Strength of BA-MK GP Mortar

Compressive Strength N/mm^2 (AC)			Compressive Strength N/mm^2 (SC)		
3 days	**7 days**	**28 days**	**3 days**	**7 days**	**28 days**
58.2	61.7	78.24	66.74	68.15	82.24



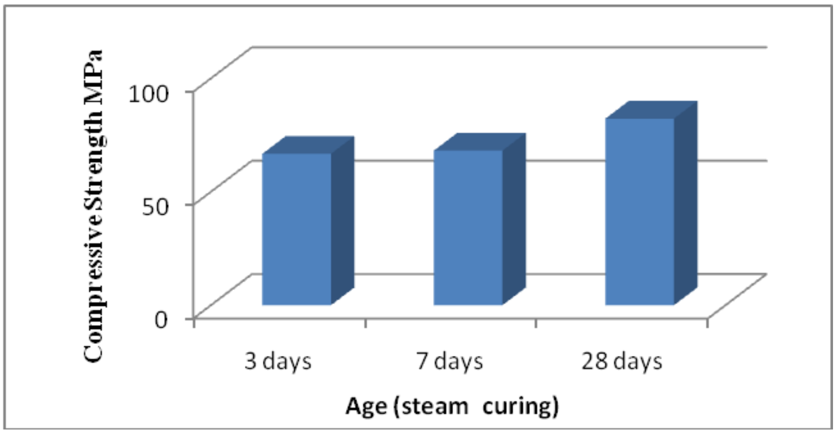


Fig 4.1 & 4.2 Compressive Strength of BA-MK GP

4.2.1 Sulphate Resistance of BA-MK GP Mortar

The mass change of specimens exposed to magnesium sulphate up to 1 month is presented in Table 4.2. The results showed that mass gain in the mix under ambient curing condition is less while comparing with mass loss of specimens in steam curing condition. BA-MK GP mortar mix had gained mass to 0.8% at AC and 3.7% at SC in one month sulphate exposure.

Table 4.3 shows the compressive strength of GP mortar mixes immersed in sulphate solution. It is clearly understood from the table 4.2 the compressive strength loss was remarkably less under AC and SC in one month exposure to sulphate solution. BA-MK GP mortar mix had compressive strength loss to 2.5% at AC and 3.2% at SC in one month sulphate exposure.

Table 4.2 Mass of BA-MK GP Mortar Mixes Immersed in Sulphate Solution

Mass, gm (Ambient Curing)		Change in Mass	Mass, gm (Steam Curing)		Change in Mass
Before Immersion	After 1 month Immersion		Before Immersion	After 1 month Immersion	
743	749	0.8%	749	777	3.7%

Table 4.3 Compressive Strength of BA-MK GP Mortar Mixes Immersed in Sulphate Solution

Ambient Cured Compressive Strength (MPa)		Change in Compressive Strength	Steam Cured Compressive Strength (MPa)		Change in Compressive Strength
Before Immersion	After 1 month Immersion		Before Immersion	After 1 month Immersion	
78.24	76.25	2.5%	82.24	79.58	3.2%

4.2.2 Salt Resistance of BA-MK GP Mortar

The mass change of specimens showing to sodium chloride up to 1 month is presented in Table 4.3. The results showed that mass gain in the mix under ambient curing condition is less while comparing with mass loss of specimens in steam curing condition. BA-MK GP mortar mix had gained mass to 3.5% at AC and 3.7% at SC in one month chloride spotlight.

Table 4.3 shows the compressive strength of GP mortar mixes immersed in sodium chloride solution. It is clearly understood from fig 4.4 & 4.5 the compressive strength loss was remarkably less under AC and SC in one month exposure to chloride solution. BA-MK GP mortar mix had compressive strength loss to 3.5% at AC and 3.7% at SC in one month chloride exposure.

Table 4.4 Mass of BA-MK GP Mortar Mixes Immersed in Salt Solution

Mass, gm (Ambient Curing)		Change in Mass	Mass, gm (Steam Curing)		Change in Mass
Before Immersion	After 1 month Immersion		Before Immersion	After 1 month Immersion	
749	775	3.5%	767	795	3.7%

Table 4.5 Compressive Strength of BA-MK GP Mortar Mixes Immersed in Salt Solution

Ambient Cured Compressive Strength (MPa)		Change in Compressive Strength	Steam Cured Compressive Strength (MPa)		Change in Compressive Strength
Before Immersion	After 1 month Immersion		Before Immersion	After 1 month Immersion	
78.24	77.10	1.5%	82.24	79.88	2.9%

4.2.3 Acid Resistance of BA-MK GP Mortar

The mass change of specimens exposed to hydrochloric acid up to 1 month is presented in Table 4.6. The results showed that mass gain in the mix under ambient curing condition is less while comparing with mass loss of specimens in steam curing condition. BA-MK GP mortar mix had gained mass to 3.6% at AC and 0.4% at SC in one month hydrochloric acid contact.

Table 4.7 shows the compressive strength of GP mortar mixes immersed in acid solution. It is clearly understood from table 4.7 the compressive strength loss was remarkably less under AC and SC in one month exposure to hydrochloric acid solution. BA-MK GP mortar mix had compressive strength loss to 2.1% at AC and 2.9% at SC in one month hydrochloric acid disclosure.

Table 4.6 Mass of BA-MK GP Mortar Mixes Immersed in Acid Solution

Mass, gm (Ambient Curing)		Change in Mass	Mass, gm (Steam Curing)		Change in Mass
Before Immersion	After 1 month Immersion		Before Immersion	After 1 month Immersion	
751	778	3.6%	765	768	0.4%

Table 4.7 Compressive Strength of BA-MK GP Mortar Mixes Immersed in Acid Solution

Ambient Cured Compressive Strength (MPa)		Change in Compressive Strength	Steam Cured Compressive Strength (MPa)		Change in Compressive Strength
Before Immersion	After 1 month Immersion		Before Immersion	After 1 month Immersion	
78.24	76.57	2.1%	82.24	79.87	2.9%

V. CONCLUSION

The test results revealed the following conclusions. Bottom ash –metakaolin blend yielded very high strength at early ages and at later ages at AC and SC.

1. Sulphate resistance, of BA-MK GP maintained 97.5% and 96.8% strength in one month exposure of acid solution for AC and SC.
2. In salt resistance, BA-MK GP had maintained 98.5% and 97.1% strength in one month exposure of acid solution for AC and SC.
3. Acid resistance revealed that 97.9% and 97.1% strength in one month exposure of acid solution for AC and SC.

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