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Capital University of Science and Technology, Islamabad Pakistan

ONE PART GEOPOLYMER USING RICE HUSK ASH AND METAKAOLIN

[a] Ammar Iqtidar, [b] Muhammad Faisal Javed, [c] Umer Khurshid, [d] Jawad Ihsaan, [e] Hadi Kamal

a: Department of Civil Engineering, COMSATS University Islamabad Abbottabad Campus, ammariqtidar@gmail.com
b: Department of Civil Engineering, COMSATS University Islamabad Abbottabad Campus, arbabfaisal@cuiatd.edu.pk
c: Department of Civil Engineering, COMSATS University Islamabad Abbottabad Campus, umerkhurshidkj@gmail.com
d: Department of Civil Engineering, COMSATS University Islamabad Abbottabad Campus, jawadihsan20@gmail.com
e: Department of Civil Engineering, COMSATS University Islamabad Abbottabad Campus, hadikamal777@gmail.com

Abstract- This research is conducted to assess the compressive strength of one part geopolymer mortar containing rice husk ash (RHA) and metakaolin (MK). Sodium Silicate in powder form is used as activator for the geopolymer. Water to binder ratio is kept constant at 0.5 for each sample. Two percent super plasticizer by weight of binder is added in mortar mix. The strengths of GM samples with different RHA/MK mass ratios are tested on 7, 14, and 28 days. The casted samples are placed in oven at 70°C for first 24 hours and then at ambient temperature of 19°C for rest of the time, till testing. Compressive strength of RHA/MK mass ratio of 10/90 is highest among all mixes. It is found that increasing the RHA more than 10 percent, results in reduced compressive strength.

Keywords- Geopolymer Mortar (GM), Metakaolin (MK)**,** One Part Geopolymer, Rice Husk Ash (RHA)

INTRODUCTION

Concrete is the second largest used material in world after water. Its constituents such as cement requires higher amount of energy to be prepared, this energy is obtained by burning fossil fuels. Along this, the hydration reaction of cement with water during preparation of concrete is an exothermic process and it releases energy in form of heat into the environment while forming bonds [1]. These two are the main reasons that contribute towards a great carbon footprint of concrete. About 9 percent of carbon dioxide in environment is due to manufacturing or use of concrete and its constituents [2]. So, attempts are being made to produce greener concrete with lowest carbon footprint and highest strength and sustainability. One of these attempts is to make green concrete using geopolymer (GP) materials available abundantly throughout the globe. Mainly the materials having properties same as cement are used for this purpose, called supplementary cementitious materials (SCMs). The SCMs include RHA, Ground Granulated Blast Furnace Slag (GGBFS), Fly Ash (FA), Condensed Silica Fumes (CSF) and various other industrial and agricultural wastes that are rich in silica and alumina [3].

While Pakistan is an agricultural country and produces tons of agricultural wastes annually, the use of these agricultural wastes by incorporating them in concrete can be taken into consideration. Pakistan produces 6.7 million tons of rice husks (RH) every year, as of year 2017, as rice is one of its major consumed and cash crops [4]. These RH are used as a fuel for boiling rice paddy in rice mills. The ash obtained from burning RH, known as rice husk ash (RHA), is then discarded into open environment or rivers which causes ground, air and water pollution. RHA is one of the SCMs that contains more than 90 percent silica. RHA when mixed with other materials such as GGBFS, FA in the presence of alkaline activators yields strength higher than that of normal OPC [5],[6]. RHA, containing silica, alone cannot replicate the properties of cement so an alumina source is also needed. Metakaolin (MK) contains considerable amount of alumina [7]. When inert Kaolin (KN) is calcined at elevated temperature then reactive metakaolin is formed. Several researches have been conducted which have shown that metakaolin can be used effectively with a silica source to replicate the properties of cement by the process of geopolymerization [8].

In this study RHA is used with MK to synthesize one part GP and then its strength is assessed. The use of GP based mortar utilizes the wastes of agricultural industry and consumes less energy as compared to the preparation of OPC. It results in reducing the depletion of natural resources that are used in manufacturing of OPC, as well as environmental pollution is also reduced which is caused by dumping RHA openly and a sustainable environment is created due to lesser emission of carbon dioxide.

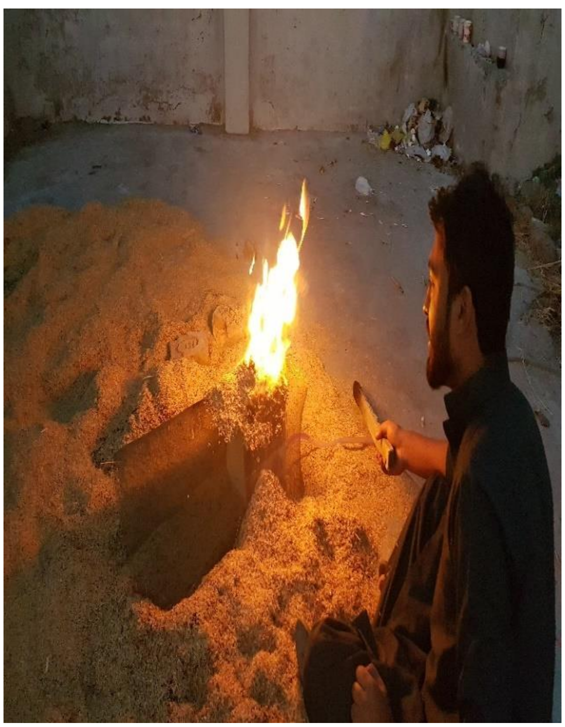
EXPERIMENTAL DETAILS AND RESEARCH METHODOLOGY

1.1 Raw Materials

For research purposes, the raw materials are collected from nearby markets. RH (Figure 1a) are easily available on hay stocks that spread throughout the Hazara Region. KN (Figure 1b) is available in different qualities in small industrial area of Mansehra namely, single washed KN and double washed KN. Single washed KN contains more impurities than double washed KN, so double washed KN is acquired. This KN is calcined to obtain MK. MK along with RHA is used for making GP mortar. Since this research is focused on one-part GP, so sodium silicate is obtained in powder form from a vendor. Sand used in this research is obtained from Havelian sand quarry.

1.2 Raw Materials Processing

Rice Husks are first burnt in an uncontrolled environment. It helped in shrinking down the mass of RH. But the RHA obtained from uncontrolled burning is black in colour. The RHA obtained from uncontrolled burning is burnt under controlled temperatures in muffle furnace at 750℃ for 3 hours for elimination of carbon. The resulting RHA is white in colour. The larger chunks of white KN are first broken into smaller pieces with hammer and then calcined in muffle furnace at 750℃ for 6 hours (Figure 2a). The resulting MK is light brown in color. The RHA (Figure 2b) and MK are then separately grinded in roller jar mill. Then the grinded materials are passed through ASTM sieve number 200 and stored in air-tight bags, to prevent the materials from absorbing any moisture from atmosphere.

a) 

b) 

Figure 1: Raw materials, a. rice husks and b. kaolin

a) 

b) 

Figure 2: Raw materials processing, a. kaolin being calcined and b. grinded RHA

1.3 Mixing, Casting and Testing

After acquiring the desired materials for GP, a mix design is necessary to prepare the GP mortar. As both MK and RHA are high water absorbing materials so the water to binder ratio is set by hit and trial method. Mass batching is selected as the suitable batching technique for this research. After that, the mass of dry mix is determined for making three GP cubes in 5.08×5.08×5.08-cm mold. It is found out that a dry mass of 800 grams is suffice for preparing six mortar cubes for the afore-mentioned mold size. The binder to sand ratio is kept constant as 1:1. Table 1 represents only the 50 percent constituents of GP mortar, that is, binder only. The rest of 50 percent is sand. RHA, MK, Sodium Silicate and Sand are added and mixed in dry form with the help of cobalt mixture for 5 minutes on low speed. Then water is sprinkled slowly on the mix while mixture kept rotating. Super plasticizer is added after water and mixture speed is set at high for another two minutes. A homogenous GP mortar is obtained. Moulds are lubricated with oil and assembled. Then the GP mortar is added in moulds in three layers with 25 blows on each layer with a pastel. The surfaces of cubes are made even with a cutter. The moulds are kept in oven for 24 hours at 70°C. Then the mortar cubes are demolded and kept at ambient temperature of 19°C for 7,14 and 28 days till testing. The compressive strength of cubes is tested by universal testing machine according to ASTM C109. A total of 9 cubes are prepared for each GP mortar sample (3 cubes are tested for each curing age, for example, for determining the 7 days compressive strength of R10M90, 3 cubes are tested by universal testing machine and their average is taken). So, for 3 samples a total of 27 GP mortar cubes are prepared. And for Ordinary Portland Cement (OPC), 9 cubes are prepared separately.

Table 1- Mix design of GP mortar

Sample ID	RHA (% of mass of binder)	MK (% of mass of binder)	OPC (% of mass of binder)	Water to Binder Ratio	Super-plasticizer (% of mass of binder)
R10M90	10	90	0	0.5	2
R20M80	20	80	0	0.5	2
R90M10	90	10	0	0.5	2
OPC	0	0	100	0.5	-

RESULTS

The results of compressive strength on different curing age are shown in table 2. For each curing age three cubes are tested. The average of three compressive strengths is calculated and presented as the compressive strength of that single day. The table shows vigorous increase of compressive strength till 7 days and then the compressive strength keeps increasing gradually till 28 days. The 28th day strength is the maximum of all. The results show that R10M90 imparts greatest compressive strength of all mixes. However, by increasing the amount of RHA to 20 percent, the compressive strength is reduced as compared to R10M90. If quantity of RHA is increased to 90 percent, the compressive strength gets affected much adversely. It can be seen in the table below that 7, 14 and 28 days compressive strength of R10M90 is 48,53 and 64 percent, respectively, more than that of OPC sample. The highest compressive strength is also shown by R10M90 at 28 days, that is 21.05 MPa. The main reason for increase in compressive strength is due to bonds present between Silica of RHA and Alumina of MK, which represent the properties of geopolymers.

Table 2- Difference in compressive strength as compared to OPC

Sample ID	Compressive strength at different curing ages (MPa)						
	7 Days	**Difference in compressive strength as compared to OPC (%)**	**14 Days**	**Difference in compressive strength as compared to OPC (%)**	**28 Days**	**Difference in compressive strength as compared to OPC (%)**	**Standard Deviation (For three GP mortar samples)**
R10M90	17.56	48.18	19.26	53.34	21.05	64.45	7.19 (28 days)
R20M80	15.25	28.70	16.86	34.23	17.65	37.89	6.67 (14 days)
R90M10	04.82	-59.32	06.70	-46.65	07.25	-43.35	6.78 (7 days)
OPC	11.85	-	12.56	-	12.80	-	-

Table 2 represents the difference of compressive strengths between GP mortars and OPC mortar. It can be noted that two GP mortar samples R10M90 and R20M90 have greater strength than OPC mortar at 7, 14 and 28 days. While R90M10 GP mortar sample has less strength than that of OPC at all days. The negative sign (-) for R90M10 in strength difference columns represents that this GP mortar has strength less than that of OPC.

CONCLUSION

Following conclusions can be drawn from the conducted study:

- One part geopolymers can be made successfully by incorporating RHA and metakaolin.
- Maximum compressive strength can be achieved by using 10 percent RHA and 90 percent metakaolin in one part geopolymers.
- RHA quantities more than 10 percent results in decrease in compressive strength, when used with metakaolin.

The above outcome is favorable indicating the one part GPs can be synthesized successfully in Pakistan. The next step should be to make concrete from this one part GP, having higher compressive strength and higher durability. The chemical activator source should be replaced with the one found in nature.

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