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Experimental Study on Geopolymer Motor with Marble Powder under High Temperature

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ABSTRACT

Geopolymers belong to a range of inorganic polymeric materials formed by activating silica aluminium rich minerals. Silica-aluminium rich industrial wastes etc. are activated with alkaline or alkaline-silicate solution at ambient or higher temperature to get Geopolymers. Geopolymerisation involves a number of processes such as dissolution, diffusion, polycondensation, and hardening. Optimization of such a complex system requires systematic study of several synthesizing parameters as well as of their interactions, which are extremely important issues for a geopolymer. Secondly, marble powder from different sources show different level of reactivity under specific geopolymer synthesis conditions and consequently affects the final properties. Hence, for manufacturing high performance geopolymer binder from marble powder, it is necessary to understand the effects of a various synthesis parameters and their relationship with mechanical properties and microstructure. The geopolymer mix composition is normally controlled by adjusting alkali and silicate content of activating solution. The SiO2 /Na2O ratio is an extremely important parameter which has major influence on physical and mechanical properties as well as on its microstructure. In the present study, an attempt has been made to study overall performance of geopolymer composites. Percentage of Na2O was taken 8 % and 10 %. SiO2 / Na2O ratio was varied from 1 to 1.6. Sand to marble powder ratio was kept 2:1, 1:1, and 1:2. Curing temperature and curing time were 800C and 72 hours respectively. After seven days, specimens were heated in Kiln at 2000C, 4000C, and 5500C for four hours and then kept in air for cooling. The effect of various synthesizing parameters at different temperature exposure on different properties such as Workability, Weight loss, Compressive strength, Sorptivity, Bulk density, Water absorption, Apparent porosity & Surface texture have been studied and the results were presented in the graphical and tabular form. It was observed that the geopolymer mortar is quite temperature resistant up to 5500C and remains dimensionally stable. However, some reduction in compressive strength was observed.

Keywords: Compressive Strength, Water Absorption, Dry Density.

I. INTRODUCTION

Geopolymer binder are used together with aggregate to produce Geopolymer concrete which are ideal for building and repairing infrastructure and for pre-casting unit. The properties of Geopolymer include high early strength, low shrinkage and resistance to freeze-thaw, sulphates and corrosion resistance. This material can save up to 80% of CO2 emission cause by the cement and aggregate industries.

The global use of concrete is second only to water. As the demand for concrete as a construction material increases, so also the demand for Portland cement. It is estimated that the production of cement will increase from about from 1.5 billion tons in 1995 to 2.2 billion tons in 2010 (Malhotra, 1999).

On the other hand, the climate change due to global warming has become a major concern. The global warming is caused by the emission of greenhouse gases, such as carbon dioxide (CO2), to the atmosphere by human activities. Among the greenhouse gases, CO2 contributes about 65% of global warming (McCaffery, 2002). The cement industry is held responsible for some of the CO2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO2 into the atmosphere (Davidovits, 1994; McCaffery, 2002).

Several efforts are in progress to supplement the use of Portland cement in concrete in order to address the global warming issues. These include the utilization of supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin, and the development of alternative binders to Portland cement.

II. METHODS AND MATERIAL

1) Water absorption

The volume of pore space in specimen matrix, as distinct from the ease with which a fluid can penetrate it, is measured as absorption. Water absorption is usually measured by drying a specimen to a constant mass, immersing it in water, and measuring the increase in mass as a percentage of dry mass. In the present research, water absorption of specimens will be determined as per ASTM C-642. The 28 days aged specimens is dried for 48 hours at 65°C & then immersed in water for 24 hours. The test specimens soaked in water is removed from the immersion container, wiped clean and weighted immediately in saturated-surface-dry (SSD) condition to find increase in mass.

2) Compressive Strength

The direct compressive strength of hardened Geopolymer specimens will be obtained at the age of 7 days, using 2000 KN capacity digital compressive testing machine. At 7 days age, three identical samples were tested in accordance with ASTM C-109 -02 and the mean values of compressive strength are reported in relevant tables and graphs. Also for the specimens heated at elevated temperature, compressive strength will be measured after the specimens attain room temperature. A typical testing of mortar specimen is shown in Fig. 3.7

Figure 1. Setup for water sorptivity test

3)Manufacturing process of Geopolymer mix

Geopolymers prepared by mixing only marble powder with alkali activator solution is called „Geopolymer paste". The mixture is usually homogenous slurry which is dark gray in colour. The silica sand was added as filler material in paste to produce „Geopolymer mortar mix". Both Geopolymer paste and mortar mix were cohesive in nature in fresh state. In present research, for manufacturing of Geopolymer mixes, following range of different constituents will be selected.

- Low calcium dry marble powder : 40% to 70% by weight of Geopolymer mix
- Ratio of activator solution-to-fly ash : 0.3 and 0.6 by weight of Geopolymer mix
- Alkali content (% Na2O) : 8% and 10% by weight of marble powder
- Silica content (% SiO2) : 6.5% to 17.5% by weight of powder
- Water to marble powder ratio : 0.38 by weight.
- Fine aggregates : 30% to 70% by weight of marble powder

Following manufacturing process will be adopted for preparing Geopolymer specimens.

- Mix sodium silicate solution, sodium hydroxide pellets and water according to mix proportion, to make alkaline activator, at least one day prior to its use in manufacturing Geopolymer. mixer is used for preparing Geopolymer mix .Mix marble powder and alkaline activator in the mixer for about four to five minutes to make homogeneous paste.
- For preparing mortar specimens, sand in saturated surface dry condition is slowly added to Geopolymer paste while wet mixing in progress in

mixer and continue wet mixing for another 4-5 minutes after adding the sand.

- Transfer Geopolymer mix to moulds. Vibrate fresh Geopolymer mix in the moulds on vibration table for 2-3minutes to remove entrapped air in the mix.
- Rest period of 60 minutes is given to fresh specimens prior to placing them in the oven for thermal curing for 72 hours at 80°C. The rate of heating in oven is 0.5°C to 1°C per minute starting from room temperature and it was controlled depending on temperature level.

III. RESULTS AND DISCUSSION

Compressive Strength of Concrete:

Table 4.12 Compressive Strength results for cubes cured in water

Specimen id	Compressive strength (MPa) (72hours curing)	Compressive strength (MPa) (200°C)	Compressive strength (MPa) (400 °C)	Compressive strength (MPa) (550°C)
GM A3	28.09	25.29	22.84	18.52
GM B3	26.28	23.3	18.4	16.32
GM C3	24.3	13.46	13.8	9.64

Durability Studies

Table 4.13 Compressive Strength results for cubes cured in 1% sulphuric acid solution

Specimen id	Compressive strength (MPa) (72hours curing)	Compressive strength (MPa) (200°C)	Compressive strength (MPa) (400°C)	Compressive strength (MPa) (550°C)
GM A2	25.6	22.12	20.56	12.91
GM B2	22.12	19.5	14.5	9
GM C2	17.3	13.46	5.74	5.74

Table 4.1f Compressive strength

Specimen id	Compressive strength (MPa) (72hours curing)	Compressive strength (MPa) (200°C)	Compressive strength (MPa) (400°C)	Compressive strength (MPa) (550°C)
GM A1	24.5	18.52	15.23	9.42
GM B1	18.56	15.64	10.25	6.23
GM C1	11.69	8.4	3.54	1.04

Table 4.3 a Dry Density (kg/cum) (Sand : Marble powder =1:2)

Specimen id	Dry Density (kg/cum) Normal curing	Dry Density (kg/cum) (200°C)	Dry Density (kg/cum) (400°C)	Dry Density (kg/cum) (550°C)
GM A1	1606.254	1580.458	1550.568	1532.995
GM A2	1635.045	1610.54	1582.745	1561.05
GM A3	1656.02	1633.697	1615.192	1598.497

Table 4.3 b Dry Density (kg/cum) (Sand: Marble powder =1:1)

Specimen id	Dry Density (kg/cum) Normal curing	Dry Density (kg/cum) (200°C)	Dry Density (kg/cum) (400°C)	Dry Density (kg/cum) (550°C)
GM B1	1702.016	1680.247	1665.064	1650.64
GM B2	1747.791	1735.256	1725.995	1704.86
GM B3	1775	1764.415	1752.396	1735.46

Table 4.3 c Dry Density (kg/cum) (Sand : Marble powder =2:1)

Specimen id	Dry Density (kg/cum) Normal curing	Dry Density (kg/cum) (200°C)	Dry Density (kg/cum) (400°C)	Dry Density (kg/cum) (550°C)
GM C1	1818.797	1804.35	1780.228	1758.725
GM C2	1840.986	1820.258	1800.256	1775.254
GM C3	1852.821	1830.247	1813.826	1792.585

Table 4.3d Apparent Porosity (Sand : Marble powder= 1:2)

Specimen id	Apparent Porosity Normal curing (%)	Apparent Porosity (200°C) (%)	Apparent Porosity (400°C) (%)	Apparent Porosity (550°C) (%)
GM A1	21.229	21.684	22.932	25.847
GM A2	18.876	19.325	20.619	23.903
GM A3	17.796	18.129	18.713	20.610

Table 4.3e Apparent Porosity (Sand : Marble powder= 1:1)

Specimen id	Apparent Porosity Normal curing (%)	Apparent Porosity (200°C) (%)	Apparent Porosity (400°C) (%)	Apparent Porosity (550°C) (%)
GM B1	19.79	20.54	22.29	23.10
GM B2	17.15	18.57	20.23	21.12
GM B3	15.94	16.86	17.63	18.63

Table 4.3f Apparent Porosity (Sand : Marble powder= 2:1)

Specimen id	Apparent Porosity Normal curing (%)	Apparent Porosity (200°C) (%)	Apparent Porosity (400°C) (%)	Apparent Porosity (550°C) (%)
GM C1	15.962	17.437	18.212	19.347
GM C2	14.901	15.867	17.157	18.254
GM C3	14.174	14.835	15.253	15.929

Table 4.4a Water absorption (Sand: Marble powder = 1:2)

Specimen id	Water absorption Normal curing (%)	Water absorption (200°C) (%)	Water absorption (400°C) (%)	Water absorption (550°C) (%)
GM A1	12.617	13.004	13.934	16.843
GM A2	11.182	11.745	12.549	14.984
GM A3	9.841	10.513	11.524	12.847

Table 4.4b Water absorption (Sand: Marble powder = 1:1)

Specimen id	Water absorption Normal curing (%)	Water absorption (200°C) (%)	Water absorption (400°C) (%)	Water absorption (550°C) (%)
GM B1	11.627	11.896	12.45	13.04
GM B2	9.629	10.412	11.66	12.15
GM B3	8.995	9.518	10.080	10.88

IV. CONCLUSION

- The low calcium marble powderobtain from local industrial station was suitable for manufacturing Geopolymer composite of very good engineering performance at ambient as well as elevated temperature.

- The preparation of Geopolymer mortar has been accomplished by mixing of allumino-silicate source material „marble powder‟ with an activating solution that contains sodium hydroxide and soluble sodium silicate. Study on workability of the marble powder based Geopolymer mortar result shows that the percentage of Na2O, SiO2 / Na2O ratio and Sand to marble powder ratio affects the mortar flow. Increasing the Sand to marble ratio mixture become stiffer and workability become low. Increase the alkali (% Na2O) content and silicate ratio (SiO2 / Na2O) increase the workability of the Geopolymer mixture.

  Marble to Sand ratio at different elevated temperature (2000C, 4000C and 5500C) plays a vital role in compressive strength development. Increase in sand to marble powder ratio decrease the strength of the Geopolymer mortar. Minimum compressive strength loss of around 60 % was found at 5500 C for sand to marble powder ratio equal to 2.0 and SiO2 / Na2O = 1.6 , which was due to higher thermal shrinkage.
- Silicate ratio (SiO2 / Na2O) was also found to be crucial factor affecting the compressive strength of the Geopolymer mortar. The high reactive silica content involved in the formation of high amount of alkali alumina-silicate gel, resulting in high compressive strength. Compressive Strength loss at higher elevated temperature was less for higher SiO2 /Na2O ratio. At 5500C temperature, average 37 % strength was lost for SiO2 / Na2O=1.6. (Ref. Fig. 4.6, 4.7, 4.8, 4.19)
- The alkali content (% Na2O) was also important parameter affecting compressive strength of Geopolymer mortar. Increasing alkali concentration in Geopolymer system increased bulk concentration of hydroxide ions, resulted in increase of the dissolution rate of Si and Si-Al phase of marble . For alkali content (8 % Na2O), the unexposed and exposed compressive strength was found to be 25.6 MPa and 12.91 MPa respectively. When alkali content was increased from 8 % to 10 %, the unexposed and exposed compressive strength was found to be 30.64 MPa and 14.24 MPa respectively
- Compressive strength and UPV increases with increase in SiO2 / Na2O ratio and % Na2O. The maximum compressive strength of 30.40 MPa were obtained for unexposed condition at SiO2/Na2O ratio = 1.3, 10 % Na2O and Sand/FA= 0.5 and the maximum compressive strength of 18.40 MPa was obtained for exposed condition (5500 C) at SiO2 / Na2O ratio = 1.6, 8 % Na2O and Sand / FA= 0.5 respectively.
- Dry density was found to increase with increase in Sand to marble powder ratio, percentage of Na2O, and SiO2/Na2O ratio. After exposed to elevated temperature dry density value was decreased.
- Apparent porosity, water absorption and water sorptivity was found to decrease with increase in Sand to marble ratio, SiO2 / Na2O ratio and percentage of Na2O for both normal and elevated temperature condition.

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