Role of Composition of Raw Materials and Activation Parameters on Properties of Geopolymer Materials: A Third-Generation Cement

PhD Research scholar: Taj Muhammad, Institute of Chemical Sciences
University of Peshawar

Abstract

Shelter is the second important requirement of human being, however modern construction is not possible without cement. At the present Ordinary Portland Cement (OPC) is used for construction purposes, which is manufactured by heating clay and limestone at high temperature i.e. about 1400 ^{o}C in a rotary kiln. Due to rapid increase in global population the demand and production of OPC is also rising on a massive scale. However, the production of OPC not only involves huge consumption of natural resources like limestone and clay, but is associated with a number of other issues during its course of production such as high cost, disturbance of natural ecosystem and environmental pollution. During the production of OPC, large quantities of fossil fuel is consumed which emits various gaseous pollutants, including particulates, NOx, SO_3, and CO_2, leading to a number of environmental issues such as acid rain, greenhouse effect and photochemical smog. It is therefore of utmost importance to develop an alternative cementitious material for construction industry. An effort in this regard is the development of Geopolymer cement, which is an inorganic polymeric aluminosilicate, synthesized predominantly from silicon and aluminum rich sources under alkaline medium.

In this study, geopolymer cement was synthesized from alumina and silica rich wastes, including Waste Brick Kiln Dust, Clay, Ceramic dust and coal ash by alkaline activation. During geopoylmerization process the raw material was treated with definite volume of alkaline activator solution, in the presence of silicates, under known temperature for specific duration. The slurry was transferred to a steel mold 50x 50x 50 mm cube. and cured at different durations and temperatures to form geopolymer blocks. The compressive strength of the geopolymer blocks was monitored by Universal Testing machine (UTM) as a function of different optimization parameters such as concentration of alkaline activators, curing time, curing temperature, ratio of NaOH, silicates and $Ca(OH)_2$ and various additives.

In case of geopolymer based on brick dust, the 7 days compressive strength of 3.40 MPa was obtained with 12 M NaOH as an activator solution, Liquid to Solid (L/S) ratio of 0.45, 10 % $Ca(OH)_2$ at 60 ^oC. Whereas, using KOH as an activator under same conditions, the geopolymer strength of 3.14 MPa was recorded. For clay based and Ceramic dust geopolymer, the optimum activation parameters were found to be; 10 M NaOH, NaOH-Na_2SiO_3 to clay/ceramic dust ratio of 0.5, 10 % $Ca(OH)_2$ at 60 ^oC, under which the compressive strengths of 4.89 and 4.95 MPa was attained after 7 days curing. Likewise coal ash based geopolymer synthesized with 12 M NaOH/silicates and 10% $Ca(OH)_2$ for 20 hours, exhibited the compression strength of 4.11 MPa. In comparison, the same size of block of OPC shown compressive strength of 5.1 MPa.

The geopolymer mortar mix prepared by mixing the brick dust, clay, ceramic dust and coal ash based geopolymer with sand (9:11), exhibited the 28 days compressive strengths of 4.86, 5.91, 6.68 and 4.78 MPa, respectively, in comparison the OPC sand mortar mix (5:15) shown compressive strength of 6.56 MPa. The bulk strength of the large sized geopolymer block i.e. 2.2 kg, for the brick dust, clay, ceramic dust and coal ash based geopolymer shown the compressive strengths of 33.48, 46.6, 53.16 and 36.47 MPa. All the geopolymers were found to be high ther mal and acid resistance, the maximum of upto 3.4 % of loss on ignition was observed for heating at 800 ^oC, whereas upto 38% decrease in strength was observed by submerging in 20 % HCl and H_2SO_4 solutions for 28 days.

The XRF analysis exhibited that brick dust, clay, ceramic dust and coal ash contain 41 to 68 % silica and upto 29 % alumina, rending them suitable raw materials for synthesis of geopolymers. The FTIR analysis of the geopolymers samples indicated the major peaks at 872, 976 cm^{-1} and several other peaks upto 1416 cm^{-1}, which confirms the synthesis of geopolymer binder. The XRD analysis confirmed the geopolymer configurations by exhibiting the quartz, alumina, kaolinite and mullite phases in the XRD patterns of all geopolymers. The morphology of the geopolymers investigated by SEM microscopy reveled that all samples exhibit smooth and compact geopolymer mass with convoluted and layered texture.

Various reinforcing agents were added to the clay and ceramic dust based geopolymers which included graphite powder, glass waste, marble dust, slag, ash, gypsum, plastic waste, PVC, starch and silica , which shown that only addition of 5 wt % of slag leads to improve the compressive strength by 8-10%, whereas less than 7 % by the rest of additives.

These results concludes that geopolymers investigated in the current study may be accepted as a viable alternative to the OPC for construction purposes, however further studies on improvement in strength and durability are suggested.