A Green Building Material from Demolition Waste

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Abstract: Due to the rapid urbanization and construction of several permanent structures in developing country, the outcome of demolition wastes become large. The amount of such a large waste is creating economical burdening as well as environmental pollution. These wastes are rich in SiO_2 and Al_2O_3, which is used as a raw material for the preparation of geopolymer. Such geopolymer can be used as a building material which can reduce the greenhouse gas emission as well as fulfill the depletion of natural resources.

In the present study, two types of demolition wastes were selected. *i.e.*, brick dust and sand cement dust. During the variation of NaOH, a concentration of 6 M was selected and the compressive strength of geopolymer was found to be 6.7 and 2.9, respectively using brick dust and sand cement dust. Then a 30 % of dolomite was selected in both cases. Finally the maximum compressive strength of the geopolymer prepared from brick dust, sand cement dust and a mixture of brick and sand cement dust with an alkaline solution were found as 45.1, 36.3 and 43.2 MPa, respectively.

Keywords: Brick dust; Compressive strength; Dolomite; Geopolymer; Sand cement dust

1. Introduction

Green building materials are composed of renewable (not nonrenewable) resources. These materials are manufactured with resource-efficient processes including reducing energy consumption, minimizing waste (recycled, recyclable and/or source reduced product packaging) and reducing greenhouse gases. These materials are environmentally responsible due to the impacts over the life of the product. These materials products promote conservation of dwindling nonrenewable resources globally. In addition, integrating green building materials into building projects can help to reduce the environmental impacts associated with the extraction, transport, processing, fabrication, installation, reuse, recycling, and disposal of these building industry source materials (Mohamed 2010).

Demolition waste has become an important issue not only from the perspective of cost efficiency but also due to its adverse effect on the environment. In an attempt to protect the environment and to minimize the demolition waste, recycling and utilization of demolition these wastes will be a significant contribution to environment and sustainable development.

Geopolymers are members of the family of inorganic polymers. These made from a silica-alumina source, such as fly ash, metakaolin, blast furnace slag, construction and demolition waste and a strong alkali activator, such as sodium hydroxide, water glass, potassium hydroxide, sodium sulphate, lime or their combinations.

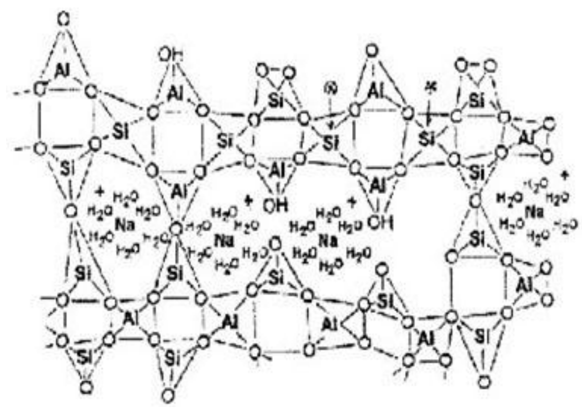

Figure 1: Proposed geopolymer structure (Barbosa et al. 2000)

The chemical composition of a geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous (Davidovits 2008). The polymerization process involves a substantially fast chemical reaction under alkaline conditions on Si-Al minerals, resulting in three-dimensional polymeric chains and ring structures consisting of Si-O and Al-O bonds (Davidovits 1994a). It is proposed that the geopolymer gel can diffuse into larger interstitial spaces between the particles (Hua and van Deventer, 2000). When the gel hardens, the separate alumino-silicate particles are therefore bound together resulting the matrix. The geopolymer structure consists of cross-linked SiO_4 and AlO_4 tetrahedral that the negative charge on Al^{+3} sites in IV-fold coordination is compensated with alkali ions such as Na^+ and K^+. A structural model proposed by Barbosa *et al.* is shown in Figure 1 (Barbosa et al. 2000).

Durability of the geopolymer is already accepted by the specifiers such as government, architects and design engineers. Road authority has recognized for non-structural applications (van Deventer et al. 2012).

Compressive strength of geopolymer developed from brick dust with an alkaline activator has been reported to be 11.43 MPa (Pathak, et al. 2014). Also in other work on brick-dust, demolished-cement-sand-concrete-mixture, demolished -cement-sand-mixture and coal fly ash a higher compressive strengths of geopolymeric has been reported (Pathak, et al. 2012).

The demolition wastes brick dust and sand cement dust are the rich source of alumino-silicate while these materials are creating environmental problem due to their deposits. The main objective of the present study is to utilize these waste materials for the synthesis of geopolymer and thus characterize the obtained materials through various instrumental techniques.

2. Experimental Method

2.1 Raw Materials

Demolished brick and sand cement waste were selected to prepare geopolymer. The brick, sand cement waste and dolomite were first grinded and sieved and the different size 75, 90 and 120 µm.

2.2 Alkali activator

Laboratory grade pellet of NaOH (97%, Merck, Germany) was used to prepare 2 – 8 M. and the a solution of 6M NaOH and sodium silicate pentahydrate was prepared by dissolving sodium silicate into 6M NaOH solution using magnetic stirrer for one hour at 65-70 ^{o}C.

2.3 Sample Preparation

At first alkali concentration was varied in a range of 2 M – 8 M NaOH solution. Then brick dust and sand cement dust of different size were treated with selected alkali concentration. Then dolomite variation of 10 % to 50 % was carried out with selected alkali concentration and particle size. Finally sodium silicate pentahydrate was dissolved in 6 M NaOH by stirring using magnetic stirrer at 60-70 ^{o}C. A paste was prepared by mixing 60 g of waste dust with 18 ml of activator solution. The mixtures were separately kept in mould (2.5 cm × 2.5 cm × 2.5 cm cubic) and cured at 40 °C. Three different geopolymer samples were prepared using brick dust, sand cement dust and a mixture of brick and sand cement dust. In the mixture 60 g of brick dust and 40 g of sand cement dust was first mixed and then 70 % of the mixture and 30 % of the dolomite was mixed in dry state and then paste was made with the alkali activator.

2.4 Measurement of compressive Strength

The compressive strength of the prepared geopolymer was measured using SLF 9 Load frame machine at Central Material Testing Laboratory, Institute of Engineering Pulchowk Campus, Tribhuvan University.

2.5 Characterization

The raw sample and fragments of few characteristic samples obtained from the compressive strength testing were powdered and examined by *X-ray diffraction* patterns obtained by a scanning rate of 2° per min from 2θ = 10° to 80° (D2 Phaser Diffractometer, Bruker, Germany) available at National Academy of Science and Technology (NAST).

3. Results and Discussion

3.1 Compressive Strength

3.1.1 Alkali concentration variation

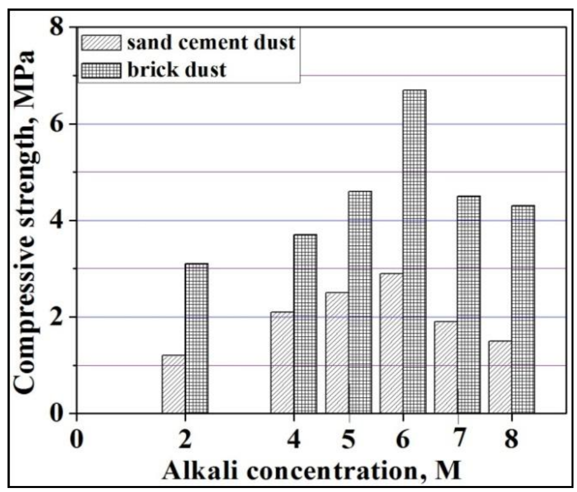

Figure 2: Compressive strength of the geopolymeric products with a variation of NaOH concentration

Sodium hydroxide concentration of 6 M was selected as the maximum compressive strength at 7-days of geopolymer product made from brick dust and sand cement dust of size 75 µm were found to be 6.7 and 2.9 MPa. respectively shown in Figure 2.

3.1.2 Particle size variation

With the decrease in the size of brick dust and sand cement dust particle, there is increase in compressive strength at 7 days of the geopolymeric product with 6 M NaOH was found to be 6.7 and 2.9 MPa, respectively shown in Figure 3.

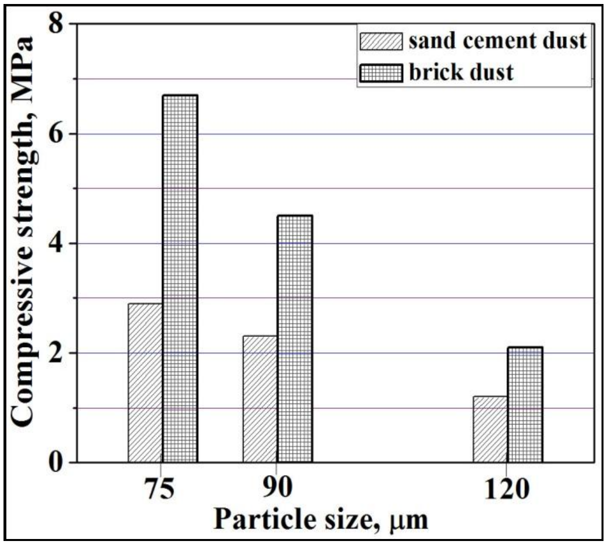

Figure 3: Compressive strength of the geopolymeric products with a variation of particle size

3.1.3 Dolomite Percentage variation

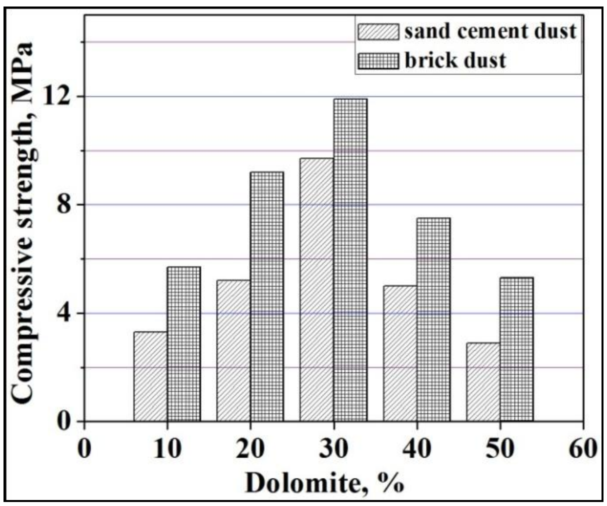

Figure 4: Compressive strength of the geopolymeric products with a variation of curing time

30 percent of dolomite was selected as the maximum compressive strength at 7-days of geopolymeric product made of brick dust and sand cement dust with the selected alkali concentration of 6 M NaOH were found to be 11.9 and 9.7 MPa respectively shown in Figure 4.

3.1.4 Curing time variation

The maximum compressive strength of the geopolymer

product of brick dust, sand cement dust and their mixture with alkaline activator solution containing 6 M NaOH and sodium silicate was found to be 45.1, 36.3 and 43.2 MPa, respectively at 28 days shown in Figure 5.

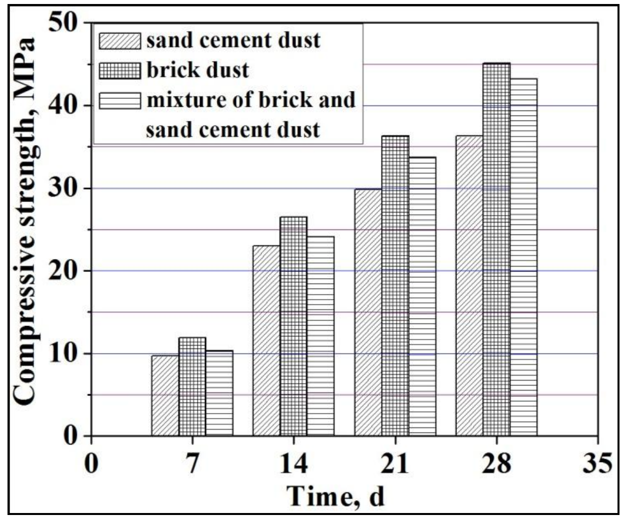

Figure 5: Compressive strength of the geopolymeric products with a variation of dolomite composition

3.1.5 XRD Analysis

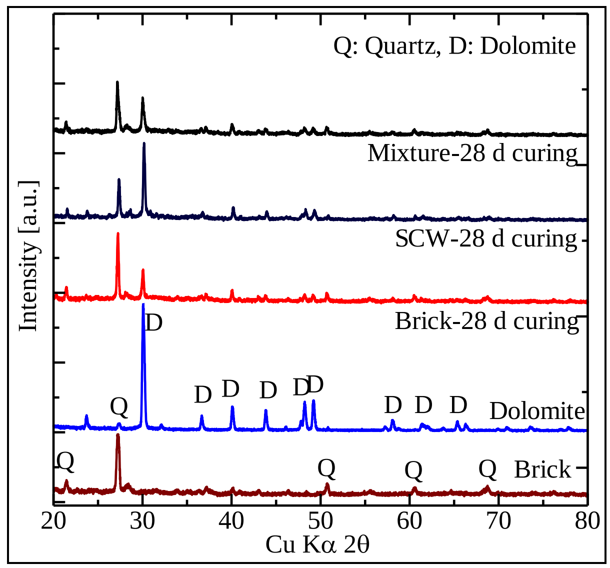

Figure 6: XRD patterns of geopolymer samples obtained from various starting materials

The XRD patterns of brick dust, dolomite and its geopolymer products are shown in Figure 6.

Major peaks of the brick dust at 2θ = 21.36, 27.18, 50.70, 60.50 and 68.75º were that of quartz silica and the major peak of dolomite at 2θ = 30.07, 36.63, 40.05, 43.81, 48.21 and 49.17º were mostly the peaks of $CaCO_3$ and $MgCO_3$. These peaks were also found diminished on treating with the alkaline activator solution. This is due to the dissolution of silica in the presence of alkali and formation of more geopolymeric network.

4. Conclusion

The maximum compressive strengths of geopolymer developed from brick dust, sand cement dust and their mixture were found to be 45.1, 36.3 and 43.2 respectively. The increase in compressive strength was assumed due to the formation of additional calcium silicate hydrate gel which fills the voids and pore within the geopolymeric binder. It helps to bridge the gaps between the different hydrated phase unreacted particles. Thus geopolymer material suitable for building applications may be synthesized from demolition waste such as brick dust and sand cement dust which is one of the perspective sustainable cementitious materials in 21st century.

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