Journal of Civil Engineering and Environmental Technology
Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 1, Number 2; August, 2014 pp. 57-60

http://www.krishisanskriti.org/jceet.html

Impact of Coal Combustion Fly Ash used as a Binder in Pavement

Priyanka Ramkripal Singh[1], N.D. Shah[2]

[1]*Galgotia University, School of Civil Engineering, Greater Noida*
[2]*Chandubhai S Patel Institute of Technology, CHARUSAT, Gujarat*

Abstract: **Highway Engineers have long back recognized the importance of long term benefits of increasing the strength and durability of pavement by mixing cementitious binder during the construction of pavements. Fly ash is a pozzolanic powdery residue collected in electric or mechanical dust collectors following combustion of coal in coal fired power plants. There are many possible applications of this cheap binder, among others, the road construction industry can use it in large quantities, reducing the costs and solving environmental problems as well. The utilization of this by-product as a geopolymer raw material can effectively solve the environmental risk due to its good mechanical behavior and immobilization capacity. Based on laboratory experimental results it can be concluded that mechanical activation of the raw fly ash has a positive effect on geopolymerisation. The present paper deals with a general overview of fly ash and two prosperous fly ash utilization possibilities: 1) hydraulic binder and 2) geopolymer through laboratory experimental results. The key to a fly ash-based geopolymer product with optimum binding properties was stated by Ferndandez- Jimenez to be derived from using a fly ash material with the following properties: less than five percent of unburned material; less than 10 percent Fe_2O_3; a low content of CaO; 40–50 percent relative silica; 80–90 percent of particles with diameter equal to of less than 45 µm; and a high vitreous phase.**

Keywords: **Compressive strength, Cementitious binder, Geopolymer, Pozzolanic Reactions, Durability.**

1. INTRODUCTION

The huge demand of concrete due to population explosion has entailed the need for sustainable and eco friendly building materials. Researchers have tried to incorporate fly ash (a cementitious binder), ground granulated blast furnace slag (GGBS), lime stone dust, rice husk ash, welding flux slag and other waste products into building material so as to improve its sustainability. An interesting area of research which has attracted interest of many scholars is Geopolymer binder which utilizes industrial waste products to form sustainable green binders In order to comply with sustainable development concept, it is very important to minimise the negative environmental impacts of all construction works. The negative environmental impacts associated with the OPC production are much noticeable. During the manufacturing process of one ton of OPC, it releases a ton of Carbon Dioxide (CO2) gas to the environment due to the process of calcination of limestone and combustion of fossil fuels [1]. One of the alternatives which have been discussed as a substitute for OPC concrete is the geopolymer concrete. It can be easily produced with fly ash, which is a waste product of the coal-fired power stations. In India, it is estimated that by end of 2012, from the total thermal capacity of about 90 coal / lignite based Thermal Power plants, generate ash in the form of fly ash (80-90%) and bottom ash (10-20%) would be of the order of 173 Million Tons(Mt) per annum considering 38% ash content in coal as an average and at 80% Plant Load Factor (CEA 2009-10). It is further estimated that only about 51% of the ash generated found gainful utilization.

Given the fact that economic growth of the Nation is generally linked to power availability and given the trend of high proportions of coal based thermal power stations (TPS), fly ash generation is likely to increase in future. It is estimated that coal ash generation will likely to grow over 200Mt by the year 2017. Unless we find more ways to utilise this industrial waste fully, in line with its output, it will greatly endanger the environment.

The main objective of this research was to develop a fly ash based geopolymer concrete which can be used as a substitution for OPC concrete in pavement blocks with its enhanced durability feature and is much more environmental friendly. This paper will present the findings of various research programs and laboratory tests on the behavior of geopolymers to be used as pavement blocks.

2. LITERATURE REVIEW

The term geopolymer was termed by Davidovits in 1988 [7] to represent mineral polymers. Geopolymers are chemically similar to Zeolite but has amorphous microstructure consisting predominantly of Si and Al atoms. During the synthesized process, silicon and aluminium atoms are combined to form the building blocks that are chemically and structurally comparable to those binding the natural rocks [8-11].Most of the literature in geopolymer deals with geopolymer pastes and geopolymer concrete. Geopolymer based binder was patented in USA in 1988 as High Strength Mineral polymer and the binder was prepared using GGBS which replaced cement mortar in precast structural elements. Geopolymer has advantages like availability of abundant raw materials, quick strength gain, good durability especially in acidic environment, reduced energy consumption and reduced greenhouse gas emission [12]. The hydrophobic nature of fly ash gives pavements better resistance to stripping. Fly ash has also been shown to increase the stiffness of the asphalt matrix, improving rutting resistance and increasing mix durability. Geopolymers More recently, fly ash has been used as a component in geopolymers, where the reactivity of the fly ash glasses is used to generate a binder comparable to a hydrated Portland cement in appearance and properties, but with possibly reduced CO2 emissions.It should be noted that when the total carbon footprint of the alkali required to form geopolymer cement is considered, including the calcining of limestone as an intermediate to the formation of alkali, the net reduction in total CO2 emissions may be negligible. Moreover, handling of alkali can be problematic and setting of geopolymer cements is very rapid (minutes versus hours) as compared to Portland cements, making widespread use of geopolymer cements impractical at the ready mix level.

3. MATERIALS

This paper describes the experimental investigation carried out to develop geopolymer concrete based on alkali activated fly ash by Sodium Hydroxide with Sodium Silicate. Effects of the factors such as method of curing and concentration of NaOH on compressive strength as well as the optimum mix proportion of geopolymer paste, mortar and concrete were investigated.It was possible to achieve compressive strengths of 14 N/mm^2 and 37 $N/mm^2$for the geopolymer paste and mortar respectively after 7 days of casting when cured for 5hours at 80^0 C.

Results indicated that the increase of water content of all three forms of geopolymer resulted in decrease of the compressive strength. Strength development of geopolymer at room temperature was also studied and found that only half of the compressive strength of the heat cured sample was achievable even after 28 days. Most of the results were very promising and showed a great potential for this material as a substitute for Ordinary Portland Cement concrete. Fly ash based geopolymer mortar solid block (with a compressive strength of 24 N/mm^2) and a concrete interlocking paving block (with a compressive strength of 48 N/mm^2) were developed using the optimum mix proportions obtained.Results of XRF analysis of the fly ash is indicated in Table 1. Fly ash falls under Class F as per ASTM Standard. The specific gravity of fly ash was found to be 2.05.

Sieve Analysis of bottom ash also was carried out mainly to determine the quantity of particles size distribution and was found to be well graded.

Table 1. Chemical Composition of fly ash.

Oxide	Mass Percentage
SiO_2	53.3
Al_2O_3	29.5
Fe_2O_3	10.7
CaO	7.6
SO_3	1.8

Table 2. Composition of Bottom Ash

Oxides	Mass Percentage (%)
SiO_2	56.76
Al_2O_3	21.34
Fe_2O_3	5.98
CaO	2.88
SO_3	0.72

2.1 Sodium Silicate and Sodium Hydroxide

Laboratory grade (97% pure) sodium hydroxide was in the form of pellets (3mm approximately) with specific density of 2.13 g/cm3. The chemical composition of sodium silicate solution was Na2O=15.23% by mass, SiO2=35.67% by mass and remaining water. The Molar Ratio SiO2/Na2O) was found to be 2.34. The density of sodium silicate solution was found to be 1.53 g/cm3.

4. INTERLOCKING PAVING BLOCK

Using the optimized mix of geopolymer concrete, an interlocking block with a surface area of 26, 551 mm^2 was cast using the vibrating paving block making machine(see Figures 1 and 2). The mix was loaded to the paving machine where it was first vibrated and then compressed using a heavy plate and produced a 70mm thick interlocking paving block. The heat curing process lasted for 5hrs at 80^0C and checked the compressive strength after 7 days.

The top surface of the paving block was made smooth by applying Plaster of Paris and was placed between two plywood plates before they were being tested in the Amsler machine.

Figure 1: Making of the interlocking paving block in progress

Figure 2: Interlocking paving block

3.1 Optimum mix proportions

After analysing all the test results and experimental observations, the following optimum mix proportions were obtained for each phase of geopolymer (Table 3).

Table 3-Geopolymer concrete (Weight per m3)

NaOH8mol/dm^3	Na_2SiO_3	Fly ash
36 kg	87 kg	510 kg

Sand	10 mm Aggregate	Additional water
545 kg	932 kg	90 kg

5. RESULTS AND DISCUSSION

Test results corresponding to the compressive strengths of geopolymer concrete with time, NaOH concentration, additional water content and other parameters were analyzed to obtain the effect of each parameter on compressive strength.According to the experimental results of geopolymer concrete, the following observations can be made.

1. There was a rapid strength development during first 3 days of heat cured geopolymer samples.
2. The time taken for the strength gain in ambient cured samples was much higher than that of the heat cure samples. Approximately half of the strength achieved by heat curing after 28 days can be also achieved by keeping it at room temperature for the same time period. This may be due to the slow speed of polymerization at low temperatures.
3. Fly ash based geopolymer concrete can be efficiently used to manufacture relatively high strength interlocking paving blocks.

REFERENCES

[1] Lingling, Xu, et al. "Study on fired bricks with replacing clay by fly ash in high volume ratio." *Construction and Building Materials* 19.3 (2005): 243-247.

[2] Malhotra, S. K., and S. P. Tehri. "Development of bricks from granulated blast furnace slag." *Construction and Building Materials* 10.3 (1996): 191-193.

[3] Turgut, Paki, and Halil Murat Algin. "Limestone dust and wood sawdust as brick material." *Building and Environment* 42.9 (2007): 3399-3403.

[4] Rahman, M. A. "Properties of clay-sand-rice husk ash mixed bricks." *International Journal of Cement Composites and Lightweight Concrete* 9.2 (1987): 105-108.

[5] Caroline EV, Dylmar PD, Jose N, Ronaldon P. "The use of submerged-arc welding flux slag as raw material for the fabrication of multiple-use mortars and bricks." *Soldagem Insp* 2009;14(3):257–62.

[6] Raut, S. P., R. V. Ralegaonkar, and S. A. Mandavgane. "Development of sustainable construction material using industrial and agricultural solid waste: A review of waste-create

bricks." *Construction and Building Materials* 25.10 (2011): 4037-4042.

[7] Davidovits, J. “Soft Mineralurgy and Geopolymers.” *In proceeding of Geopolymer 88 International Conference, the Université de Technologie*, 1998, Compiègne, France.

[8] Davidovits, J. “Chemistry of geopolymer systems, terminology.” *In Proceedings of Geopolymer ’99 International Conferences*, 1999, France.

[9] Duxson P, Fernandez-Jimenez A, Provis JL, Lukey GC, Palomo A, Van Deventer JSJ. “Geopolymer technology: the current state of the art.” *Journal of Material Science* 2007;42:2917–33.

[10] Dimas, D., I. Giannopoulou, and D. Panias. "Polymerization in sodium silicate solutions: a fundamental process in geopolymerization technology." *Journal of materials science* 44.14 (2009): 3719-3730.

[11] Majidi, Behzad. "Geopolymer technology, from fundamentals to advanced applications: a review." *Materials Technology: Advanced Performance Materials* 24.2 (2009): 79-87.

[12] Joseph Davidovits, James L. Sawyer “Early high-strength mineral polymer”, US Patent Publication No. US 4509985 A.

[13] Lyon, Richard E., et al. "Fire-resistant aluminosilicate composites." *Fire and Materials* 21.2 (1997): 67-73.

[14] Palomo, A., M. W. Grutzeck, and M. T. Blanco. "Alkali-activated fly ashes: a cement for the future."