USE OF INDUSTRIAL WASTE ON SUSTAINABLE DEVELOPMENT: A REVIEW

Mr. Laxmikant D.Girhale
PG Student, School of Civil Engineering
G H Raisoni University, Amravati (M.S.)

Prof. Pranav Lende
Asst. Professor, School of Civil Engineering
G H Raisoni University, Amravati (M.S.)

ABSTRACT

In the present day, Indian Economy is developing very fast paralleled to other countries in the world. Construction segment is the major contributor for this growth. It is one of the largest employers in India, employs 18 and 14 million people directly and indirectly respectively. In addition, migration from rural to urban areas in developing countries has increased significantly due to employment and other opportunities. Due to increasing urban population, the demand for housing has also increased exponentially. Building components such as foundation, floor, slab, columns, beams and masonry require a large amount of construction materials such as concrete, steel, bricks, mortar, etc. which directly or indirectly affects the environment and economy. This sector not only contributed in employment but also more than 250 industries such as cement, steel, wood and bricks and building materials are dependent on this sector. In construction sector, the use of cement is very extensive and it affects directly or indirectly on environment and economy. For every ton of cement production, about 900 kg of CO2 emits, which contributes to 5-7 % of total CO2 emission over the globe. Due to which, as an alternative solution, geo-polymer made from alkali activation of alumina silicates with lesser environmental impact and desired performance were investigated by researchers. These source materials are obtained from industrial wastes generated by agro industries, mine waste, construction and demolition waste, etc. Use of geo-polymer based construction materials has been increased significantly due to its high strength, eco-friendly and durable nature. Masonry is one of the important parts of building that consists of masonry unit, which is joined and finished by mortar. Application of geo-polymer mortar in masonry construction enhances the performance of the building as well it makes the masonry construction eco-friendly. Utilization of waste materials for partial or full replacement of cement in masonry mortar gives the sustainable solution. Use of sustainable materials derived from solid waste has been suggested through many studies. Human and industrial activities generate vast variety of solid waste. It becomes necessary to identify and characterize these waste which will create nuisance in environment, if left unattended.

Keywords: *construction materials, cement production, geo-polymer, sustainable materials,* Co-firing

1. INTRODUCTION

Geopolymer was the name given by DAIDOVITS in 1978 to materials which are characterized by chains or networks or inorganic molecules. Geopolymer cement concrete is made from utilization of waste materials such as fly ash and ground granulated blast furnace slag (GGBS). Fly ash is the waste product generated from thermal power plant and ground granulate blast furnace slag is generated as waste material in steel plant. Both fly ash and GGBS are processed by appropriate technology and used for concrete works in the form of geopolymer concrete. The use of this concrete helps to reduce the stock of wastes and also reduces carbon emission by reducing Portland cement demand. The main constituent of geopolymer source of silicon and aluminum which are provided by thermally activated natural materials (e.g. kaolinite) or industrial byproducts (e.g. fly ash or slab) and an alkaline activating solution which polymerizes these materials into molecular chains and networks to create hardened binder. It is also called as alkali-activated cement or inorganic polymer cement. Compressive strength of geopolymer concrete have been found up to 70 MPa (N/mm^2). The concrete gains its compressive strength rapidly and faster than ordinary Portland cement concrete. The concrete strength after 24 hours have been found to be more than 25 MPa. Compressive strength after 28 days have been found to be 60 to 70 MPa. -Ref. Paper by – James Aldred and John Day and Test results by SERC Chennai. The drying shrinkage of is much less compared to cement concrete. This makes it well suited for thick and heavily restrained concrete structural members. It has low heat of hydration in comparison with cement concrete. The fire resistance is considerably better than OPC based concrete. -Reference – Paper by – James Aldred and John Day. This concrete permeability rating of ‘low’ to ‘very low’ as per ASTM 1202C. It offers better protection to reinforcement steel from corrosion as compared to traditional cement concrete. This concrete are found to possess very high acid resistance when tested under exposure to 2% and 10% sulphuric acids. The applications is same as cement concrete. However, this material has not yet been popularly used for various applications. This concrete has been used for construction of pavements, retaining walls, water tanks, precast bridge decks. Recently world’s first building Structural Building.

1.1. The types of geopolymer materials

1.1.1. Fly Ash: - Fly ash is the residue from the combustion of coal which is widely available worldwide and lead to the anthropogenic pollution. Thus, fly ash-based geopolymer concrete is a good alternative to overcome the abundance of fly ash. Fly ash is rich in silicate and alumina, hence it reacts with alkaline solution to produce aluminosilicate gel that binds the aggregate to produce good concrete. In fly ash-based geopolymer concrete, the silica and the alumina present in the source materials are first induced by alkaline activators to form a gel known as aluminosilicate.

1.1.2. Kaolin: - Kaolin is a fine clay, rich in kaolinite and used in ceramics. Frequently used aluminosilicate sources are of kaolinite, fly ash, callcined kaolin, and chemically synthesized kaolin. Geopolymer are synthesized by polycondensation below 100 ^{o}C at ambient pressure in an alkaline solution. In terms of past literatures, effects of calcined kaolin at high temperatures (800-900 ^{o}C) towards properties of post obtained geopolymer have not been elaborately discussed. Kaolin, most versatile white mineral that possess outstanding properties such as chemically unreactive over a wide range of pH and good covering powder when used as a pigment or extender. Secondary kaolin's that are fine had been used as gloss materials due to their smaller particle size.

1.1.3. Metakaolin: - Metakaolin is a dehydroxylated form of the clay mineral kaolinite. An aluminosilicate material such as kaolinite can be dissolved in an alkali-silicate solution to form a rock hard brittle ceramic. Using the proper chemistry, one can attain a high strength material that can set as little as a few hours at room temperature. During the last few decades, fly ash, slag, kaolinite, mine tailings, etc. are used as raw materials to synthesize geopolymer. Among them kaolinite is the most common raw material due to its relatively purer components. In its raw form, kaolin can react and form a fully hardened geopolymer.

1.1.4. Dolomite: - Calcium carbonate and calcium-magnesium carbonate in the form of limestone, dolomite, marl, chalk, and Oyster shell are one of the most widely utilized non-metallic materials in the industrial world. The largest use of limestone or calcium carbonate is in the cement industry where it is used as a source of CaO and also in the concrete industry where it is used as the primary course aggregate. Following the cement industry, the second largest user would be the lime industry.

2. Literature Survey:

2.1.1 Hydration of coal–biomass fly ash cement, E. Tkaczewska, 2008

This paper presents possibilities of use of fly ashes from co-combustion bituminous coal and biomass in cement production process. Both fly ashes coming from co-combustion bituminous coal and biomass and the ones from bituminous coal combustion were analyzed. The following properties of cement were tested: heat of hydration, $Ca(OH)_2$ content, unreacted C_3S content and microstructure. Cement samples containing coal-biomass fly ashes demonstrate adverse features like lower heat of hydration, higher $Ca(OH)_2$ content and lower rate of C_3S hydration in comparison to the ones containing fly ashes from bituminous coal. The incorporation of coal-biomass fly ashes in cement results in an increase of porosity of cement paste, leading to a microstructure of lower density. The coal–biomass fly ashes retard cement hydration, prolonging the induction period and lowering the heat evolution main peak more than fly ash from bituminous coal combustion. For coal–biomass fly ashes, the

2.1. 2. Use of co-fired blended ash in the development of sustainable construction materials, Shashi Ram, ICE Publishing, [06/08/17].

This experimental investigation studied the potential of co-fired blended ash (CFBA), obtained from co-firing sawdust and coal, for the development of bricks and mortar. The identified new raw material CFBA underwent chemical (X-ray fluorescence spectrometry), physical (specific gravity determination, sieve analysis), mineralogical (X-ray diffraction) and morphological (scanning electron microscopy) characterization. CFBA was used as a partial fine aggregate substitute in the production of bricks and as a supplementary cementitious material in mortar. The developed bricks were tested for compressive strength, water absorption and efflorescence. Bricks developed with 15% sand substitution by CFBA were found to be in accordance with the Indian standard (IS 1077) and were suggested for non- load-bearing walls. In contrast, in the case of mortars (10–30% CFBA content), decreases in compressive strength (25–63%) and flexural strength (3–9%) were observed in comparison with standard mortars. Hence, the study concluded that the use of CFBA as an alternative raw material for the production of bricks was feasible. The results of the investigation suggested that CFBA can be used as a micro-filler, but it was found to be incapable of enhancing masonry strength when used as a pozzolanic additive.

2.1. 3. Development of a modeling approach to predict ash formation during co-firing of coal and biomass , V. Doshi, Elsevier , 2009

The scope of this paper includes the development of a modelling approach to predict the ash release behavior and chemical composition of inorganics during co-firing of coal and biomass. In the present work, an advanced analytical method was developed and introduced to determine the speciation of biomass using pH extraction analysis. Biomass samples considered for the study include wood chips, wood bark and straw. The speciation data was used as an input to the chemical speciation model to predict the behaviour and release of ash. It was found that the main gaseous species formed during the combustion of biomass are KCl, NaCl, K2SO4 and Na2SO4. Calculations of gas-to-particle formation were also carried out to determine the chemical composition of coal and biomass during cooling which takes place in the boiler. The GGBS started to decrease after 28 days, and the phenomenon of ettrigite was investigated due to the high levels of sulfur content. The CaO content results obtained in this work are considered to be valuable and form the basis for accurately determining the ash deposition during co-firing.

2.1. 4. Recycling of Sustainable Co-Firing Fly Ashes as an Alkali Activator for GGBS in Blended Cements, Yann-Hwang Wu, Materials 2015,

This study investigates the feasibility of co-firing fly ashes from different boilers, circulating fluidized beds (CFB) or stokers as a sustainable material in alkali activators for ground granulated blast-furnace slag (GGBS). The mixture ratio of GGBS and co-firing fly ashes is 1:1 by weight. The results indicate that only CF fly ash of CFB boilers can effectively stimulate the potential characteristics of GGBS and provide strength as an alkali activator. The mixtures of SA fly ash and SB fly ash with GGBS, respectively, were damaged in the compressive strength test during seven days of curing. However, the built up strength of the CF fly ash and GGBS mixture can only be maintained for 7–14 days, and the compressive strength achieves 70% of that of a controlled group (cement in hardening cement paste). The strength of blended CF fly ash and

in sustainable co-firing fly ashes must be higher than a certain percentage in reacting GGBS to ensure the strength of blended cements. The maximum strength from mixing GGBS and CF co-firing fly ashes achieved is around 70% of that of the control group, cement hardened cement paste.

2.1. 5. Comparative study on the characteristics of fly ash and bottom ash geopolymer, Prinya Chindaprasirt , Waste Management 29 ,539–543, Elsevier , (2009)

This research was conducted to compare geopolymers made from fly ash and ground bottom ash. Sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) solutions were used as activators. A mass ratio of 1.5 Na2SiO3/NaOH and three concentrations of NaOH (5, 10, and 15M) were used; the geopolymers were cured at 65°C for 48h. A Fourier transform infrared spectrometer (FT-IR), differential scanning calorimeter (DSC), and scanning electron microscope (SEM) were used on the geopolymer pastes. Geopolymer mortars were also prepared in order to investigate compressive strength. The results show that both fly ash and bottom ash can be utilized as source materials for the production of geopolymers. The properties of the

, percentage of fly ash replaced by slag, temperature and curing time, have been changed and optimized using the Design Of Experiments (DOE) approach. In order to estimate the thermal cycling stability of geopolymer mortars at

geopolymers are dependent on source materials and the NaOH concentration. Fly ash is more reactive and produces a higher degree of geopolymerization in comparison with bottom ash. The moderate NaOH concentration of 10M is found to be suitable and gives fly ash and bottom ash geopolymer mortars with compressive strengths of 35 and 18MPa. The compressive strength of the fly ash geopolymer mortar is reasonably high at 35MPa, and it is signif-i-cantly higher than the 18MPa of the bottom ash geopolymer mortar. The strength of a geopolymer is also dependent on NaOH concentration. The optimum NaOH concentration of 10M is suitable for both ash materials.

2.1. 6. Thermal cycling stability of fly ash based geopolymer mortars, F. Colangelo, 1359-8368, Composites Part B 129, Elsevier Ltd. (2017)

In this paper fly ash based geopolymer mortars have been prepared and their thermal behavior evaluated in order to assess the suitability of fly ash based alkali-activated binders for thermal energy storage in solar thermal plants. Different parameters,

elevated temperatures, mechanical strength and weight loss of each sample subjected to different thermal cycles in the temperature range 150e550 C were evaluated. Finally, thermal conductivity of some of the mixtures, selected on basis of the thermal stability test results, have been measured. Fly ash based geopolymeric mortars remained stable after each thermal treatment and specimens treated at elevated temperatures retained acceptable compressive strength. The thermal stability was preserved also after repeated thermal cycles, proving that fly ash based geopolymers are suitable materials for thermal energy storage concretes.

2.1. 7. Effect of elevated temperatures on geopolymer paste, mortar and concrete, Daniel L.Y. Kong, Cement and Concrete Research 40 (2010) 334–339, Elsevier Ltd. (2010)

In this paper author research on, Geopolymer are generally believed to provide good fire resistance due to their ceramic-like properties. Previous experimental studies on geopolymer under elevated temperatures have mainly focused on Metakaolin-based geopolymer. This paper presents the results of a study on the effect of elevated temperature on geopolymer paste, mortar and concrete made using fly ash as a precursor. The geopolymer was synthesized with sodium silicate and potassium hydroxide solutions. Various experimental parameters have been examined such as specimen sizing, aggregate sizing, aggregate type and super-plasticizer type. The study identifies specimen size and aggregate size as the two main factors that govern geopolymer behavior at elevated temperatures (800 °C). Aggregate sizes larger than 10 mm resulted in good strength performances in both ambient and elevated temperatures. Strength loss in geopolymer concrete at elevated temperatures is attributed to the thermal mismatch between the geopolymer matrix and the aggregates.

2.1. 8. Structure and strength of NaOH activated concretes containing fly ash or GGBFS as the sole binder. Deepak Ravikumar, Cement & Concrete Composites 32, Elsevier Ltd. (2010)

This paper has provided extensive experimental results and analysis on the compressive strengths, porosities, and microstructure of cement-free binder (CFB) pastes and/or concretes containing either fly ash or GGBFS as the sole binder and activated using NaOH solutions of different concentrations. The influence of the concentration of the activating agent (4, 6, or 8 M sodium hydroxide solution), and activator-to-binder ratio (0.40, 0.50, or 0.60) on the compressive strengths, pore structure features, and microstructure of concretes containing Class F fly ash or ground granulated blast furnace slag (GGBFS) as the sole binder is reported. The starting material contents and the curing parameters (temperature and curing duration) are optimized to provide the highest compressive strengths. Statistical analysis of the compressive strength results show that the activator concentration has a larger influence on the compressive strengths of activated concretes made using fly ash and the activator-to-binder ratio influences the compressive strengths of activated GGBFS concretes to a greater degree. Activated fly ash concretes and pastes are found to be more porous and contains a larger fraction of pores greater than 10 lm in size as compared to activated GGBFS mixtures. The differences in the microstructure and the reaction products between activated fly ash and GGBFS pastes are detailed.

2.2. Conclusion Drafted from Literature Survey:

After studying these literature survey, it is observed that possibilities of use of fly ashes from co-combustion bituminous coal and biomass in cement production process. Concerns regarding the potential global environmental impacts of fossil fuels used in power generation and other energy supplies are increasing worldwide. One of the methods of mitigating these environmental impacts is increasing the fraction of renewable and sustainable energy in the national energy usage.

2.1. 9. Experimental studies on co-firing of coal and biomass blends in India, K.V. Narayanana, Renewable Energy 32, Elsevier Ltd. (2007)

This paper discusses the 'gaseous emission characteristics namely NOx; SO2, suspended particulate matter and other characteristics like specific fuel consumption, total fuel required, actual and equivalent evaporation, total cost of fuel, etc. from a 18.68 MW power plant with a travelling grate boiler, when biomass was cofired with bituminous coal in three proportions of 20%, 40% and 60% by mass. Bagasse, wood chips (Julia flora), sugarcane trash and coconut shell are the biomass fuels co-fired with coal in this study

A number of techniques and methods have been proposed for reducing gaseous emissions of NO_X; SO_2 and CO_2 from fossil fuel combustion and for reducing costs associated with these mitigation techniques. Some of the control methods are expensive and therefore increase production costs. Among the less expensive alternatives, co-firing has gained popularity with the electric utility producers.

Recommendations were made to the power plant management, regarding the best choice of fuel blend and proportion, so that the Management, Government and environment as a whole are benefited. It has also been recommended to the power plant management, that bagasse, wood and coconut shells can be stored as and when available in the respective seasons, and co-fired along with bituminous coal. This co-firing method of power generation also results in more revenue, when supplied to the main power grid.

A strong motivation for biomass fuel usage comes from the fact that gaseous emissions are reduced when biomass is fired with coal. Waste disposal is a perennial problem with some biomass resources. Co-firing these biomass fuels also reduces waste accumulation and attendant soil, water and air pollution.

Dedicated energy crops can be cultivated to ensure continuous supply of biomass fuels to utilities; more jobs will be created in the agriculture sector. Co-firing implementation cost would be very low; if biomass fuel costs are low, a net profit can be obtained compared to coal only firing.

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