International Journal of Research in Engineering, Science and Management
Volume-2, Issue-12, December-2019
www.ijresm.com | ISSN (Online): 2581-5792

Eco-Friendly Utilization of Fly ash to Formulate Aggregate and Bricks

Sushmita Sapkal[1], Vaibhav Shetty[2], Sushant Mondal[3]
[1,2,3]*Student, Dept. of Chemical Engineering, Bharati Vidyapeeth College of Engineering, Navi Mumbai, India*

***Abstract*: Generation of electricity in India mainly depends on coal based power plant. These power plants require coal of high calorific value in order to generate optimum heat and consequently to generate electricity. Along with heat and electricity this process also generates a by-product such as fly ash or coal ash. These by-products are generated in very large quantity and hence the processing and manufacturing industries face a great challenge of disposal of such residual waste. One way of utilizing fly ash is using it as construction material. Hence this paper will briefly review the technique to produce fly ash aggregate and bricks using polymeric binder which could replace natural sand and clay bricks for construction purposes.**

***Keywords*: Calcium Carbonate ($CaCO_3$), fly ash, eco-friendly, economic, polymeric binder, polystyrene.**

1. Introduction

Thermal Power Plants powered by Coal/Lignite have been the mainstay of the power capacity of the country since long. In India the coal available is of low grade with 30-45% of ash content compared to 10-15% of the imported coals. Burning of coal in the electric generating plants produces a by-product Fly ash. It is one of three general types of coal combustion by products (CCBP's). Fly ash is outlined as a heterogeneous mixture of amorphous and crystalline phases and is generally available in form of a powdered ferro-aluminosilicate material with various predominant elements including Al, Ca, Fe, Na and Si. It is a potential source of pollution not only for the atmosphere but also for the other components of the environment. Deposition of fly ash in storage places can have detrimental or adverse effects on the quality of water reservoirs and soil because of their size distribution, morphology and mineral composition as well and filtration properties. Thus considerable amount of ash is being generated by coal based Thermal Energy Stations in the country, which aside from requiring large area of land for its disposal also acts as an environment pollutant. The use of landfills for fly ash disposal is currently the main option in many countries. However, more stringent measures for special waste landfills, along with an emerging recycling philosophy, have encouraged the recycle and reuse of this waste. In India the overall fly ash utilization stands at a fairly low level of about 15% of the quantity generated. Some among the numerous factors that account for the low level of utilization are listed as follows:

- Inadequate knowledge of the composition of fly ash and its derivatives.
- Unavailability of standards and specifications for fly ash products.
- Insufficient information regarding end applications of Fly ash.
- Poor public awareness about the products and their performance.
- Lack of trustworthy monitoring of quality for fly ash products.
- Deficiency of synchronization between users of ash and producers such as thermal power plants.

Certain elements and compounds (such as metals and salts) are available in abundance in Fly ash and therefore has the feasibility to be used as a raw material. Each potential application for fly ash results in three main advantages: first, the use of a zero-cost raw material, secondly, the conservation of natural resources, and thirdly, the elimination of waste. Nine possible applications were identified and grouped into three main categories as follows:

Construction materials

- Cement production
- Concrete
- Ceramics
- Glass and glass–ceramics

Geotechnical

- Road pavement
- Embankment

Agriculture

- Soil amendment

Here we shall utilize fly ash for making construction material. Sand has become an increasingly scarce commodity in many countries and low cost and environmentally sustainable synthetic materials could provide a solution. This can only be really done by changing the size of a bulk component e.g. crushing rock. An alternative however, is to up-size a finer material, and a potentially suitable, widely available candidate is stockpiled fly ash. The need of fly ash utilization also arises out of the fact that good quality Natural River sand required in concrete and in the cement mortar, is depleting day by day and scarcity of good quality sand is felt by all metro and mega cities in India. Hence in this study we shall explores the possibility of making fine aggregate with fly ash which could be a replacement for natural river sand. Our method includes the use of raw materials such as fly ash, toluene, expanded polystyrene and calcium carbonate. Expanded polystyrene is nothing but a synthetic aromatic polymer made from the monomer styrene (a monomer is a molecule that binds chemically to other molecules to form a polymer). Its chemical formula is $[CH(C_6H_5CH_2)]_n$. They are extensively used for packaging and transportation of fragile items such as glassware, electronic equipment. It is a good thermal insulator and hence is used for food packaging. However versatile it might be, one of its biggest drawback is that it cannot be easily degraded which raises concerns about the disposal. The reason we are using it to make our polymer binder is so that we can recycle waste polymer effectively along with fly ash.

2. Methodology

Method to check the solubility of polystyrene in toluene is:

Cohesive energy density (CED) is a measureable amount of the magnitude of secondary bonding, it is the total energy per unit volume needed to separate all intermolecular contacts. The relation between the cohesive energy density (CED) and solubility parameter (δ) is: CED = δ2. A polymer δ1 will dissolve in a solvent δ2 if; δ1 – δ2 ≤ 1.7 – 2.0. Solubility parameter of toluene is 8.9 and that of polystyrene is 9.0; hence it readily dissolves in toluene. According to previous research it is observed that some solvent form good quality of adhesive; these solvents are petrol and toluene. Since toluene is a more feasible and easily available solvent it is selected for preparation of binder.

A. *Method of forming Polymer Solution:*

Requirements:

- Name of Solvent: Toluene (99%)
- Quantity of solvent used: 100ml
- Quantity of waste polystyrene used: 40.8 gm

100 ml of toluene solvent is taken in a clean and dry glass beaker. The polystyrene foam which has been cut into small pieces is add slowly to toluene in the beaker. Mixture is stirred continuously while adding polystyrene foam into the beaker. After a while when the solubility of Polystyrene is reached, no more dissolution of polystyrene foam toluene takes place. Mixture is allowed to stand for a few minutes. The beaker containing toluene thickens and form a homogeneous, viscous liquid with sticky nature.

B. *Preparation of fly ash aggregate*

Fly ash is mixed with polystyrene solution in the ratio of 10:4. This mixture is then cured in atmospheric conditions for 7-14 days. The block is then broken into small pieces and passed through a roll crusher. Crushed sand is collected and tabling is done using a sieve shaker. All the sand is poured into stacked sieves with sizes ranging between. Sieve shaker is operated for 10mins. The sand is then stored according to its particle size.

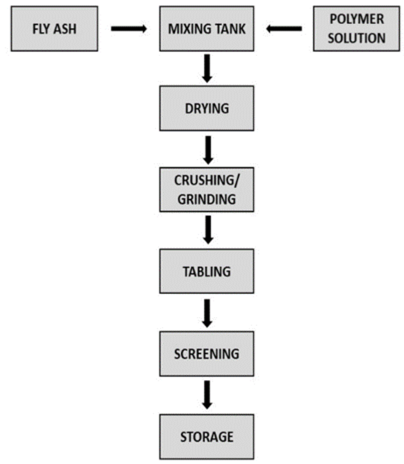

Fig. 1. Block diagram of process used to formulate sand

Segregation of fly ash aggregates

- After curing, fly ash aggregates were segregated into fine and coarse aggregates based on the size of the pellets.
- The aggregates having size less than 4.75 mm were sieved as fine aggregates and size more than 4.75 mm were sieved as coarse aggregates.
- The aggregate below 20 mm size sieve used in the concrete specimen as a filler material.

C. *Fly ash Brick Forming Process*

There are four major steps involved in producing sample of bricks. These include, proportioning of constituents, mixing, moulding/pressing of bricks and followed by firing, oven-drying or air-curing. It is a simple & economic technique that requires no additive, catalyst or any intermediate substance are use. During processing any gaseous or residual product are not formed, hence the technique is eco-friendly.

100 gm of fly ash is weighed and taken in a beaker. Different amount of Calcium carbonate is added to fly ash in order to prepare 3 samples-

- First sample contains 0 gm of $CaCO_3$.
- Second sample contains 2 gms of $CaCO_3$.
- Third sample contains 4 gms of $CaCO_3$.

40 gm of PS binder solution is weighed and added to the dry mix. It is then mixed thoroughly and uniformly. A mould of size 10 cm x 10 cm x 10 cm is greased and lined with a sheet of paper. The mixture is then placed into the mould and pressed in. After the mixture sets and is taken out of the mould. Sample is then cut into pieces of size 1cm x 1cm. It is left to cure at room temperature for 7 days. After curing the samples are ready for further testing.

3. Tests Performed

A. *Water absorptivity test*

Sample brick specimen is air cured and weighed (W_1). The brick is immersed in water at room temperature for 24 hours. It is then taken out, excess water is wiped and brick is weighed again (W_2). This is repeated for 3 different samples of fly ash bricks. Water absorption % by mass, after 24 hours immersion in normal water at atmospheric conditions is given by the formula:

$$W = \frac{(W2 - W1)}{W1} \times 100$$

For sample 1 W_1 = 658.79 kg W_2 = 709.18 kg

$$W = \frac{(709.18 - 658.79)}{658.79} \times 100 = 7.64\%$$

The average percentage absorption of fly ash brick was 8.82%. Voids are created during brick formation. These voids are the main places of accumulation of water. Larger the size of reinforcement material, larger will be the size of voids that are created. As fly ash is very fine the reinforcement particle size is small. As a result during the formation of bricks, fly ash particles get easily blended with the polymer solution reducing formation of large voids. Hence water absorbed by the samples is drastically reduced. The acceptable water absorption for clay bricks are between 12% and 20%. Above test results show that the average water absorption by the three samples is 8.82% which is much less than that of clay bricks. This also tells us that the fly ash brick is highly compact.

B. *Fire retardancy test*

For this test 3 brick samples containing different amounts of calcium carbonate is used.

Table 1
Quantity of fly ash and calcium carbonate in brick samples

Sample no.	Quantity of fly ash	Quantity of calcium carbonate
1	100 gm	0 gm
2	100 gm	2 gm
3	100 gm	4 gm

These fly ash brick containing fly ash, polymer binder and calcium carbonate are formed into samples of size 1cm x 1cm is held on a constant undisturbed flame. Time taken for complete burning of sample is noted. This is repeated for 3 different samples. Time taken by the sample to catch fire is noted and the data is plotted in a graph below.

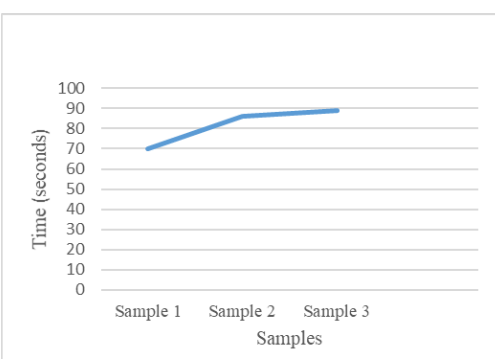

Fig. 2. Graph for flame test

From the result we can conclude that the brick sample with highest amount of calcium carbonate took more time to catch fire and hence it could be used as a potential fire retardant id fly ash brick.

C. *Compressive strength test*

Compressive strength test is carried out using Compressive strength test machine. The brick is placed between two plates and load is applied on it at uniform rate until failure. Failure occurred when the indicator needle fell back in spite of progressively adjusting the machine controls or the specimen experienced explosive collapse. The maximum load carried by the specimen during the test was recorded. To obtain the strength, the maximum load obtained from the compressive strength test was divided by the area of the bed face determined earlier.

The calculation of compressive strength of brick:
Area of the brick = 19x10 = 190cm^2 = 1900 mm^2
Range of load selected = 0-10000 kg
Maximum load applied = 3700 KgF = 95614.84 N

$$\text{Compressive strength} = \frac{\text{Load in N}}{\text{Area in mm}^2}$$

$$= \frac{95614.84}{1900}$$

$$= 50.32\ N/mm^2$$

The compressive strength of a first class construction brick is found to be 10.3 N/mm^2. Thus we can conclude that the compressive strength of a fly ash brick is almost 5 times more than a normal construction brick.

4. Conclusion

Fly ash is clearly more than just a waste by product, by mixing it along with a seemingly other waste material, such as used Polystyrene can lead to formation of a valuable substance into which the fly ash confers its desirable characteristics for various applications. The fly ash brick formed in the above process has shown better results compared to ordinary brick in terms of flame resistance, water absorption and compressive strength. Thus we can conclude that fly ash bricks can be successfully used for construction purposes. Also the aggregate formed can be used instead of river sand in concrete. However fly ash aggregate still requires more research in order to study its properties and to determine its suitability. In this paper a simple and easily applicable process has been developed so that the economic barriers can be overcome in terms of high value and high volume utilization of the other industrial applications of fly ash.

References

[1] Saurabh Attarde, Sagar Marathe, Avick Sil, “Utilization of fly ash in construction industries for environment management”, International Journal of Environmental Sciences, Vol. 3, no. 2, pp. 117 – 121, 2014.
[2] Lokeshappa B, Anil Kumar Dikshit, “Disposal and Management of Fly ash”, APCBEE Procedia, pp. 35-37, 2011.

[3] R. K. Traeger, “Physical Properties of Rigid Polyurethane Foams”, Journal of cellular plastics, pp. 1-2, 1967.
[4] Anil Kumar Dikshit and Lokeshappa B, “Disposal and Management of Fly ash”, International Conference on Life Science and Technology IPCBEE, vol.3, pp. 12-13, 2011.
[5] Niyazi Ugur Kockal, Turan Ozturan, “Characteristics of lightweight fly ash aggregates produced with different binders and heat treatments”, Cement & Concrete Composites, vol. 33, pp. 63-64, 2010.
[6] M. Ahmaruzzaman, “A review on the utilisation of fly ash”, Progress in energy and combustion science, Vol. 36, Issue 3, June 2010.
[7] J. Skopp, Particle size separation/ Sieving / Screening, pp. 1826-1828, 2000.
[8] M.J. Dudas, “Long Term Leachability of Selected Elements from Fly ash”, Journal of Environmental Science Technology, vol. 15, no. 7, pp. 840-843, 1981.
[9] S.M. Rao, I.P. Acharya, “Synthesis and characterization of fly ash geo-polymer sand”, J. Mater. Civ. Eng. pp. 186–190, 2014.
[10] P. Karunakaran, C. Jegadheesan, P. Dhanapal, and P. Sengottuvel, “Sugar Industry Fly Ash: An Additive for Molding Sand to make Aluminum Castings”, Russian Journal of Non-Ferrous Metals, May 2014.
[11] Homnuttiwong S., Jaturapitakkul C. and Chindaprasirt P., Permeability, “Abrasion Resistance of Concrete Containing High Volume Fine Fly Ash and Palm Oil Fuel Ash”, Computers and Concrete pp. 349-360, 2012.
[12] R. Jones, and A. McCarthy, “Utilizing Unprocessed Low Lime Coal Fly Ash in Foamed Concrete”, pp. 1398-1409, 2005.
[13] Siddique R., “Effect of Fine Aggregate Replacement with Class F Fly Ash on Mechanical Properties of Concrete”, pp. 539-547, 2003.
[14] Papadakis, V.G. “Effect of Fly Ash on Portland cement Systems Part-I: Low Calcium Fly Ash”, pp. 1727-1736, 1999.
[15] Filho, J.H., Medeiros, M.H.F. Pereir, E., Helene, P. and Isaia, G.C. “High Volume Fly Ash Concrete with and without Hydrated Lime: Chloride Diffusion Coefficient from Accelerated Test”, Journal of Materials in Civil Engineering, pp. 411-418, 2013.