Chapter 10

Flyash as a Resource Material in Construction Industry: A Clean Approach to Environment Management

Mohammad Nadeem Akhtar and Nazia Tarannum

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.82078

Abstract

The maximum amount of electricity is produced by most of the thermal power plants by burning coal at their operating facilities. Due to this activity, various types of secondary materials are generated. Any material resulting from coal-combustion processes may be called as a coal-combustion product (CCP). Among different CCPs reported worldwide by coal-burning power plants, flyash is the most common one. As per the characterization report, flyash is considered as a powdery material being collected by dust collectors installed in the thermal power plants with the use of coal as fuel. There are different problems related to flyash like requirement of large area of land for disposal and toxicity caused by flyash which leach to groundwater. The study has established flyash as air and water pollution source. It is considered as waste that may act as a resource material in construction industry, thereby acting as a resource for waste and environment management. Till a decade back, flyash was treated as waste material worldwide, but now it is developed as an environment savior.

Keywords: thermal power plants, coal-combustion product, flyash, waste material

1. Introduction

A naturally cementitious material that is obtained as a by-product after coal-combustion is flyash. In order to reduce pollution, flyash is extracted from the precipitators installed in smokestacks of coal-burning power plants. In near future, it is expected that a number of thermal power stations will increase with the increasing demand of power and coal. Flyash is spherical in shape and solidify in suspension form in exhaust gases. The composition of flyash constitutes silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3). As per the need and use of flyash, their physical and chemical requirement may vary. The specific requisites for the use of flyash in concrete or soil stabilization are discussed in [1, 2]. According to Ref. [1], flyash is broadly classified into two classes, viz. Class F and Class C. The major difference between these two classes is the percentage of calcium, silica, alumina, and iron content. The chemical content of burned coal properties, i.e., anthracite and bituminous, decides the chemical content of the fly-ash. When older and harder anthracite burns, they produce Class F flyash, which is pozzolanic in nature with 10% lime (CaO). In order to possess cementitious property, Class F flyash with the glassy silica and alumina requires a cementing agent like Portland cement, quicklime, or hydrated lime. The addition of sodium silicate (water glass) as a chemical activator to a Class F flyash may lead to the geopolymer formation. The burning of younger sub-bituminous coal produces flyash with pozzolanic and self-cementing properties. The presence of water hardens Class C flyash and enhances its strength with time. More than 20% lime is possessed by Class C flyash. Like self-cementing Class C flyash does not require an activator unlike Class F. The percentage of alkali and sulfate (SO_4) are high in Class C flyash. Till a decade, flyash was considered as an industrial waste pollution and was disposed off in ash ponds. Several cumulative researches have been carried out worldwide for flyash management and disposal. The quality of flyash depends on various factors like coal, percentage of ash in coal, coal particle fineness, combustion technique used, air/fuel ratio, burners used, and type of boiler. During last few decades, innovative and alternate building materials with economic construction techniques have been developed by intensive research efforts which provide an opportunity to bring down the cost of construction. Flyash is the by-product of industry generated about 112 million tons from Thermal Power Plants (TPPs) with proven suitability for various applications such as admixture in cement/concrete/mortar, lime pozzolana mixture (bricks/blocks), etc. The cement industry is responsible for 50% utilization of flyash, the total utilization of this accounts for 30MT (28%). The other application areas include low lying area fill (17%), roads and embankments (15%), dyke raising (4%), brick manufacturing (2%) and in paint industry, agriculture, etc. [3]. According to 2001 census, India is the first largest country for the production of flyash worldwide. **Figure 1** shows the flyash production (million tons/year) in various countries.

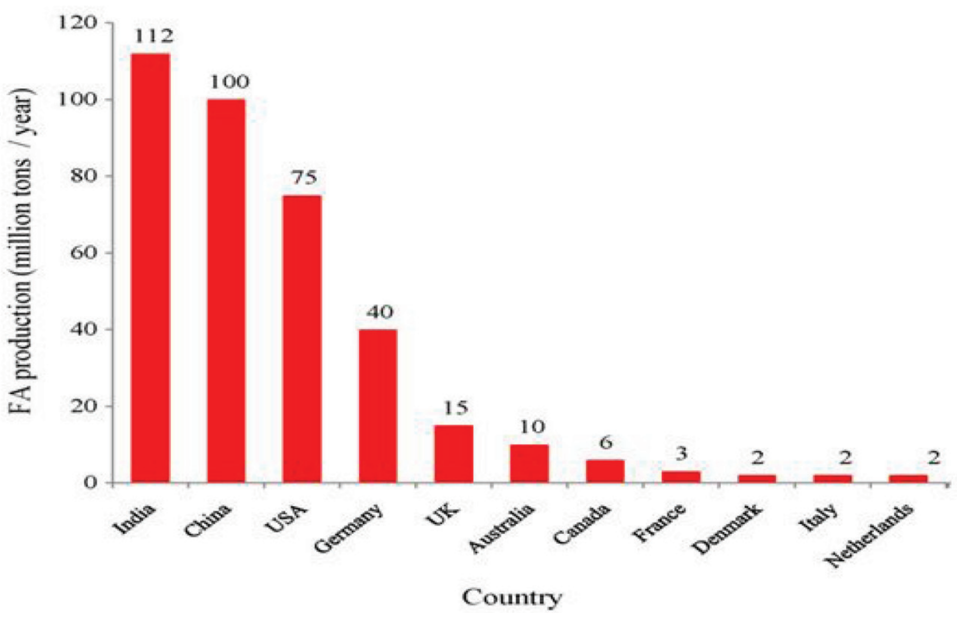

Figure 1. Representation of the production (million tons/year) of flyash in different countries.

http://dx.doi.org/10.5772/intechopen.82078

2. Current scenario of flyash in India

Recent production of flyash, a by-product from coal-based TPPs annually, is about 160 million tons (MT) and is expected to be about 600 MT by 2030 according to the current ENVIS CSIR report. As per the reports, India is among the largest producer of coal and contributes about 70% of the total installed capacity for power generation [4]. The bituminous and sub-bituminous coal-use contains over 40% ash content. About 120–150 million tons of coal flyash are generated from 120 existing coal-based TPPs in India [5]. The emerging amount of average generation and utilization data received during the last 5 years by ENVIS Centre on flyash [6] is 166 million and 96 million tons. Flyash generation and utilization during the year 2011–2012, 2012–2013, 2013–2014, 2014–2015, and the first half year of 2015–2016 are shown in **Table 1**.

Flyash generation and utilization data for the first half of 2015–2016 (April 2015 to September 2015) is expected to be 132 coal/lignite-based thermal power stations of different power utilities in the country. As per the data received on March 15, 2016, a conclusion was derived on the current status of flyash generation and its utilization in the country [7]. Flyash utilization percentage (of 146 thermal power stations) has increased during the first half of 2015–2016 compared to utilization during first half of the previous year 2014–2015 [7]. ENVIS Centre on flyash hosted by CSIR-Central Building Research Institute, Roorkee sponsored by the Ministry of Environment, Forests and Climate Change, Government of India shows the correlation between production and utilization from 1990 to 2030. The flyash generation and utilization scenario in India is shown in **Figure 2**.

2.1. Materials and method

The flyash utilized in the study was collected through electrostatics precipitators of Harduaganj Thermal Power Station Aligarh (UP), India [8]. The chemical analysis of flyash was done to determine the oxides of silica, iron, calcium, aluminum, total sodium, magnesium, and total potassium. The procedures used to determine the abovementioned elements are as per the specification of ASTM Designation: D 4326. About 0.50 g of the ashed flyash sample and 6.5 g

Description	2011- 12	2012-13	2013-14	2014-15	1st Half Year 2015-16
Nos. of Thermal Power Stations from which data was received	124	138	143	145	132
Installed capacity (MW)	1,05,925.3	1,20312.30	1,33,381.30	1,38,915.80	1,30,428.80
Coal Consumed (million tons)	437.41	482.97	523.52	549.72	251.69
Average Ash Content (%)	33.24	33.87	33.02	33.50	33.23
Flyash Generation (million tons)	145.42	163.56	172.87	184.14	83.64
Flyash Utilisation (million tons)	85.05	100.37	99.62	102.54	46.87
Percentage Utilization	58.48	61.37	57.63	55.69	56.04

Source: ENVIS Centre on Flyash Hosted by CSIR-Central Building Research Institute, Roorkee. Sponsored by Ministry of Environment, Forests & Climate Change, Govt. of India.

Table 1. Flyash generation and utilization current scenario in India.

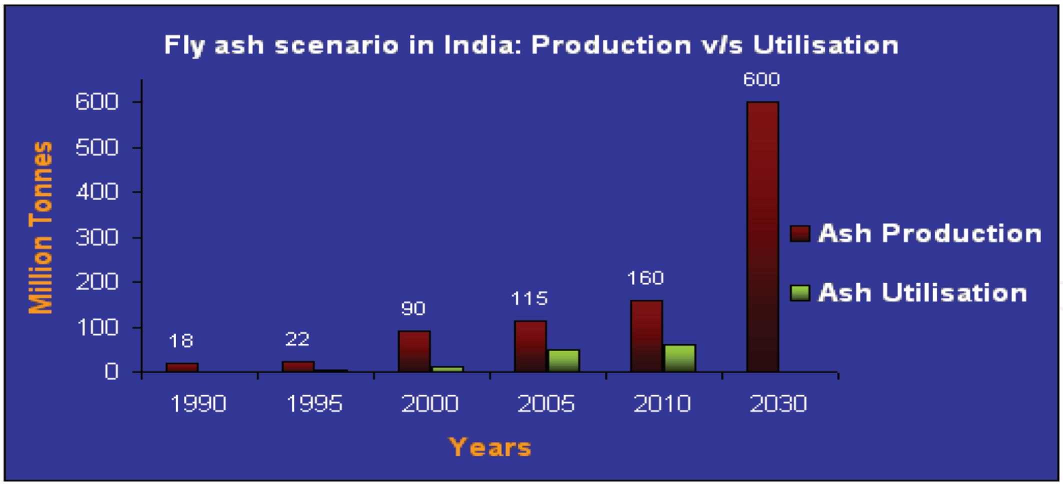

Figure 2. Current flyash scenario generation vs. utilization. Source: ENVIS Centre on Flyash Hosted by CSIR-Central Building Research Institute, Roorkee sponsored by Ministry of Environment, Forests & Climate Change, Govt. of India.

of fluxing material were taken into the crucible with 400 μL of liquid lithium bromide before fusing. In order to determine the loss on ignition, available sodium oxide, potassium oxide and alkali were used in accordance with ASTM designation C311.3. The sulfur trioxide with the carbon sulfur determinator was used to determine sulfur. XRF (X-ray fluorescence), X-ray diffraction (XRD), wavelength dispersive spectroscopy (microprobe WDS), and X-ray micro-analysis (EDS) techniques are used in the chemical analyses of flyash. The physical properties were determined by Indian standards.

2.2. Chemical analysis of flyash

Determination of chemical composition of flyash is mandatory for classification of flyash as per the standards. The chemical composition of flyash consists of silicon, aluminum, calcium, iron, sulfur, and magnesium oxides along with carbon and other trace elements. These elements found in the ash possess high melting points and the short duration of the ash particles remain in furnace during combustion process. The SiO_2 causes the initiation of the combustion process and are maintained as quartz in the coal ash. The clay mineral loses water molecule and melt forming alumino-silicate crystalline and noncrystalline (glassy) materials. Fe, Ca, and Mg along with oxygen in the air form oxides, such as magnetite (Fe_2O_3), lime (CaO), and periclase (MgO).

2.2.1. Chemical analysis of Class F flyash for present study

Locally available samples were examined in the present study. The detailed image analysis about the surface morphology and texture of individual particles were studied by Scanning Electron Microscopy (SEM) with Energy Dispersive Spectroscopy (EDS). SEM is one of the widely used techniques for the chemical characterization of ash. The exact chemical composition is discussed in **Table 2**. The elements identified in the flyash samples were found to be C, O, Al, Si, K, Ca, and Ti in various compound forms (Al_2O_3, SiO_2, K_2O, CaO, TiO_2, etc.). The quantitative result from point analysis of Class F flyash used in the study is shown in **Figure 3**.

http://dx.doi.org/10.5772/intechopen.82078

Element	Weight %	Atomic%
C	14.42	21.05
O	54.59	59.83
Al	11.96	7.77
Si	16.47	10.29
K	0.73	0.33
Ca	0.94	0.41
Ti	0.88	0.32

Table 2. List of Elements with their weight (%) and atomic (%) present in Class F flyash.

2.2.2. SEM/EDS analysis for present study

The surface morphology characterization has a vital role to play in understanding the physical and chemical behavior of the material. There detailed knowledge of the physical nature of solid surfaces in the fields of material science and surface chemistry is of utmost importance. SEM is a technique to study different modes of association of particle for surface irregularities detection. SEM is used to investigate the surface morphology of the sample. **Figure 4** shows SEM images recorded on Class F flyash sample surface at ×2000, ×5000, and ×6000 magnifications. As, it can be seen, **Figure 4a** and **b** clearly indicates the presence of irregular shaped particles of variable size, covered with relatively smooth grains of quartz. The micrographs in **Figure 4c** and **d** also designated dark areas as organic materials, light areas as mineral matter, and gray as mixture of coal and ash. The solid and porous part indicated the presence of mineral matter most likely quartz, partially burnt coal particles were shown by irregular black porous parts. Particles size 10 μm at WD 13 mm appeared to be spherical with small bulging of siliceous and aluminous glass **Figure 4e**. EDS of flyash sample suggested the presence

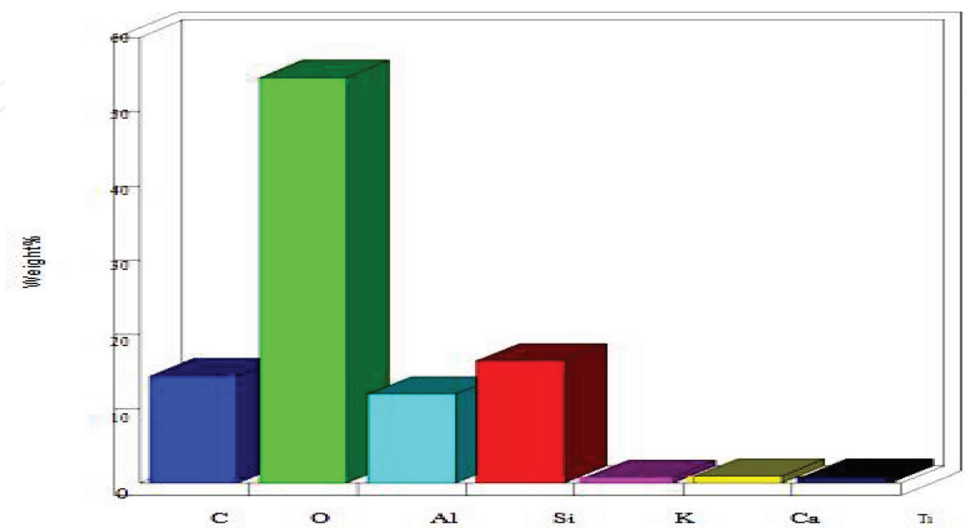

Figure 3. Quantitative results from point analysis of Class F flyash.

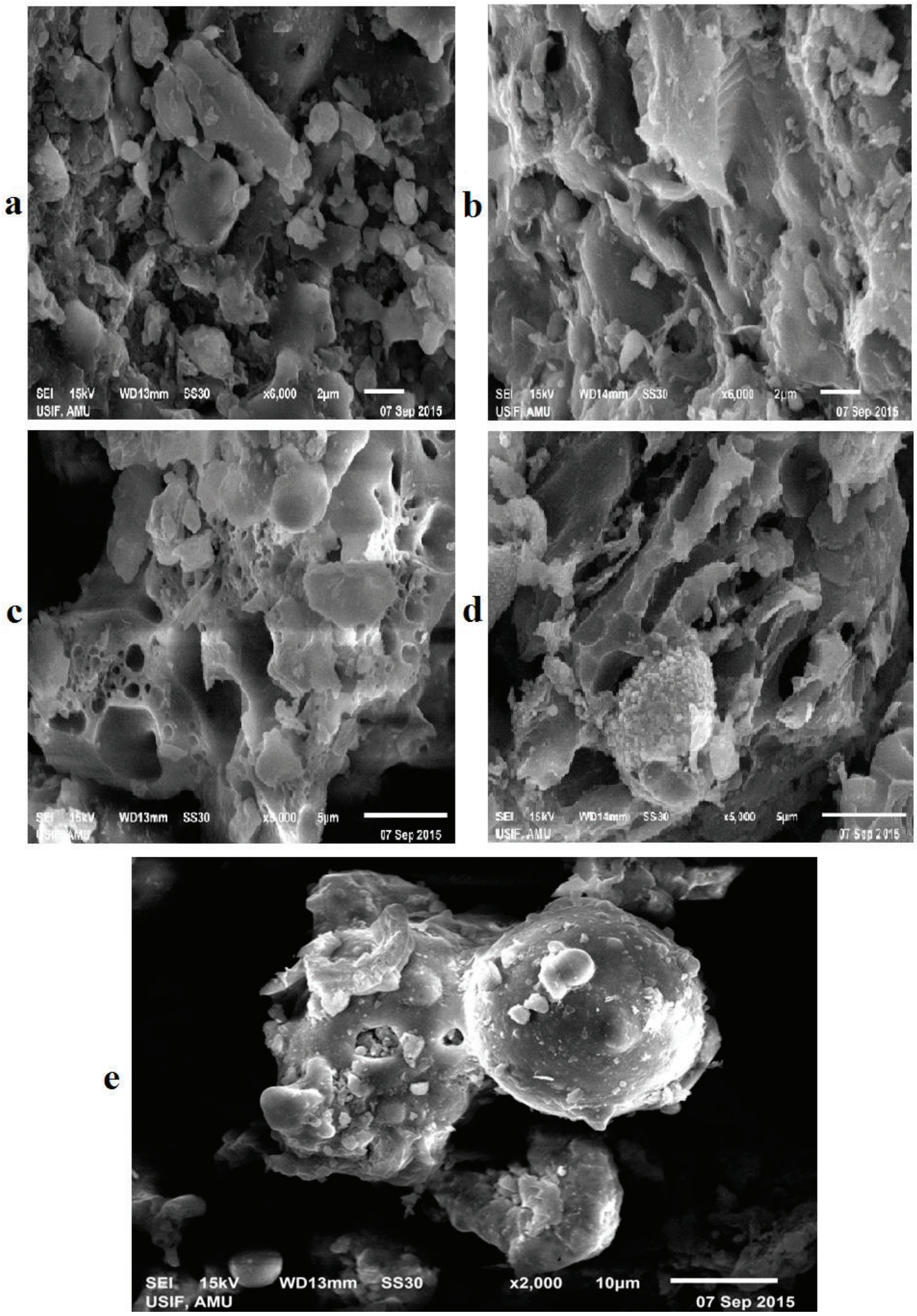

Figure 4. SEM micrograph of Class F Flyash with different particles size (a) 2 μm at WD 13 mm; (b) 2 μm at WD 14 mm (c); 5 μm at WD 13 mm; (d) 5 μm at WD 14 mm; and (e) 10 μm at WD 13 mm.

of carbon, oxygen, aluminum, silicon, potassium, calcium, and titanium as the primary elements. Hence, SEM/EDS are one of the important and widely used techniques for physicochemical analysis of flyash samples. The identified elements in the flyash samples were found to be C, O, Al, Si, K, Ca, and Ti in various compounds (Al_2O_3, SiO_2, K_2O, CaO, TiO_2, etc.) as determined by EDS, as shown in **Figure 5**.

http://dx.doi.org/10.5772/intechopen.82078

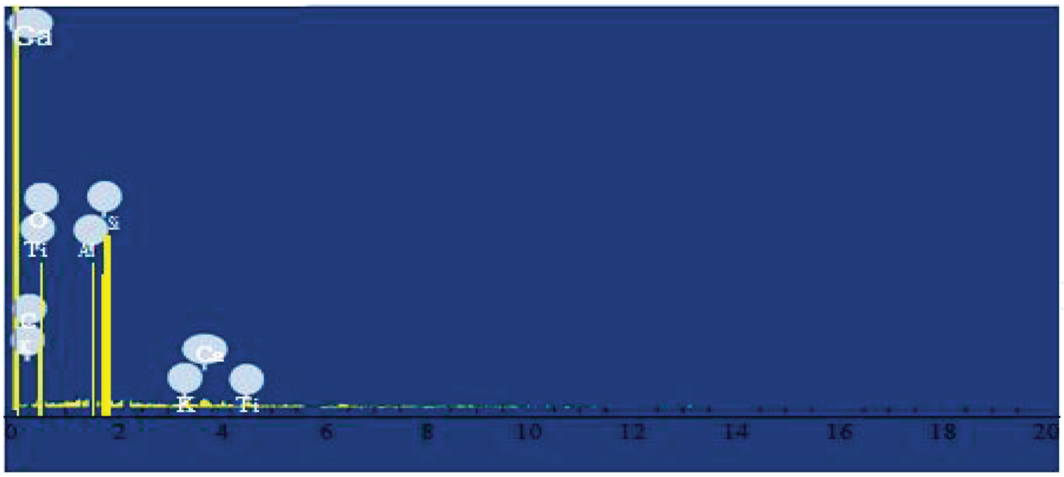

Figure 5. Identified element of Class F flyash by EDS.

2.3. Physical analysis of Class F flyash for present study

Physical analysis is one of the important parameter for selection and consideration of material in the civil engineering construction industry. Its geo-technical properties make it a good substitute of soil and the required percentage provide the general range of physical geo-technical properties available in the flyash sample. As determined in the present study, the physical properties of Class F flyash are listed in **Table 3**. The physical properties of common soils

Parameter	Range Experiment Present Study	CBRI (2016)
	Class F Flyash	Common soil
Bulk Density (gm/cc)	1.25	1.3–1.7
Specific Gravity	2.12	2.5-2.8
Plasticity	Lower or non-plastic	Lower or non-plastic
Maximum Dry Density (gm/cc)	1.2875	1.3-2.4
Optimum Moisture Content (%)	18	5.0-30.0
Angle of Internal	28	30-40
Friction(degrees)	2.1	Negligible
Cohesion (kN/m^2)	1.650 × 10^{-5}	8×10^{-6} - 7×10^{-4}
Permeability (m/sec)	Higher	Low - high
Shrinkage Limit (Vol stability)	Major fine sand range / and very small per cent of clay size particles	Major sand size fraction / silt and clay fraction and small per cent of gravel size fraction
Grain size		
Clay (percent)	Negligible	Low- medium
Free Swell Index	Very low	very low
Classification (Texture)	Sandy silt to silty loam	sandy clay, silty clay, clay loam and silt loam
Water Holding Capacity (WHC) (per cent)	40-60	10-70
Porosity (per cent)	30-65	15-75

Table 3. Summary of test results for different experiments on Class F Flyash.

mentioned in [6] for Indian soil are selected for the comparison also provided in **Table 3**, the typical variations of comparative study obtained by **Table 3**. The sample of locally available common soil also tested for comparison with Class F sample. It is found in the study that the physical properties of Class F flyash is very close to the relative values of common soils though it may differ from one country to another on their geographical conditions. There are several factors as to why soils differ with respect to region. The parent material are the source of most influential factors, others include climate and terrain of the region as well as the type of plant life and vegetation present. As per the study, the focus is on the geo-technical functions of the flyash and its comparison with the common soil which is an important criterion to replace any natural material. The strength and durability are two important factors to replace any material in construction industry. A material is considered as a building material if it requires properties suitable enough to be engineered for construction. A series of experiments conducted [9] showed that the addition of flyash improved the soil properties, viz., texture, structure, and bulk density. Permeability of clay loam soil increased from 0.54 to 2.14 cm/h by 50% addition of flyash, whereas it decreased from 23.80 to 9.67 cm/h in sandy soil by 50% flyash addition. Water retaining capacity of sandy soil increased from 0.38 to 0.53 cm/cm at 50% level. The characterization studies have been performed by researchers to evaluate the suitability of flyash for other fields of applications. The nature of Indian flyash is alkaline, hence, its use in agricultural soils increase pH of the soil thereby, neutralizing acidic soil [10].

2.4. Published studies on flyash

The production of high performance concrete (HPC) needs to incorporate the supplementary cementations materials such as flyash and kaolin in the concrete mix [10]. The fiber combination in the premix reinforced flyash lime stone dust brick (10FRFALSDB3') to have highest compressive strength (9.155 MPa) with 10% stone dust, and sand combination at 10% cement [11]. Ref. [12] carried out several tests on flyash-based brick tiles of Class F type. After experimental investigation, it was proved that the tiles failed on the lower compressive strength as compared to the conventional clay roof tiles. The highest compressive strength reached 6.896 MPa for 15TFASDBT combination. The experimental investigation [13] discloses that on increasing the content of Cement (C) at the fixed percentage of Treated Flyash (T.F.A) and Radish Stone Dust (R.S.D), the permeability values lowered down. Although the permeability (k) dropped with variation of the coarse sand (C.S) with C, k has been found to be in the range 10^{-7} much closer to the value of clay readily available in the market for making bricks and roof tiles. Through new sets of experiment conducted by [14], its compressive strength increased up to 30.65% as compared to past learning of [12]. The Class C flyash category was employed as a raw material for full replacement of clay for making flyash bricks. In that particular study, the effect of flyash with high replacement of clay mixed with different materials were studied at a constant percentage of cement, i.e., 10%. It also revealed that the highest compressive strength (79 kg/cm^2) was obtained in the case of 25TFASDB which was compared to be less than the maximum strength (105 kg/cm^2) of standard first class clay brick. Moreover, the study was important as it replaced 50% of top soil by flyash. The 25TFASDB bricks can be safely used in frame structure buildings as a non-load bearing walls and also in load bearing walls in case of single storey constructions [15]. Ref. [16] suggested that the flyash-scrap tire fiber composite offered a sustainable supplement to traditional insulation. This not only increased the competence of traditional insulation, but also helped in significantly reducing the environmental issues related to disposal of waste products.

2.5. Flyash utilization in different sectors

Since the last 30 years, flyash is not considered as hazardous waste; and researchers are extensively exploring the area of research related to utilization of flyash in various sectors. The programs concerned with flyash utilization may be broadly analyzed as extenuating the effects of environment and considering disposal issues (low value–high volume utilization) [17]. Below are addressed some of the potential areas of flyash utilization.

2.5.1. Development of flyash-based polymer composites as substitute for wood

Recently, flyash-based polymer composites have been developed with jute cloth as reinforcement and flyash as filler. This technology may be used as a substitute for wood which may have applications in door shutters, flooring tiles, partition panels, ceiling, wall paneling, etc. The technology of flyash-based polymer composite was developed by Regional Research Laboratory, Bhopal in collaboration with Building Materials and Technology Promotion Council (BMTPC) and TIFAC. A commercial plant is being based near Chennai for the above developed technology [18].

2.5.2. Flyash-based cement

According to the specifications of Bureau of Indian Standards, up to 35% flyash is permissible in PPC manufacture in India; whereas worldwide other countries permit up to 55% flyash utilization in PPC production. In such applications, 25% of cement production is meant for OPC and the rest 75% may be for PPC with 30% flyash content [18]. This would utilize around 25 MT flyash, thereby replacing cement clinker with gross net saving of Rs. 2500 crores [19].

2.5.3. Role of bio-amelioration of flyash on soil

Recent studies recommend the use of flyash with organic compounds like cow manure, paper factory sludge, press mud, sewage sludge, farmyard manure, organic compost, and crop residues for upgrading degraded/marginal soil [20]. The beneficial effects of flyash along with soil organic matter are reduction in the availability of heavy metal and sludge pathogens [21]; improvement in nutrient concentration of soil and better texture quality, lesser bulk density, better porosity and content of mass moisture, and increase in content of fine-grained minerals [22]; improvement in biological activity of the soil [23]; reduction in the leaching of major nutrients [24]; and favorable for vegetation growth [25]. The utilization of swine manure along with flyash improved the accessibility of Ca and Mg in the soil, thereby balancing the monovalent and bivalent cations ratio (Na^{++} K^{+}/Ca^{2+} Mg^{2+}) that is detrimental to the soil [26]. The utilization of “slash” in a mixture of flyash, sewage sludge, and lime (60:30:10) had valuable soil ameliorating effect. The incorporation of “slash” in soil demonstrated positive effects on soil pH and Ca, Mg, and P content and reduction in the translocation of Ni and Cd [27] and enhanced growth and yield of corn, potatoes, and beans in pot trials. Therefore, changes in flyash may enhance the quality of agricultural sector for crop production [28].

2.5.4. Flyash bricks

According to a study by Central Fuel Research Institute, Dhanbad, India, a technology is proposed for the use of flyash in building bricks [17]. About 40–70% flyash is used in building bricks. The current scenario suggests a market with production of 100 billion clay bricks a year. In case, on technical acceptance of flyash brick which are environment friendly and economically viable, it may target at least 2 billion flyash bricks per year. This would consume approximately 5 million ton of flyash/year, hence generating a saving of around Rs. 200 million per year. There are several advantages of flyash bricks over conventional clay bricks. Apart from this, unglazed tiles for footpaths can be made from flyash bricks. The Government has to provide special incentives for such ecofriendly approach in the near future [25].

2.5.5. Flyash in distemper

The use of flyash in manufacture of distemper has replaced white cement. Several buildings in Neyveli, Tamil Nadu have been reported to use flyash distemper in the interior surface with satisfactory performance. This would decrease the cost of production of distemper by 50% [17].

2.5.6. Flyash-based ceramics

In order to provide superior resistance to abrasion, National Metallurgical Laboratory, Jamshedpur, India has developed ceramics from flyash [17].

2.5.7. Ready-mixed flyash concrete

In developed countries, ready-mix concrete is pretty popular; but in India, it utilizes less than 5% of total cement consumption. Recently, the application of ready-mixed concrete has grown at a rapid rate. Several ingredients and quality parameters are strictly controlled in ready-mix concrete, which is quite not possible in concrete production at site and it may accommodate higher quantity of flyash [18].

2.5.8. Minefills

Almost one-third of Indian TPPs are near to pit heads. These mines heave sand for backfilling from river beds, normally 50–80 km away. The cost includes not only royalty, but also transportation cost of sand. An estimation suggests that about 15–20 million ton of ash per annum can be safely consumed in minefills generating an economy of about Rs. 1500 million per annum [19].

2.5.9. Flyash in road construction

Flyash is used in construction of roads as well. It saves surface soil which is usually used, avoiding formation of low lying areas [4]. Flyash is used in road construction for stabilizing and constructing sub-base or base; upper layers of pavements; filling purposes, etc. The use of concrete with flyash (10–20% by wt.) is quite cost effective and enhances performance of rigid pavement. The mixture of soil with flyash and lime enhances California Bearing Ratio (CBR) to (84.6%). As per the reports, National Highway Authority of India (NHAI) is using 60 lakh m^3 of flyash currently and proposed the consumption of another 67 lakh m^3 in future projects.

2.6. Embankment

As an engineering material, the properties of flyash are somewhat unique. For the construction of embankment, soils are used; but unlikely flyash has a large uniformity coefficient due to clay-sized particles. The properties that affect flyash use in embankments include compaction characteristics, grain size distribution, shear strength, compressibility, permeability, and frost susceptibility. Among all, flyash used in embankments are Class F flyashes [17]. In order to develop road infrastructure in the country, conservative approximates about 15–20 MT of flyash consumption in construction of road and flyover embankments per year in the environs of TPPs. It would yield a saving of around Rs. 100 crore per annum [20].

2.6.1. Roller compacted concrete

Flyash may be also consumed in compacted concrete dams. There are many dams in US which are reported to be constructed with high flyash contents. The heat of hydration is lowered by the use of flyash to allow thicker placements. Data regarding this may be found at the US Bureau of Reclamation. This may also be justified by the data reports of Ghatghar Dam Project in India [29].

2.6.2. Asphalt concrete

Asphalt concrete is basically a composite made of an asphalt binder and mineral aggregate. Both Class F and Class C flyash are used as a mineral filler to fill the voids and provide contact points between larger aggregate particles in asphalt concrete mixes. This application is used in conjunction or as a replacement for, other binders (such as Portland cement or hydrated lime) [29]. For use in asphalt pavement, the flyash must meet mineral filler specifications outlined in ASTM D242. The hydrophobic nature of flyash gives pavements better resistance to stripping. Flyash increases the stiffness of the asphalt matrix, thereby improving rutting resistance and mix durability [3].

2.6.3. Use of flyash in agriculture

In India, agriculture and waste land have been dumped with flyash. This accidental activity of waste management has improved permeability, texture, and fertility of soil; reduced bulk density of soil; improved water holding capacity/porosity; optimized pH value; improved soil aeration; reduced crust formation, provided micro nutrients like Fe, Zn, Cu, Mo, B, Mn; provided macro nutrients like K, P, Ca, Mg, S, etc.; worked as a part substitute of gypsum for reclamation of saline alkali soil and lime for reclamation of acidic soils; ash ponds provided suitable conditions and essential nutrients for plant growth; and helped to improve the economic condition of local inhabitants. Apart from this, crops yielded on flyash mixed soil are found to be safe for human consumption and to maintain groundwater quality [3]. The improvement in crop yield is recorded with flyash doses varying from 20 to 100 ton/hectare.

About 20–30% yield has increased out of 150 million hectare of land under cultivation, 10 million hectares of land can safely be taken up for application of flyash per year. In order to take a moderate flyash dose of 20 m per hectare, it would consume 200 million ton flyash per year. The expected uptake is more than the annual availability of flyash; therefore the shortfalls may be met from 1500 million ton stock of flyash available in ash ponds. The field treated with flyash is expected to give additional yield of 5 million ton foodgrains per annum valuing about Rs. 3000 crore income [19].

3. Conclusions

As per Indian scenario, there is a vast difference in the production and utilization of flyash which is still considered as waste material. In India, the majority of flyash produced fall in Class F category. This chapter shows the chemical and physical analysis of Class F flyash for construction industry. Flyash has the capability to hold free lime that leads to lesser bleed voids and reduction of permeability to water and sulfate. Furthermore, the experimental data suggests that the strength of Class F flyash-based bricks and tiles with cement are far more as compared to standard clay and bricks. It also clarifies that physical properties of flyash are similar to local soil. With the use of Class F flyash, we may reduce the amount of soil used in the production of construction materials like blocks, tiles, roof materials, etc. Apart from this, the utilization of flyash as pozzolanic material in concrete mixture may prove to be economical. The use of additional waste material may provide both durability as well as economical means for ecological balance. For Indian condition, it is recommended that the Class F flyash may be used as filling material in construction work, i.e., buildings, roads, embankments, and low lying areas. Flyash is a lightweight material when compared to local soils, which is commonly used as fill material. As flyash is a lightweight material, as compared to commonly used fill material (local soils), it causes lesser settlements. India is an agriculture-based country. The overuse and inappropriate use of soil results in nutrient depletion, erosion, and other forms of degradation, hence the soil productivity declines; it also reduces the area available for agricultural use. By utilizing flyash as a fill material, an equal volume of top soil, which will otherwise be used in filling, can be saved. Recycling of flyash will conserve the natural raw materials and reduce the disposal cost. It will also create new revenues and business opportunities in civil engineering construction industry while protecting the environment.

Acknowledgements

The authors acknowledge the help of the staff at the Soil Mechanics Laboratory at A.M.U Aligarh, India, in conducting the experiments. They are also thankful to USIF, A.M.U Aligarh, India for providing SEM/EDX data.

http://dx.doi.org/10.5772/intechopen.82078

Author details

Mohammad Nadeem Akhtar[1]* and Nazia Tarannum[2]

*Address all correspondence to: nakhtar@fbsu.edu.sa

1 Department of Civil Engineering, Fahad Bin Sultan University, Tabuk, Saudi Arabia

2 Department of Chemistry, Chaudhary Charan Singh University, Meerut, Uttar Pradesh, India

References

[1] American Standards for Testing and Materials; 2005

[2] American Standards for Testing and Materials; 2006

[3] Alam J, Akhtar MN. Fly ash utilisation in different sectors in Indian scenario. International Journal of Emerging Trends in Engineering and Development. 2011;**1**(1):1-14

[4] Sahu SK et al. Characterization and quantification of persistent organic pollutants in flyash from coal fueled thermal power stations in India. Microchemical Journal. 2009; **92**:92-96

[5] Dwived A, Kumar Jain M. Fly ash—Waste management and overview: A Review. Recent Research in Science and Technology. 2014;**6**:30-35

[6] The Built Envison. Central Building Research Institute Roorkee; 2016

[7] Report on fly ash generation at coal/lignite based thermal power stations and its utilization in the country for the year 2015-16. Central Electricity Authority, New Delhi; 2016

[8] I.S: 3812. Specification for Fly Ash as Pozollana and Admixture (First Revision); Bureau of Indian Standard Manak Bhavan, Bahadur Shah Zafar Marg, New Delhi. 1983

[9] Dhindsa HS, Sharma RD, Kumar R. Role of fly ash in improving soil physical properties and yield of wheat (*Triticum aestivum*). Agricultural Science Digest. 2016;**36**:97-101

[10] Phung HT, Lund IJ, Page AL. Potential use of flyash as a liming material. In: Environmental Chemistry and Cycling Processes; 1978. Conf-760429 504-515

[11] Akhtar JN, Alam J, Akhtar MN. An experimental study on fibre reinforced fly ash based lime bricks. International Journal of Physical Sciences. 2010;**5**:1688-1695

[12] Alam J, Khan M, Akhtar M. Fly ash based brick tiles: An experimental study. International Journal of Emerging Trends in Engineering and Development. 2013;**6**:35-44

[13] Akhtar MN, Khan MA, Akhtar J. Use of the falling-head method to assess permeability of fly ash based roof tiles with waste polythene fibre. International Journal of Scientific and Engineering Research. 2014;**5**:476-483

[14] Akhtar MN, Akhtar JN, Al Hattamleh OH, Halahla A. Sustainable fly ash based roof tiles with waste polythene fibre: An experimental study. Open Journal of Civil Engineering. 2016;**6**:314-327

[15] Akhtar JN et al. Bricks with total replacement of clay by flyash mixed with different materials. International Journal of Engineering Science and Technology (IJEST). 2011;**3**(10):7338-7346. ISSN: 0975-5462

[16] Van de Lindt JW, Carraro JAH, Heyliger PR, Choi C. Application and feasibility of coal fly ash and scrap tire fiber as wood wall insulation supplements in residential buildings. Resources, Conservation and Recycling. 2008;**52**:1235-1240

[17] Senapati MR. Fly ash from thermal power plants—Waste management and overview. Current Science. 2011;**100**(25):1792

[18] Saxena M, Prabhakar J. Emerging technologies for third millennium on wood substitute and paint from coal ash. In: 2nd International Conference on “Fly Ash Disposal & Utilization”; February; New Delhi, India; 2000

[19] Kumar V, Mathur M, Sharma P. Fly ash: A billion dollar resource–Wasted so far. Mission beyond 2000 A. D., Fly Ash disposal and deposition: beyond 2000 A.D. Narosa Publishing House

[20] Tripathi RD, Singh SN, Singh N, Vajpayee P, Kumar A. Reclamation of fly ash landfills by successive plantation, soil amendments and/or through biotechnological approach. Final Technical Report. Directorate of Environment, U.P., India; 2000 (unpublished material)

[21] Wong JWC. The production of artificial soil mix from coal fly ash and sewage sludge. Environmental Technology. 1995;**16**:741-751

[22] Shen JF, Zhou XW, Sun DS, Fang JG, Liu ZJ, Li Z. Soil improvement with coal ash and sewage sludge: A field experiment. Environmental Geology. 2008;**53**:1777-1785

[23] Kumpiene J, Lagerkvist A, Maurice C. Stabilization of Pb and Cu contaminated soil using coal fly ash and peat. Environmental Pollution. 2007;**145**:365-373

[24] Sajwan KS, Paramasivam S, Alva AK, Adriano DC, Hooda PS. Assessing the feasibility of land application of fly ash, sewage sludge and their mixtures. Advances in Environmental Research. 2003;**8**:77-91

[25] Rautaray SK, Ghosh BC, Mittra BN. Effect of fly ash, organic wastes and chemical fertilizers on yield, nutrient uptake, heavy metal content and residual fertility in a rice–mustard cropping sequence under acid lateritic soils. Bioresource Technology. 2003;**90**:275-283

[26] Giardini L. Aspetti agronomici della gestione dei reflui zootecnici. Rivista di Ingegnaria Agraria. 1991;**12**:679-689

[27] Rethman NFG, Truter WF. Plant responses on soils ameliorated with waste products. In: 16th National Meeting of ASSMR; Albuquerque, NM, USA; 2001. p. 425

[28] Pandey VC, Singh N. Impact of fly ash incorporation in soil systems. Agriculture, Ecosystems and Environment. 2010;**136**:16-27

[29] Kumar V, Mathur M, Sharma P. Fly Ash Disposal: Mission Beyond 2000 A. D., Fly Ash Disposal and Deposition: Beyond 2000 A.D. Narosa Publishing House; 1999