Application of Thermal Power Plant Fly Ash & Water Treatment Plant Sludge in Brick Making

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Abstract— Sludge from a water treatment plant is, frequently, disposed and launched directly within the water bodies, inflicting a negative effect in the environment. Also, ash is produced due to burning of coal in thermal power plant and is the industrial solid waste most generated roughly around five million tons/year. An efficient disposal of coal ash is a problem attributable to its large volume and harmful risks to the environment. The specific purpose of this study was to judge the technical potentialities of incorporating cyclone ash and sludge from a waste water treatment plant within the production of ecological bricks. The wastes were analyzed for physico-chemical, mineralogical and morphological properties. Numerous mixtures were made ready by incorporating these industrial wastes in brick production. The results of wastes incorporation on physical properties like compressive strength and water absorption were determined. The simplest result, in terms of compression strength and water absorption, was reached by the series of bricks made with 55% soil, 15 % cement, 12 % fly ash and 18 % sludge by weight. The results showed that sludge and ash can be used as waste additives within the making of soil-cement bricks rank fraud. Malware is also detected before the time of downloading.

Key words: Soil-Cement Bricks, Ecological Bricks, Thermal Power Plant, Coal Ash, Water Treatment Plant Sludge

I. Introduction

Water treatment plants produce large quantities of sludge as a result of treatment processes of raw water such as coagulation, flocculation and filtration [1, 2]. The by-product from the purification process is a huge amount of waste in the form of sludge called water treatment residual or water Treatment sludge, which after drying is considered to be a non-biodegradable waste material.

The sludge composition in water treatment plants is mainly determined by the geology, hydrology of the river basin, human activities in catchments and chemicals used in a purification process. Consequently sludge produced from water purification processes may contain high concentrations of those chemical removed by the purification processes.

Aluminium sulphate is the most widely used coagulant in drinking water treatment. Some researchers have linked aluminum's contributory influence to occurrence of Alzheimer, children mental retardation, and the common effects of heavy metals accumulation [3,4].

The common practice by most water treatment plants is the disposal of sludge to the nearest watercourse around the treatment plant without prior treatment. However, the laws in India are demanding a change in this behavior, and thus proper management of the sludge becomes inevitable.

The mineralogical composition of sludge from a water treatment plant is clay, silt, and sand [5]. This means that the waterworks waste has the potential to be used as a possible new additive to clay-based products [5,6]. The reuse of waterworks waste for obtaining soil-cement bricks has also been recently suggested [7,8].

Similarly, the disposal of the large amount of fly ash generated from combustion of coal is also a major concern as it possesses health hazards and severe implications for the environment. The main drawback of Thermal power plants in India is the high production of ash. Fly ash represents about 65-85 % of coal-ash produced by thermal power plants, while bottom ash accounts for 15-35 % [9].

The fly ash is a fine-grained, powdery particulate material that is carried off in the flue gas and usually collected from the flue gas by means of electrostatic precipitators, bag houses, or mechanical collection devices such as cyclones [10].

Fly ash from a bag house filter produced in the Indian power plant is mostly recycled as a cement raw material to be used in civil engineering materials. However, cyclone ash does not find at present time a commercial application; rather, it is usually stored in an abandoned surface mine or dumped in landfills in the vicinity of the power plant.

The utilization of fly ash in construction, as a low-cost adsorbent for the removal of organic compounds, flue gas and metals, light weight aggregate, mine back fill, road sub-base, and zeolite synthesis has been widely examined. However, there is a perpetual request for new applications of fly ash since the amount of this coal waste released by thermal power plants has been increasing throughout the world.

The purpose of this study was to investigate the characteristics and possible utilization of water treatment plant sludge and thermal power plant fly ash in the Manufacturing of bricks. The suitable conditions of using dried sludge and coal fly ash in producing bricks under the criteria of Indian Standards (IS) were investigated. The influence of wastes proportion in the raw materials in relation to the brick was also examined.

II. Experimental

A. *Materials*

All the reagents used for experimental studies were of analytical grade. The samples of coal fly ash from a cyclone filter were obtained from a thermal power plant located at Korba in Chhattisgarh. The used sludge from a water treatment plant used was collected from a waterworks located in Bhopal, Madhya Pradesh. Pozzolana Portland cement (PPC) 43 Grade and sandy soil were used.

B. *Production of Bricks*

The methodology consisted in identifying the most appropriate proportion of fly ash, sludge from a water treatment plant, soil, cement or lime for the manufacture of bricks.

Fly ash, sludge, soil, cement or lime mixtures with different mass ratios were prepared, besides a bricks series without addition of wastes and lime (the control pattern) are presented in Table 1. The dimensions of the bricks were 230 X 100 X 100 mm. Technical evaluation of the bricks was performed according to Indian Standard. Compressive strength and absorption tests were performed on the bricks according the standard after the curing time of 28 day. From each series, tests were done to determine the compression resistance and water absorption tests on 5 bricks.

Group	Proportion of materials (mass %)				
	Soil	Cement	Fly Ash	Sludge	Lime
G-0	85	15	-	-	-
G-1	-	-	10	90	-
G-2	45	5	4	46	-
G-3	55	10	8	27	-
G-4	55	15	12	18	-
G-5	55	-	16	18	11
G-6	60	-	7	18	15

Table 1: Materials used in the Preparation of Bricks

III. RESULTS & DISCUSSION

A. *Characterization of Sludge from a Water Treatment Plant*

The X-ray diffraction pattern of the waterworks waste sample is shown in Figure 1. The sample exhibited peaks that are characteristics of kaolinite (Al2Si2O3(OH)4), quartz (SiO2), goethite (FeO (OH)), and muscovite (KAl3Si3O10(OH)2), also known as mica, with predominance of kaolinite and quartz.

Table 2 presents the chemical composition of the water treatment waste sample. Although the properties of the sludge samples are highly variable and dependent on both the type of the raw water and the chemical composition of coagulant [11], it can be seen from Table 2 that aluminum is the dominant component in the dewatered alum sludge with ~39 % in mass expressed as Al2O3. The other principal chemical components were SiO2 and Fe2O3.[18]

Oxides	wt%
Al2O3	39.1
SiO2	30.2
Fe2O3	25.8
K2O	1.4
TiO2	1.4
MgO	0.6
SO3	0.6
P2O5	0.3
MnO	0.3
CaO	0.2
others	< 0.09

Table 2: Chemical composition of the water treatment waste

This result is consistent with the X-ray diffraction data (Figure 1). The alumina does not occur in its free form in the waterworks waste sample, being bounded to the clay minerals (kaolinite and muscovite). The quartz is present in the structure of clay minerals and free silica particles. The iron oxide is present in the structure of the goethite. The contents of alkaline oxide (K2O), TiO2, alkaline earth (CaO and MgO), SO3 and P2O5 are between 0.2 -1.4 %.

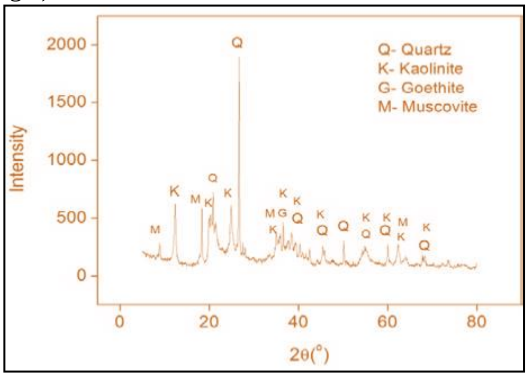

Fig. 1: X-ray Diffraction Pattern of the Waterworks Waste Sample

The presence of these elements is attributed to the use of aluminium sulfate as coagulants in water treatment plants and due to the composition of the water, which contains suspended materials, such as sand and clay materials.

Some important physicochemical characteristics of waterworks waste sample are shown in Table 3. Usually, the moisture content of the waterworks sludge is at least 80 %. Loss on ignition (LOI) implied in high weight loss of about 52.0 wt. %, is mainly attributed to the presence of clay minerals, hydroxides, and organic matter in the waste sample [12].

Characteristics	Obtained Values
Humidity (%)	85.0
Loss og ignition (%)	52.0
pH in water	5.57
CEC (meq 100 g-1)	9.34
Organic matter content	24.3
Apparent density (g cm-3)	1.75
True density (g cm-3)	2.27
Specific surface area (m^2 g-1)	106.9
Total solids (%)	9.85
Fixed solids (%)	2.16
Volatile solids (%)	0.0769

Table 3: Chemical Composition of the Water Treatment Waste

The pH (in water) of the waste sample was 5.57, which can be considered as being of a medium acidity. The sample presented a value of a cation exchange capacity (CEC) of 9.04 meq/100 g within the CEC range of kaolinitic clays (3 - 15 meq/100 g) [12], corroborating the kaolinitic character of the investigated waterworks waste.[17]

It was also found that the water treatment waste presented a high organic matter content (24.3 %). This result suggested that the organic matter significantly contributed to the high value of loss on ignition. The waste sample presented real density of 2.27 g cm^{-3}, which reflected its mineralogical composition. The surface area of water treatment plant sludge was 106.9 m^2 g^{-1} indicating a porous material.

Water treatment plant sludge was characterized by the following granulometric composition: a sand fraction, 58.2 % (particles with diameters between 0.06 and 2.0 mm); a silt fraction, 6.83 % (particles with diameters between 0.002

and 0.06 mm); and a clay fraction, 35.2 % (particles with diameter lower than 0.002 mm).

Figure 2 shows the scanning electron micrograph of sludge from a water treatment plant. As shown by the result of the SEM analysis, the sludge has irregular shapes which are probably flakes of fine kaolinite clay particles [13]. In addition, a wide particle size range can be observed, in accordance with the particle size data.

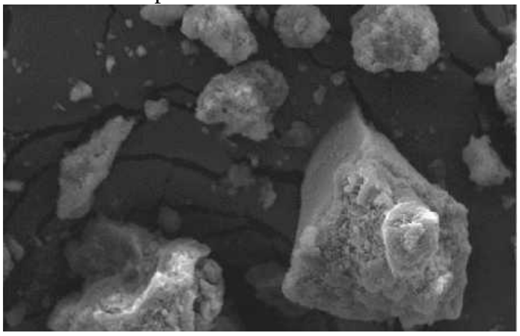

Fig. 2: Morphology of the Waterworks Waste Particles

The TG and DTG curves for the 10°C min-1 heating rate under a N2 atmosphere are shown in Figure 3. The profile of sludge from a water treatment plant weight loss exhibited three stages during the degradation process (Figure 3). The first occurred rapidly between 30 and 202 °C with loss of mass of around 12 %, while the second occurred between 202 and 397 °C with mass loss of 8.4 %. Finally, the third stage occurred between 399 and 906 °C with mass loss of 9.9 %. The remaining solid residue was 68 % of the original mass.

The thermal events observed on the DTG curve are according to mass losses evidenced on the TG curve. The event which occurred at 76.1°C (T peak) was the major reaction area and represents the elimination of free water between the particles. The T peak = 275.2°C is probably related to water loss from hydroxides and to the combustion of organic matter. The T peak = 490.9°C is attributed to the dissociation of constitution water (or structural water), i.e., comprising the hydroxyl group of the kaolinite clay mineral.

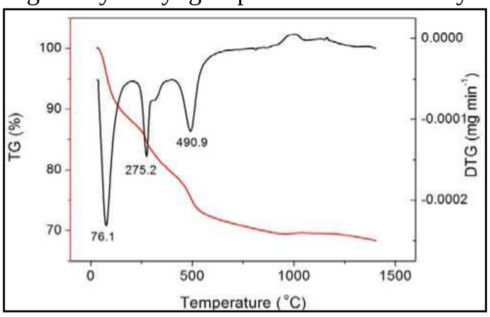

Fig. 3: TG and DTG Curves of Waterworks Waste

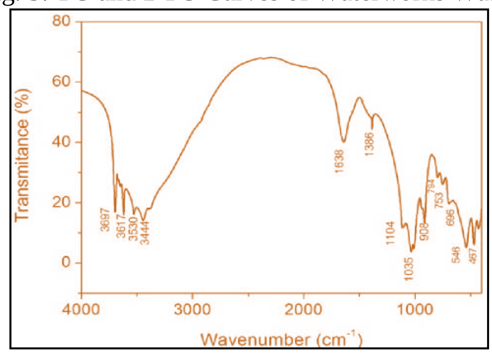

Fig. 4: FTIR Spectra of Water Treatment Waste

Figure 4 shows the FTIR spectrum for sludge from a water treatment plant. The FTIR spectrum of the raw sludge showed the presence of kaolinite, quartz, goethite and muscovite identified by XDR (Figure 1) and some organic matter. The assignments for FTIR spectrum has been reported elsewhere [14]. The sludge from a water treatment plant sample had an FTIR spectrum consistent with previous reports in the literature [15].

B. Characterization of Fly Ash

The XRD analysis of CFA powder revealed the presence of quartz crystallite and mullite as a major component of ash and some amounts of hematite, anhydrite and albite. The presence of amorphous phases are identified as a broad diffraction 'hump' in the region between 18 to 30 degrees 2θ (Figure 5). The intensity of quartz is very strong, with mullite forming a chemically stable and dense glassy surface layer.[16]

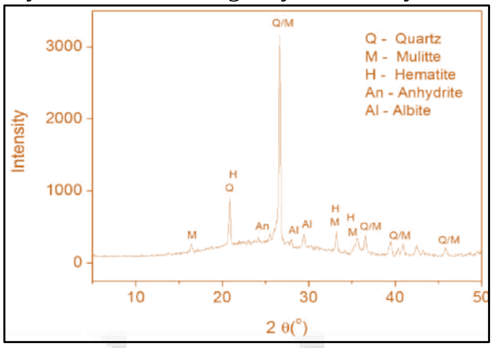

Fig. 5: X-Ray Diffraction Pattern of Cyclone Fly Ash

The sample of coal fly ash collected by the cyclone from Figueira Power Plant was characterized and some physico-chemical characteristics of this material are shown in Table 4. The chemical composition of CFA sample reveals that the major components are SiO2, Al2O3, and Fe2O3. Some minor components like Fe2O3, SO3, CaO, K_2O and trace elements (< 1.2 wt %) are also present in CFA sample. The characteristics of Indian coal fly ashes have been previously discussed in the literature [14].

The FTIR spectrum of CFA is shown in Figure 6. The band at 3433 cm^{-1} is attributed to the asymmetric and symmetric stretching vibrations v(O-H), suggesting the presence of an amorphous silicate material (glass) or possibly hydrated aluminum silicates. The band at 1622 cm^{-1} is attributed to the bending mode of H_2O molecules. A broad band at 1069 cm-1 is due to Si-O-Si asymmetric stretching vibrations of silica. The bands at 794 and 460 cm^{-1} could be assigned to quartz and silica, respectively.

Characteristics	Obtained Values
Humidity (%)	85.0
Loss on ignition (%)	52.0
pH in water	5.57
CEC (meq.100 g^1)	9.34
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Apparent density (g cm^{-3})	1.75
True density (g cm^{-3})	2.27
Specific surface area (m^2 g^{-1})	106.9
Total solids (%)	9.85
Fixed solids (%)	2.16
Volatile solids (%)	0.0769

Table 4: Physicochemical Properties of Cyclone Fly Ash

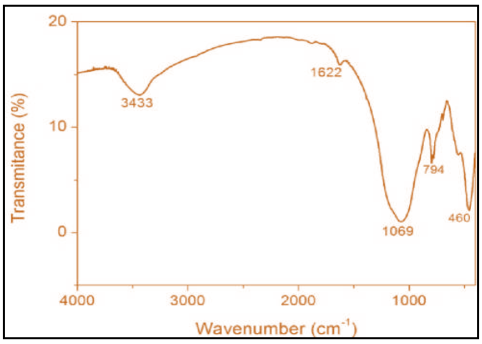

Figure 6. FTIR Spectra of Cyclone Fly Ash

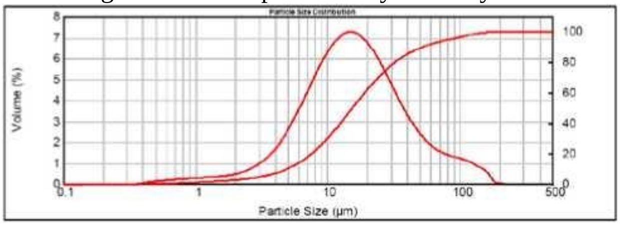

Fig. 7: Particle Size Distribution of Cyclone Fly Ash

Laser granulometric analysis results for Fly Ash are reported both as absolute and cumulative volumetric distributions (Figure 7). From the cumulative distributions, the following values for d10, d50 and d90 can be observed: 4.994, 15.575 and 52.526 ^m, respectively.

The SEM image of CFA demonstrates particles of different shapes and sizes, which majority consisted of solid spheres (Figure 8A). Different physical states of silica are responsible for the particles of irregular size. Hollow microspheres (cenospheres), plerospheres (smaller spheres inside big sphere) and irregularly shaped unburned carbon particles tended to be in the upper end of the size distribution (Figure 8B).

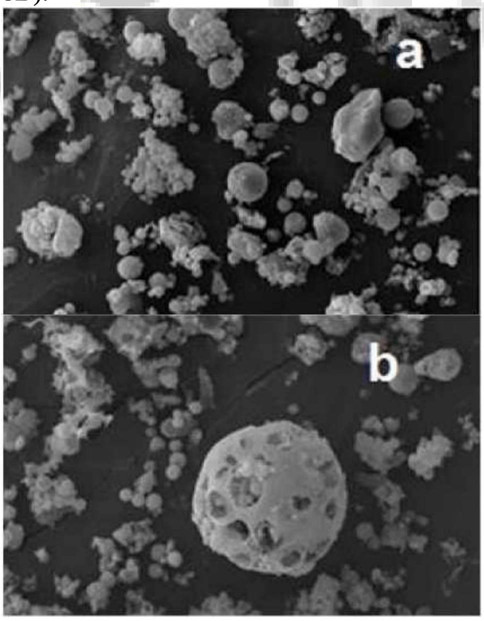

Fig. 8: SEM micrographs of cyclone fly ash (a) particles of irregular size and spherical morphology; (b) hollow sphere (plerosphere) containing smaller hollow and empty spheres (cenospheres)

C. Characterization of Bricks

In this study, sludge of the water treatment plant stations and fly ash were used for the manufacture of soil-cement and soil-lime bricks. The quality of the bricks after curing for 28 days was determined on the basis of compressive strength and water absorption. According to Indian standards, water absorption and compressive strength are properties that define the soil-cement brick quality after curing. The specified values for water absorption and compressive strength are < 20 % and >2 MPa, respectively.

The compressive strength of the bricks is shown in Table 5. The brick pieces with 0 wt. % wastes (sample BW0, 100 % soil-cement body) were used as reference materials. As it can be observed, the compressive strength of the bricks presented decrement with wastes. Such a behavior is mainly related to the following factors: i) An inadequate granulometry of the sludge of the water treatment plant stations; and ii) A small amount of Portland cement or lime in relation to other components of bricks. The values of compressive strength of G-3 sample are in accordance with the limit values of the Indian specification used for industrial production of soil-cement bricks.

Group	Resistance to compression (MPa)	Absorption of water (%)
G-0	4.4	14.7
G-1	0.7	-
G-2	1.6	22.7
G-3	2.1	14.3
G-4	2.0	20.4
G-5	1.5	17.3

Table 5: Average Resistance to Compression and Average Absorption of Water

Table 5 shows the water absorption of the bricks. Water absorption is related to the volume of the open pores (i.e., the pores that are connected with the specimen surface). In addition, water absorption is closely related to densification and the microstructures of the cementitious matrix. It can be observed that the reference bricks G-2, G-4 and G-5 showed higher water absorption values than the reference bricks (BW0 sample). This is related mainly to the presence of a high amount of clay minerals (kaolinite and illite/mica) and an organic matter in the waterworks waste sample that tends to influence the cement hydration reactions [8].

The results obtained from compression resistance tests, for the case of G-1 bricks showed unfavorable results. They presented the average values of resistance to compression less than 1.0 MPa. Therefore, they were disregarded and the study of water absorption only included mixtures showing a favorable behavior. For G-3 samples the values of water absorption are according to the Indian standard.

The brick appearance is another important parameter of brick quality. The G-3 samples were reddish brown color, free of surface stains, efflorescence (soluble salts), and defects (Figure 9).

Fig. 9: The Appearance of the Brick Specimens after curing at 28 days

IV. Conclusion

The results of this work have demonstrated that sludge-fly ash-soil-cement brick can be successfully produced using water treatment plant sludge and cyclone fly ash under the conditions and manufacturing methods used in this study. The proportion of sludge and fly ash in the mixture soil-cement and soil-lime was the two key factors affecting the quality of brick. The massive brick built with the composition of 55 % soil, 15 % cement, 12 % coal fly ash and 18 % water treatment plant sludge showed satisfactory results regarding to the mechanical and physical requirements (resistance to compression and absorption of water) stipulated by the Indian standards. This study showed that water treatment plant sludge and coal fly ash could be used as brick material for economic and environmental sustainability. The incorporation of these wastes into brick production is a suitable alternative to their current disposal paths.

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