2.1 Introduction

Characterization of raw materials is performed to know their physiochemical, geotechnical properties and bed filter suitability. It is assessed their suitability for use in different possible applications.

From the literature, it is observed that the combustion of coal produces ashes as solid waste during the power generation. By the year 2020, it is expected that about 190 million tons per annum of ashes may be generated in India (CEA, 2011).

In conventional pulverized coal combustion (PCC) boiler, due to high-temperature combustion of coal firing brought many serious environmental problems such as emission of NO_x and SO_2 (Chan and Yao, 2008; SEPA, 2007; Sun et al., 2016, 2015; Yi et al., 2007). Now a days, fluidized bed combustion (FBC) technology has been gained popularity due to clean coal burning process as well as fuel flexibility (Basu, 1999; Chindaprasirt and Rattanasak, 2010). The physicochemical property of ashes are controlled by the use of types of coal, boiler and its operating temperatures. Due to high temperature in PCC boiler, melting of ash occurs, resulting the formation of bulk agglomerated gas entrapped bottom ash particles (Kim, 2002; Kutchko and Kim, 2006; Senior et al., 2000). Whereas bottom ash produced in FBC boiler consists of free non-agglomerated particles due to lower temperature generation (<1000°C) (Mandal and Sinha, 2014).

The physical characteristics, engineering properties, and gradation analysis of bottom ash are found to be similar to sand. That’s why, it was tried to replace the sand in many applications such as construction works widely such as for stabilization of base material, making of embankments, fills materials, backfills materials, and also a mine fillings (Donatello et al., 2010; Huang and Lovell, 1990; Karim et al., 1997; Koehler, 2002; Leonards and Bailey, 1982; Parker et al., 2002; Skarżyńska, 1995; Toth et al., 1988). Bottom ash exhibits higher shear strength due to higher friction angle (Lovell et al., 1991). Various applications of bottom ash have been reported as an alternative to natural materials in the geotechnical and mining activities (Carpenter and Gardner, 2009; Indraratna et al., 2011; Zekkos et al., 2013). The hydraulic conductivity of bottom ash in comparison to fly ash is high which shows 'free-drain characteristics' in foundations. It restricts the easy swelling or shrinking of ground due to moisture content (Carpenter and Gardner, 2009). This excellent hydraulic conductivity of bottom ash attracted the same as a filter material.

Conventionally, the coal ash disposed off either dry or wet disposal methods. In the case of wet disposal, coal ashes are transported as slurry through the pipeline into the pond. There are no such well-defined code and design guidelines available for construction and maintenance of such ash dikes constructed by using same pond ash. Therefore, so many failures of ash dikes are reported in the past. In general, sand is used as the conventional filter material. The availability of well-graded sand in and around the construction site in all seasons is limited which creates problems to the stability of ash dykes. Bottom ash is non-plastic in nature like sand and available abundantly in thermal power plants as ashes may replace the conventional sand as a filtering material (Sultana, 2013). No work has been reported in the literature regarding the suitability of FBC bottom ash as filter media in making of ash dyke (Kumar and Naresh, 2012; Zekkos et al., 2013).

The objective of the present study is focused on the fluidize bed combustion (FBC) bottom ash for its utilization in comparison to conventionally used pulverized coal combustion (PCC) bottom ash with respect to geotechnical as well as filter material to replace the sand.

2.2 Experimental

2.2.1 Test Material Procurement

Iron ore slime was collected from iron ore beneficiation plant of TATA steel, Noamundi, Orissa. The sample was collected from overflow points to get the finer structure. Bottom ashes were collected from two types of combustion system as mention below:

1. FBC boiler: Usha Martin Limited, Jamshedpur having a boiler capacity of 250 MW.
2. PCC boiler: Durgapur Projects Limited, Durgapur having a boiler capacity of 300MW.

Both boilers use the same origin of coal (BCCL, Dhanbad; Jharia) having a similar composition. Along with the main raw materials, pond ash and sand samples were collected from NTPC, Unchahar, UP for comparison purpose in filter suitability criteria testing.

2.2.2 Testing Techniques

2.2.2.1 Physicochemical properties

The size, shape and texture of the materials were observed by Scanning Electron Microscope (SEM) imaging with ETD detector. Bulk Density of the samples was measured as per ASTM D6683 method (ASTM D6683, 2014). Specific gravity of the samples was determined with the help of water, using pycnometer as per method mention in ASTM C135 (ASTM C135, 2015). Specific surface area of the samples was measured by the standard BET gas absorption desorption isotherm of liquid N_2 at 77K as per ASTM C1069 (ASTM C1069, 2014). Proximate analysis of bottom ashes was done as per ASTM D7582 for determination of the volatile matter and carbon content (ASTM D7582, 2015). The chemical analysis of samples was done by XRF analysis and phase detected by XRD analysis at scan rate 2° per minute at the range of 10-80°

(ASTM C1365, 2011; ASTM D3906, 2013). The pH value of samples was measured using digital pH meter with glass electrode as per ASTM E70 (ASTM E70, 2015).

2.2.2.2 Geotechnical properties

Particle size distribution of the materials was carried out separately, for particles <75 µm size by wet sieving followed by hydrometer analysis as per ASTM C117 and for particles >75 µm size by dry sieving analysis using sieve shaker as per ASTM C136 method (ASTM C117, 2013; ASTM C136M, 2014).

Standard Proctor test was used to determine the optimum moisture content (OMC) and maximum dry density (MDD) to evaluate the amount of compaction and water content required in the field. It was done as per ASTM D1557 (ASTM D1557, 2012).

A direct shear test is a laboratory or field test used by geotechnical engineers to measure the shear strength properties of soil or rock material. Shear strength was measured by direct shear strength method as per ASTM D 3080 (ASTM D3080/D3080M, 2011).

The California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of road subgrades and base courses. It was developed by the California Department of Transportation before World War II. The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area. The measured pressure is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material. The California Bearing Ratio (CBR) test for soaked condition was done as described in ASTM D1883 (ASTM D1883, 2016).

Soils are accumulations of solid particles with interconnected voids where water can flow from a point of high energy to a point of low energy. Permeability is the measure of the soil's ability to permit water to flow through its pores or voids. Permeability (or hydraulic conductivity) refers to the ease with which water can flow through a soil. This property is necessary for the calculation of seepage through earth dams, seepage rate from waste storage facilities (landfills, ponds, etc.), and the rate of settlement of clayey soil deposits. There are two general types of permeability test methods which are routinely performed in the laboratory: (1) the constant head test method, and (2) the falling head test method. Permeability test were determined by both falling head as well as the constant head test method as per ASTM D5084 (ASTM D5084, 2010).

When a soil mass is subjected to a compressive force, its volume decreases. The property of the soil due to which a decrease in volume occurs under compressive force is known as the compressibility of soil. The compression of soil can occur due to compression of solid particles and water in the voids, compression and expulsion of air in the voids and expulsion of water in the voids etc. The compression of saturated soil under a steady static pressure is known as consolidation. It is entirely due to expulsion of water from the voids. Compressibility characteristics of the both bottom ashes under investigation have been determined using one dimensional consolidation on samples prepared at their OMC and MDD as per ASTM D2435M (ASTM D2435/D2435M, 2011).

One of the basic requirements for design of an earth, rockfill dam, ash pond is to ensure safety against internal erosion, piping and excessive pore pressure in the dam. A suitably designed internal drainage system is essential to satisfy these requirements. Sand is widely used as a bed filter material for designing of dams and ash pond. For evaluation of Filter suitability criteria for both types of bottom ash, IS:9429 standard method was adopted (IS 9429, 1999).

2.3 Results and Discussions

The obtained results were critically examined with proper analysis which are presented in the following sections.

2.3.1 Physicochemical and mineralogical properties

SEM images of iron ore slime and both bottom ashes are shown in Figure 2.1. From the figure it is evidenced that, the iron ore slime is very fine in size,(Figure 2.1a,b) uncombined solid particles, as compared to bottom ashes (i.e. FBC and PCC). FBC bottom ash is observed to be coarser, uncombined solid form of particles due to low combustion temperature in boiler which is lower than ash melting temperature as shown in Figure 2.1(c,d). The similar observation was also reported by Stevens et. al (Stevens et al., 2009). On the other hand, the bottom ash in PCC boiler is melted and accumulated in the form of lump due to the high combustion temperature. After crushing, bottom ash looked like porous, irregular, popcorn like structures as shown in Figure 2.1(e,f). Particles of PCC bottom ash are found relatively finer porous structure as compared to FBC bottom ash. It was also reported by other reserchers (Kutchko and Kim, 2006).

Specific gravity, bulk density and specific surface area of these ashes were determined and reported in Table 2.1. The specific gravity of FBC bottom ash is found more (sp. gr. 2.7) than PCC bottom ash (sp. gr. 2.3) which is marginally higher due to the presence of Fe_2O_3 content. In the other way, the bulk density of PCC bottom ash is lesser as compared to FBC bottom ash due to the presence of popcorn like porous structure. The bulk density values of both bottom ashes are lesser than the bulk density of soils. It can be attributed partly again due to the presence of its porous structure. Whereas FBC bottom ash particles are observed to be solid and irregular in nature. The specific surface area of the material was found from BET analysis which revealed that the FBC bottom ash is coarser due to its lower specific surface area as compared to PCC bottom ash.

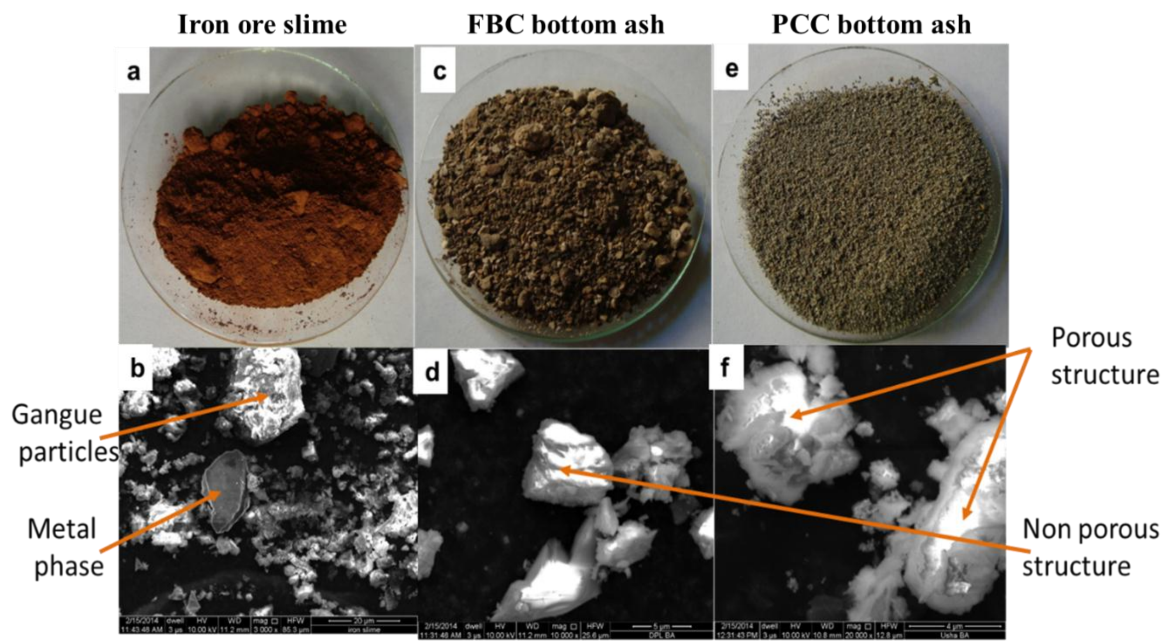

Figure 2. 1 Photographs and SEM images of (a,b) Iron ore slime; (c,d) FBC bottom ash; (e,f) PCC

The proximate analysis of both FBC and PCC bottom ashes were done in dry basis and values are reported in Table 2.1.

The phase analysis of all the raw materials were performed and their XRD pattern are shown in Figure 2.2. From the figure it is evidenced that the presence of complex phases in iron ore slime, i.e. Goethite, sodalite along with hematite and quartzite as a free phases. These mineral phases come into picture in the iron ore slime due to the washing of hematite ore. Presence of phases in bottom ash mainly depend on the composition of coal, boiler temperature and reaction time.

Table 2. 1 Different physical and chemical properties of raw materials

Raw materials	Physical			Chemical analysis (wt.%)												
					Proximate			Ultimate								
	Specific gravity	Bulk density (kg/m^3)	Surface area (m^2/kg)	pH	VM	Ash	FC	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_5	K_2O	SO_3	MnO	TiO_2
Iron ore slime	3.4	2320	2200	7.6	-	-	-	31.4	24.1	42.1	0.1	-	1.5	0.02	0.05	0.02	0.25
FBC bottom ash	2.7	1230	1280	10.0	1.5	95.5	3.00	67.3	25.7	3.7	0.3	0.5	0.8	0.09	0.19	0.03	0.28
PCC bottom	2.3	612	1650	9.4	1.1	94.7	4.20	70.0	22.1	2.5	0.8	1.2	0.6	0.10	0.16	0.03	0.34

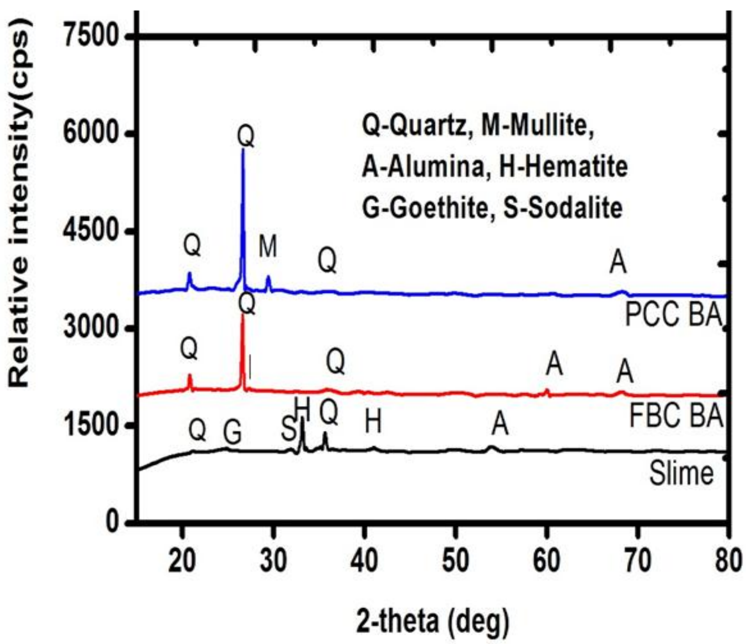

Figure 2. 2 XRD pattern for iron ore slime, FBC and PCC bottom ash

Quartz phase is the most predominant phase in all bottom ashes followed by alumina obviously due to the presence of silica as a major constituent in bottom ash. Due to the presence of high temperature in PCC boiler, formation of more high-temperature phases, like mullite (i.e. aluminium silicate) was observed. Therefore in comparison to PCC bottom ash, silica, alumina are present as an uncombined form in FBC bottom ash (Figure 2.2).

2.3.2 Geotechnical properties

2.3.2.1. Grain size analysis

The PCC bottom ash is finer than FBC bottom ash as discussed in section 2.3.1. Graph of particle size analysis shows that FBC bottom ash particles are coarser than PCC bottom ash (Figure 2.3).

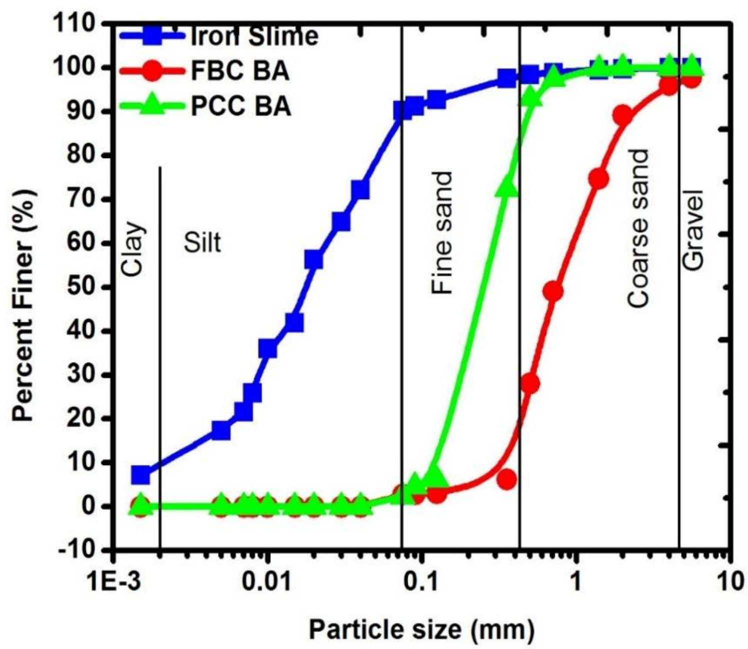

Figure 2. 3 Particle size graph of iron ore slime and both bottom ashes

The fineness modulus of both bottom ashes was calculated from the data of sieve analysis and values are reported as 2.82 for FBC and 1.24 for PCC bottom ash. The value of fineness modulus also justified the coarseness of the FBC bottom ash as compared to PCC bottom ash. As per gradation of soil, FBC bottom ash lies in well graded coarse sand category whereas PCC bottom ash in fine sand category (Figure 2.3). Both of them have zero clay content, hence, could not have self-bonding property without an addition of a suitable binder (Table 2.2).

Table 2. 2 Gradation of bottom ashes

Parameters		Iron ore slime	FBC bottom ash	PCC bottom ash
Composition (%)				
Clayey particles		9.55	0	0
Silty particles		79.66	2.26	2.98
Sand particles	Fine	8.41	15.91	79.54
	Medium	1.75	71.61	17.44
	Coarse	0.63	7.02	0.04
Gravel		0	3.20	0
Consistency				
D_{10}		0.002	0.325	0.118
D_{30}		0.009	0.524	0.179
D_{60}		0.024	0.924	0.283
(C_c)		1.560	0.913	0.966
(C_u)		11.845	2.840	2.400
Fineness Modulus		0.116	2.82	1.24

2.3.2.2 Compaction behavior

Values of dry density with respect to average moisture content was determined by using standard proctor test method and values are plotted as shown in Figure 2.4 for PCC and FBC bottom ash respectively. The maximum dry density with respective moisture content is called as maximum dry density (MDD) and optimum moisture content (OMC) which indicates the amount of compaction and water content required in the field.

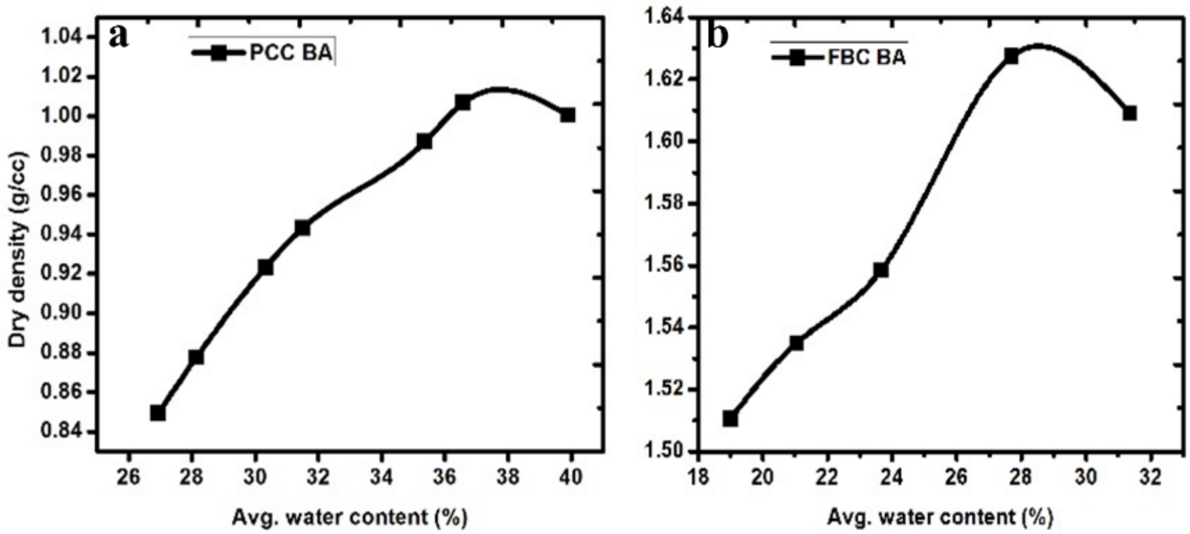

Figure 2. 4 Proctor test graph of (a) PCC bottom ash, (b) FBC bottom ash

From the above plot, the values of maximum dry density and optimum moisture content of the PCC bottom ash are 1.01 g/cc and 38 % respectively. But in the case of FBC bottom ash, the value of maximum dry density is quite higher (i.e. 1.63 g/cc) having less OMC (i.e. 29 %) due to the presence of its solid structure.

2.3.2.3 Shear strength

Shear stress verses shear displacement was plotted for different normal load for as shown in Figure 2.5. From the figure, it is evidenced that with increasing normal load, the shear stress values increases proportionally. At lower applied normal load, the shear stress values for both ashes have shown uniform increasing and decreasing trends of shear stress. But in the case of higher applied normal load, the shear stress values of PCC bottom ash drastically reduced due to degradation of its porous structure. Soil cohesion (c) and Friction angle (φ) were calculated for both ashes by plotting the graph of maximum shear stress at different normal stress (i.e. 0.5, 1, 1.5 kg respectively) as shown in Figure 2.6. The value of (c) and (φ) was found 0.156, 39.69° for FBC and 0.123, 35.75° for PCC bottom ash respectively.

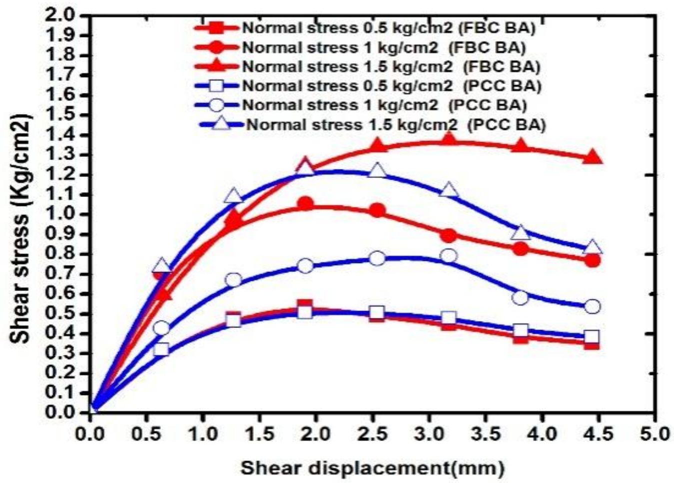

Figure 2. 5 Stress-Strain Diagram for bottom ash of different sources

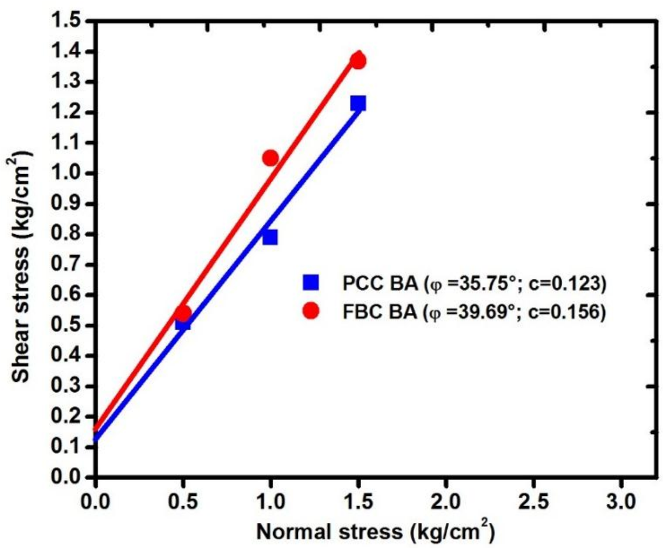

Figure 2. 6 Comparison of shear strength evolves for both FBC and PCC bottom ash

More strength value (i.e. more friction angle) was observed due to coarseness and non-porous structure of FBC bottom ash although cohesion is more. In spite of the wider particle size range variation between FBC and PCC bottom ash as shown in particle size distribution graph (Figure 2.3), due to the presence of hard mullite phase (Figure 2.2), the friction angle difference is not so high. For the same reason, the cohesion value of PCC bottom ash is less compared to FBC bottom ash, where the possibilities of generation of fines are more during loading.

Being cohesionless, non-plastic materials, bottom ash exhibits all their shear strength to the frictional component. Due to very high shear strength in bottom ash, it could be used in the field where bearing capacity, slope stability of embankments, the design of pavements and retaining structures are required.

2.3.2.4 California Bearing Ratio (CBR) test

The load-penetration curve for California Bearing Ratio (CBR), was plotted for different bottom ash as shown in Figure 2.7 which was determined in soaked condition. The load requirement for penetration of 2.5 mm and 5 mm were determined and reported as 195, 315 and 315, 655 kg respectively for PCC as well as FBC bottom ash. The ratio of experimental load to standard load (i.e. 1370 kg for 2.5 mm and 2055 kg for 5 mm penetration) was calculated and the least values which is known as CBR, was found as 22.92% for FBC bottom ash and 14.23% for PCC bottom ash.

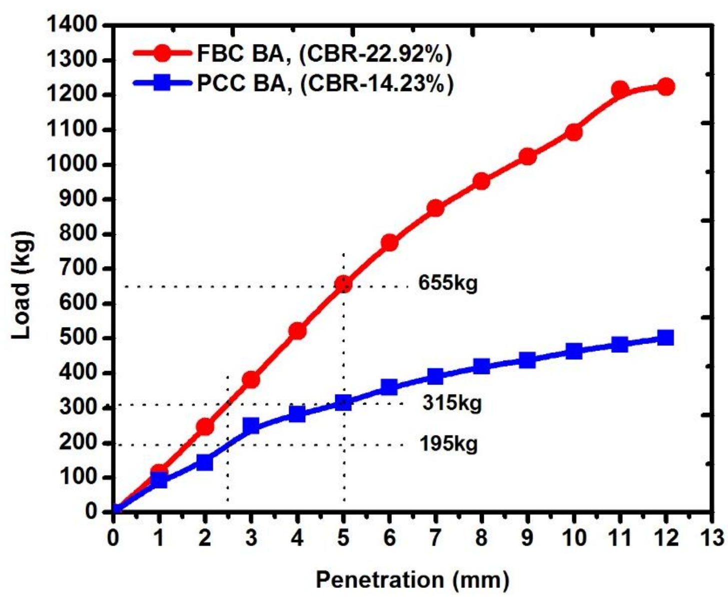

Figure 2. 7 CBR Test graph of FBC and PCC bottom ash

The calculated CBR value for FBC bottom ash was found higher (22.92%) than PCC bottom ash (14.23%) due to its coarser nature. This quality renders FBC suitable for use as sub-base materials in the construction of pavements. Mostly all design charts for the road foundations are prepared considering the CBR value for the subgrade. Therefore, FBC bottom ash will be the best choice compared with PCC bottom ash.

The stronger subgrade (the high CBR value) requires compact design for road and pavement construction. It gives a considerable cost saving. On the other hand, if CBR value is low, then a suitable thicker road pavement is required which will not be deformed, causing the failure of road pavement. Soil having <15% CBR value is not practical to build a layer of making sub base and due to this reason, PCC would not be suitable subgrade material for road construction. In such case, it is necessary to improve this value either by capping or increasing the thickness of the sub-base. For subgrades with CBR values of 15% and above the sub-base should have a standard thickness of 150 mm, a value determined as the minimum practical for spreading and compaction. Therefore, subgrades made with FBC bottom ash may be less expensive.

2.3.2.5 Permeability

The permeability data for both types of bottom ash were calculated from the performed experiments by both constant as well as variable head methods respectively are shown in Table 2.3. Due to porous popcorn like structure of PCC bottom ash, permeability is more than FBC bottom ash, although FBC bottom ash is coarser in nature. The understanding of this property is very useful in solving problems regarding yield of water-bearing strata, seepage through earthen dams, the stability of earthen dams, and embankments of canal bank which is affected by seepage, settlement, etc. Bottom ash having high permeability like PCC, cannot be more efficiently used as liner materials in waste containment structures and as an additive in the construction of actual seepage cutoffs like impervious blankets and cores in water retaining earth structures.

Table 2. 3 Permeability of FBC and PCC bottom ash

Materials	Coefficient of Permeability (cm/sec)	
	Variable head	Constant head
FBC bottom ash	3.196×10^{-3}	2.912×10^{-3}
PCC bottom ash	6.675×10^{-3}	6.825×10^{-3}

2.3.2.6 Compressibility and consolidation

Figure 2.8 shows the changes of voids ratio with respect to the applied pressure in one-dimensional compression curve of ash samples. In the case of FBC bottom ash, voids ratio decreases to a lesser extent at high pressure than PCC bottom ash. In the case of PCC bottom ash, due to porous, popcorn like structure at higher load void ratio decreased drastically. It is due to the degradation of porous structure into fines. Whilst it was not degraded in the case of FBC bottom ash due to its solid structure resulting in more compacted dense structure. It is occurred mainly by redistribution of particles inside the inter-particle spaces.

From Figure 2.8, the value of compression index (c_c) was calculated by taking the ratio of void ratio (Δe) by Log pressure ($\Delta \log \sigma$) for both bottom ashes. The intercept is indication of the void ratio (e), whereas the slope is known as the compression index (c_c) which was determined by the linear curve fitting method directly from the plot. The values (c_c) were reported as 0.0242 and 0.0127 for PCC and FBC bottom ash, respectively. PCC bottom ash having high compression index indicates the presence of porous structure. Therefore, the decrease in volume to a greater extent was observed in PCC bottom ash by increasing the compressive force as compared to FBC bottom ash.

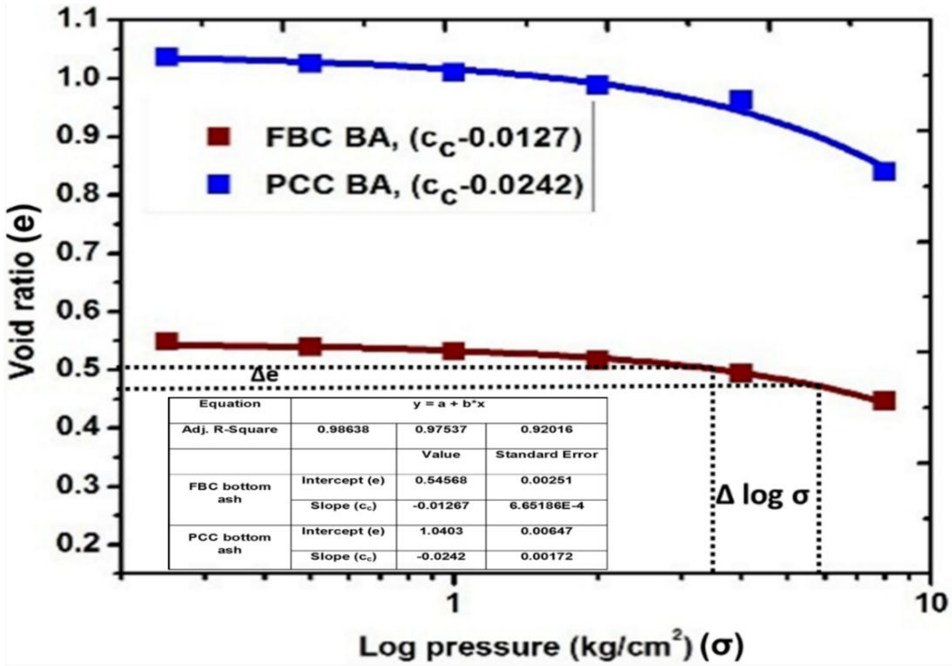

Figure 2. 8 Void ratio variation with pressure

2.3.2.7 Bed Filter Suitability

Sand is widely used as a bed filter material for construction of ash dykes (Figure 2.9). Therefore, for checking the bed filter material suitability of different bottom ashes as compared to sand, the particle size analyses of different bottom ashes along with pond ash and river sand were determined. Due to the extra coarseness, FBC bottom ash particle size was re-graded. The particle size of re-graded FBC bottom ash, PCC bottom ash, pond ash and river sand is shown in Figure 2.10.

From the particle size graphs (i.e. Figure 2.3 & 2.10), percent passing by 75 microns size as well as D_{10}, D_{15}, D_{85} and D_{90} values was determined as listed in Table 2.4.

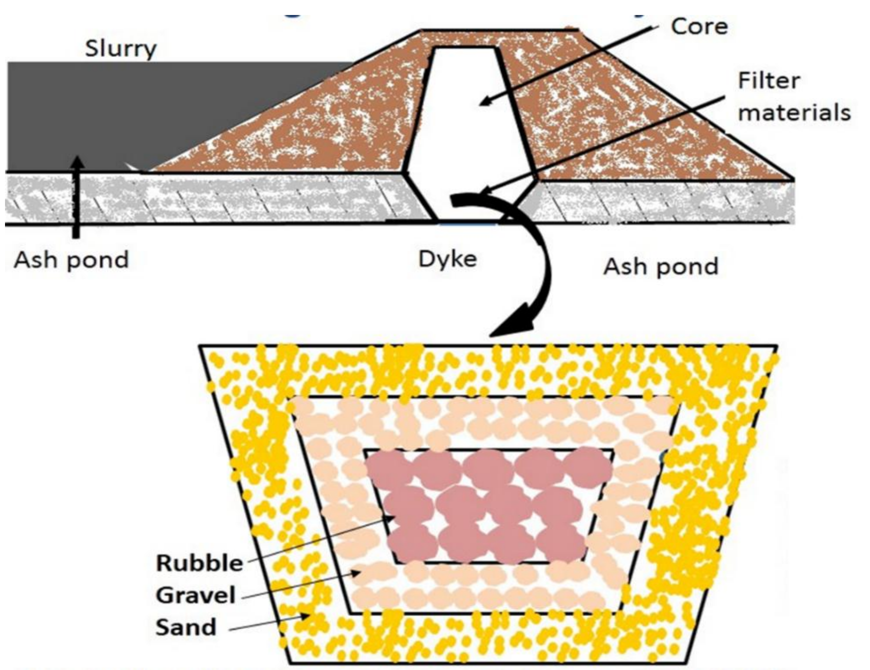

Figure 2. 9 Void ratio variation with pressure

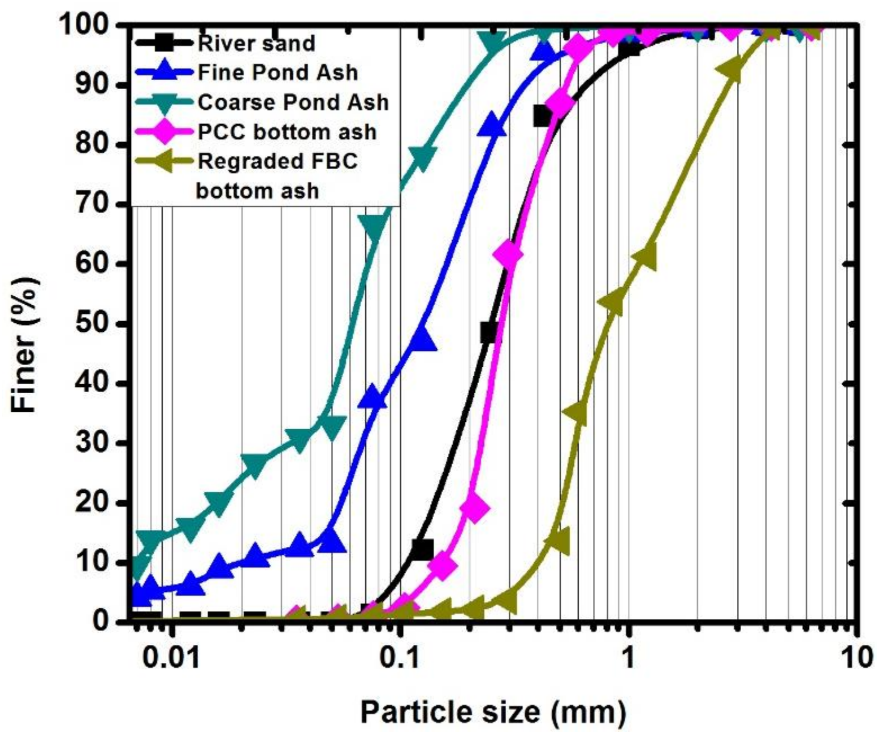

Figure 2. 10 Particle size graph of different bottom ash, pond ash, and sand, tested in laboratory

Table 2. 4 Passing by 75 microns sieve as well as D_{10}, D_{15}, D_{85} and D_{90} values of materials

Parameters	River sand	Re-graded FBC bottom ash	PCC bottom ash	Coarse pond ash	Fine pond ash
D_{10}	0.109	0.397	0.149	0.007	0.019
D_{15}	0.200	0.540	0.002	0.010	0.040
D_{85}	1.70	2.50	0.45	0.28	0.14
D_{90}	2.30	2.75	0.53	0.32	0.19
Passing 75µm	1.60	1.04	1.08	23.20	71.20
Category	4	4	4	3	2

The data of particle size for different pond ash of India, reported by various authors were collected and plotted in the Figure 2.11(Mohanty and Patra, 2015; Patil and Kulkarni, 2015; Sarkar et al., 2012; Satyanarayana et al., 2013; Singh et al., 2015; Vijayasri et al., 2015).

From the graph, the values of percent passing by 75 microns as well as D_{10}, D_{15}, D_{85} and D_{90} were determined and listed in Table 2.5.

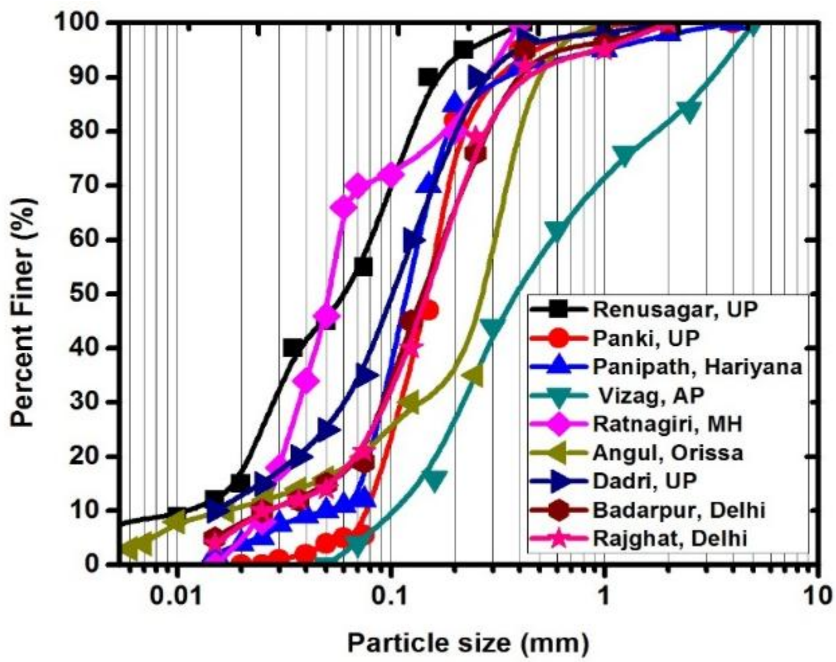

Figure 2. 11 Particle size graph of different pond ash of India reported in literature

Table 2. 5 Passing by 75 microns as well as D_{10}, D_{15}, D_{85} and D_{90} values of different pond ashes

Source of Pond Ash	**Renusagar, UP**	**Panki, UP**	**Panipath, HAR**	**Vizag, AP**	**Ratnagiri, MH**	**Angul, Orissa**	**Dadri, UP**	**Badarpur, Delhi**	**Rajghat, Delhi**
References	Vijayasri, et al, 2015	Mohanty & Patra, 2015		Satyanarayan et al, 2013	Patil & Kulkarni, 2015	Singh et.al, 2015	Sarkar, et al, 2012		
D_{10}	0.011	0.076	0.050	0.101	0.025	0.018	0.015	0.024	0.024
D_{15}	0.019	0.086	0.072	0.109	0.028	0.039	0.024	0.049	0.049
D_{85}	0.141	0.257	0.230	2.470	0.220	0.438	0.230	0.328	0.330
D_{90}	0.164	0.312	0.342	3.150	0.267	0.487	0.273	0.399	0.427
Passing 75µ	56.68	8.87	16.53	4.49	69.09	20.91	36.24	19.09	22.74
Type	2	4	3	4	2	3	3	3	3

As per different criteria mentioned in the standard IS:9429, (shown in Table B.1-B.3 of Appendix-B) the both bottom ashes were compared with respect to conventional bed filter material (i.e. river sand), and results are given in Table 2.6 (IS 9429, 1999). Simultaneously for comparison point of view, the results of both types of bottom ash along with different pond ash reported in the literature were also included in Table 2.7.

Table 2. 6 Filter material suitability of sand as well as bottom ash with respect to coarse and fine sand

Filter material	**River sand**		**FBC bottom ash**		**PCC bottom ash**	
Base material	Coarse Pond Ash	Fine Pond Ash	Coarse Pond Ash	Fine Pond Ash	Coarse Pond Ash	Fine Pond Ash
Criteria 1	S	S	S	S	NS	NS
Criteria 2	S	S	S	S	S	S
Criteria 3	S	S	S	S	S	S
Criteria 4	S	S	S	S	S	S
(NS-Not Satisfied; S-Satisfied)						

Table 2. 7 Filter material suitability of different bottom ashes with respect to various pond ash

Filter material	FBC Bottom Ash									PCC Bottom Ash								
Source of pond ash	Renusagar, UP	Panki, UP	Panipath, HAR	Vizag, AP	Ratnagiri, MH	Angul, Orissa	Dadri, UP	Badarpur, Delhi	Rajghat, Delhi	Renusagar, UP	Panki, UP	Panipath, HAR	Vizag, AP	Ratnagiri, MH	Angul, Orissa	Dadri, UP	Badarpur, Delhi	Rajghat, Delhi
References	Vijayasri, et al, 2015	Mohanty & Patra, 2015		Satyanarayan et al, 2013	Patil & Kulkarni, 2015	Singh et.al, 2015	Sarkar, et al, 2012			Vijayasri, et al, 2015	Mohanty & Patra, 2015		Satyanarayan et al, 2013	Patil & Kulkarni, 2015	Singh et.al, 2015	Sarkar, et al, 2012		
Criteria 1	S	S	S	S	S	S	S	S	S	NS	NS	NS	NS	NS	NS	NS	NS	NS
Criteria 2	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Criteria 3	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Criteria 4	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

(NS-Not Satisfied; S-Satisfied)

It can be concluded that only FBC bottom ash fulfills all the criteria individually. Therefore, it is suitable to be used as a filter material with respect to the base material of both type of pond ash (coarse as well as fine). The comparison of both types of bottom ash along with pond ash reported in the literature for the different regions of India also proves the suitability of FBC bottom ash for making dam’s embankments, etc. successfully, which could not be possible in case of conventional PCC bottom ash.

2.4 Conclusions

The main findings from this study on the characterization of physicochemical and geotechnical properties of raw materials are summarized as follows:

1. Iron ore slime and both type of bottom ashes (FBC as well as PCC) have silica, alumina and iron oxide which could be utilized as a potential material for manufacturing useable

products and not only for the land filling purposes. The major constituents of iron ore slime are hematite, silica, alumina etc. having very fine size which could be utilized as a binding material for manufacturing of light weight bricks with coarser particle size like bottom ash. Due to the presence of higher content of iron in the iron ore slime, it could be extracted through pyrometallurgical routes.

2. The presence of silica and alumina in the free states in FBC bottom ash as compared to PCC bottom ash, could be utilized for making the building bricks through geopolymerization. For the same reason, the degree of geopolymerization will be higher in less time in case of FBC bottom ash as compared to PCC bottom ash. Therefore, the preparation of geopolymer products could be feasible at a lower cost.
3. From the geotechnical experiment, it was found out that the bearing strength particularly the shear strength of FBC bottom ash is better than the PCC bottom ash which suggests its possible use for sub-layers in the pavements and road. FBC bottom ash fulfilled all the criteria of materials, required for filter design. That's why it is found to be suitable for the application as a filter material in ash dyke. It will be the source for major utilization of wastes as a geo-material fruitfully.