Bottom Ash as an alternate Filter material in construction of Ash Dyke embankment- A successful application

Vinod Kumar Mauriya

Dy.General Manager(PE-Civil), NTPC LTD, EOC Noida, Gautambudh Nagar, India-201301
vkmauriya@ntpc.co.in

Abstract. As per practice, ash dyke embankments are used for disposal of ash generated from thermal plants. Based on the type of the soil available for the embankment construction, mostly, it is a homogeneous section with internal drainage arrangement of sand chimney and sand blanket. The dyke embankments are designed as water retaining structures as per IS: 7894, 12169 and 9429. For internal drainage in these embankments, natural river sand or crushed machine sand is generally used. However, in recent years some State Pollution Control Boards and Honourable NGT have taken exception to use of natural sand. Further, at some project sites sand is not available in the vicinity and is to be borrowed from far off sources making it unviable from both schedule of construction and cost considerations.

The above situations necessitated to explore alternate filter material for dyke construction. The suitability of bottom ash as filter material with respect to base soil has been established by NTPC for its various plants. Based on laboratory tests, it was found that bottom ash possess the required filter ability, internal stability, drainage capacity, self healing properties and does not segregate. Accordingly, bottom ash has been adopted as an alternate filter material in internal drainage system of dyke embankment of various plants of NTPC. The above have been successfully implemented and found to be safe under operating phase. This use of bottom ash as a filter material has also saved the time and cost over runs and most importantly is echo friendly too.

Keywords: Dyke embankment, Bottom ash, Filter material, Base material, Raising.

1 Introduction

Ash is a non-degradable, non-perishable, inert material, which could be used even after hundreds of years. When coal can be used after millions of years of its formation, its by-product can also be used after a long time gap. The ash generated from the power plants is disposed-off in the Ash ponds. Unlike water reservoir, the dyke embankments for ash pond are generally not constructed upto ultimate height in one go and initially constructed upto a limited height with provision of subsequent raising as per requirement. Ash pond is divided into lagoons and provided with garlanding arrangements for changeover of the ash slurry feed points for even filling of the pond and for effective settlement of the ash particles.

Ash disposal areas are designed as multi-lagoon systems with minimum two storage lagoons and one over-flow lagoon (OFL). Having two or more storage lagoon facilitates sequential raising of lagoons by putting one lagoon for ash filling while the other lagoon is used for raising its dyke. OFL helps in controlling the effluent quality of the supernatant, which is recycled back to plant for making ash slurry. The typical cross-section of ash slurry storage lagoon and OFL is shown in the following Fig.1.

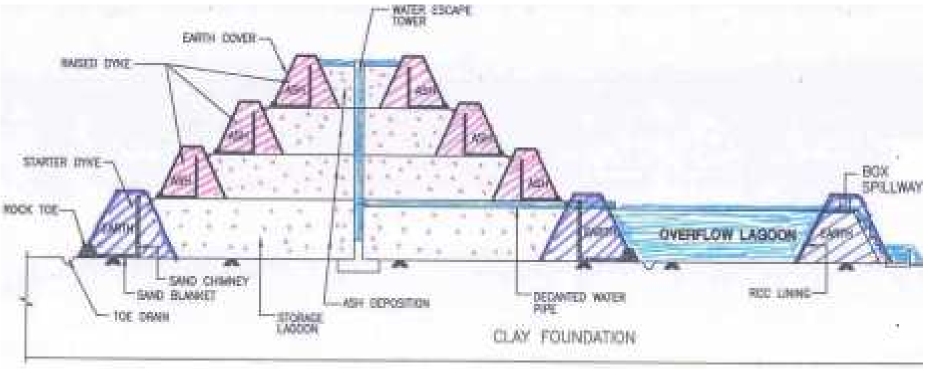

Fig. 1. Typical cross-section of storage lagoon and OFL

2 Dyke embankment

Dyke embankment is a retaining structure to contain ash slurry (or continuous placement of unused ash to ensure uninterrupted operation of the thermal plant) and settled ash (till it is used for any beneficial purpose). The embankment of the dyke is designed with sufficient strength and safety measures to avoid breaching at any point of time. The upstream slopes of the embankment is protected from wave action using brick lining and downstream slope is protected from rain cuts using stone pitching/ turfing. Suitable capacity Spillways are provided to release the excess rain-water and maintain adequate free board to avoid any chance of overtopping of dyke.

2.1 Internal drainage system

The basic requirements for design of dyke embankments are to ensure; safety against stability, safety against internal erosion and safety against overtopping. To ensure safety against internal erosion; internal drainage system is provided as indicated in Fig.2. A typical section of upstream raising with internal drainage system is indicated in following Fig. 2.

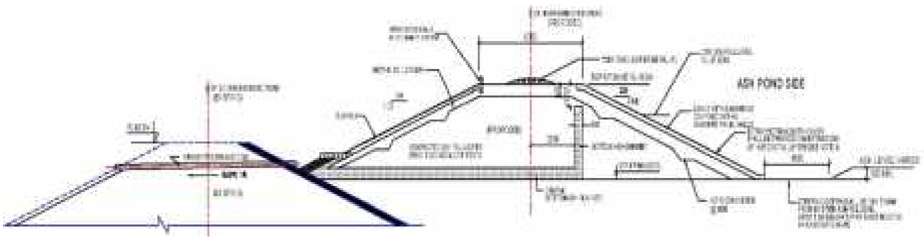

Fig. 2. Typical section of upstream raising

As the dyke embankment constructed with earth/ ash is a porous structure, it allows a gradual movement of water through its pores as can be seen in the following Fig. 3(a). In order to keep the downstream slope dry and stable, internal drainage arrangement in the form of chimney and blanket are provided to intercept the seepage, if any and channelize the same through the rock toe and toe drain as presented in following Fig. 3(b).

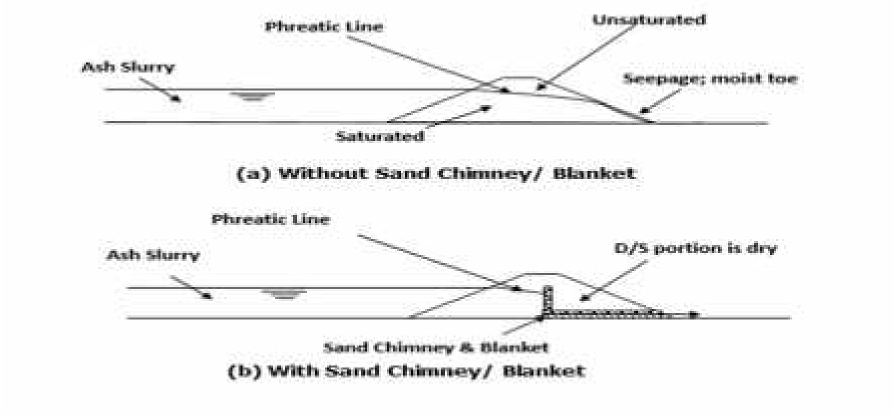

Fig. 3(a) & 3(b). Dyke embankment with and without internal drainage arrangement

2.2 Filter Material

In the internal drainage system of dyke embankments, natural river sand or crushed machine sand (M-sand) is generally used. However, in recent years some State Pollution Control Boards and Honourable NGT have taken exception to use of natural sand. Further, at some plant sites natural river sand/ M-sand is not available in close vicinity of project and is to be borrowed from far off sources making it unviable from both schedule of construction and cost considerations.

The above situation have been affecting dyke construction and in turn affecting generation due to non-availability of dyke linked to non-availability of sand. To tide over the crises NTPC have got the bottom ash samples tested with respect to base soil as pond ash for its various plants to explore use as an alternate of sand filter in dyke construction works. Out of the total ash generated, generally the percentage of bottom ash is about 20% and that of fly ash is about 80%. Pond ash is a combination of both bottom ash and fly ash and therefore contains much higher percentage of fines than bottom ash alone.

2.3 Filter Criteria

The evaluation of suitability of filter material for filter ability, internal stability, drainage capacity and self healing with respect to base material is checked in line with filter criteria specified in IS:9429.

3 Pond ash and Bottom ash

Fly ash is extracted from Electro Static Precipitator (ESP), conveyed to fly ash silos, mixed at slurry tanks and pumped to ash disposal areas using centrifugal pumps. Whereas, after coal combustion, the coarser fraction of ash comes at bottom of Boiler Furnace and crushed by clinker grinders to become bottom ash. These are generally in the range of sand size particles, which is very hot and therefore collected in water impounded hoppers and thereafter taken to slurry tanks and pumped to ash disposal areas using centrifugal pumps. Generally, the percentage of fines (particle size smaller than 75 μ) in pond ash vary from 40% to 85% since pond ash is expected to contain much more fines than the bottom ash. The bottom ash is coarser than the fly ash and the percentage of fines (particle size smaller than 75 μ) in bottom ash vary from 0% to 5%. The schematic view of a thermal power plant indicating the process of generation of fly ash and bottom ash can be seen in following Fig. 4.

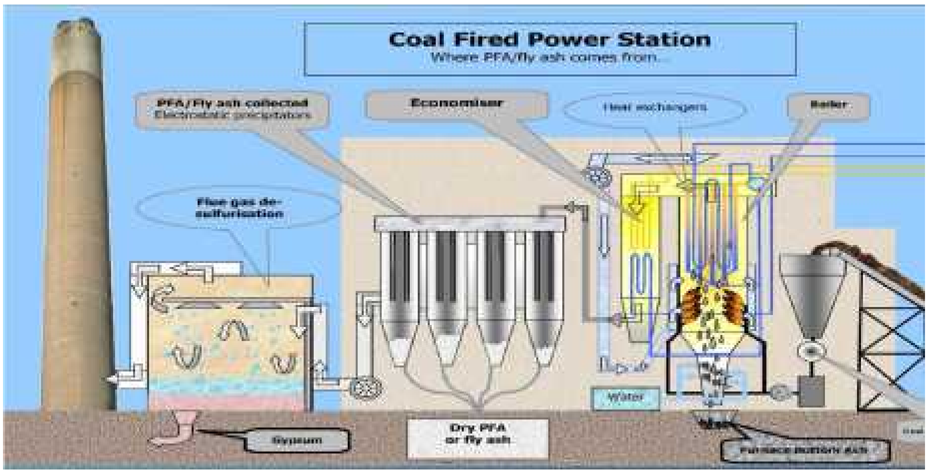

Fig. 4. Schematic view of a thermal plant indicating the process of generation of fly ash and bottom ash

3.1 Production and requirement of Bottom ash

On an average, the production of bottom ash from one typical 500 MW unit is in the range of about 15,000-18,000cum/ month, depending upon the coal/combustion/heat treatment etc. The requirement of bottom ash as a filter material in raising works is not continuous and the quantity required is in the range of 50,000-60,000 cum/year for each dyke raising, which will be in the tune of 4000-5000 cum/month. The sample bottom ash is shown in Fig. 5, which is obtained through clinker grinder as indicated in Fig.6.

Fig. 5. Bottom ash sample

Fig. 6. Typ. Clinker grinder

4 Engineering properties of Pond ash and Bottom ash

As per the IS Classification System, the Pond ash may be classified as equivalent to a low plastic silt or ML type soil. The lab permeability of pond ash is observed to be in the range of 10^{-5} cm/sec to 10^{-6}cm/sec where as that of Bottom ash is observed to be in the range of 10^{-3} cm/sec to 10^{-4}cm/sec. The engineering properties of pond ash (base material) and bottom ash (filter material) of some of NTPC plants is presented in following Table. 1.

Table. 1. Engineering properties of pond ash (base material) and bottom ash (filter material)

NTPC Plants	Pond ash					Bottom ash				
	MDD (KN/m^3)	c (KPa)	c' (KPa)	Ø	Ø'	MDD (KN/m^3)	c (KPa	c' (KPa)	Ø	Ø'
Korba, April’89	10.02	43.50	0.00	33^0	33^0	-	-	-	-	-
	8.4 (In-situ)	17.00	0.00	29^0	30^0	-	-	-	-	-
SSTPS, Jan'95	13.30	0.00	0.00	31^0	28^0	13.59	0.00	0.00	32^0	31^0
TTPS, Aug'10	11.12	20.00	-	18^0	-	-	-	-	-	-

5 Evaluation of Suitability of Bottom ash as filter material

5.1 Methodology for testing

The following laboratory tests on bottom ash (filter material) as well as pond ash (base material) are required to be carried out each on minimum five (05) samples:

i) Grain size distribution
ii) Density (Bulk & Dry)
iii) Permeability test (Laboratory)
iv) Specific Gravity
v) Atterberg limits

All the above-mentioned tests were carried out in accordance with the recommendations of the relevant Indian Standards and other standard procedures. The grain size distribution is plotted on semi-log graph. The values of D_{10}, D_{15}, D_{85}, D_{90} & % passing 75 µ of the bottom ash and pond ash are worked out from grain size distribution curve for further analysis to establish the suitability of bottom ash as filter media w.r.t. pond ash as base material of dyke embankment. The various parameter obtained from grain size analysis of Pond ash is presented in following Table.2 and that of Bottom ash is presented in following Table.3.

Table. 2. Typ. Base material (Pond ash) properties of one of the thermal plant of NTPC

Sample No.	Test on 13.02.14	Test on 26.08.15				
	BHU-1	BHU-1	BHU-2	BHU-3	BHU-4	BHU-5
$D_{15\,(B)}$ mm	0.055	0.055	0.024	0.011	0.016	0.017
$D_{85\,(B)}$ mm	0.4	0.275	0.25	0.13	0.09	0.11
% Passing 75µ	20	23	44	58	77	67
Base Soil Category	Category-3		Category-2			
$((40\text{-}A)x(4D_{85(B)}\text{-}0.7)/(40\text{-}15))+0.7)$	2.068	1.34	-	-	-	-
Average $D_{15(B)}$=	0.0297	mm				

Table. 3. Typ. filter material (Bottom ash) properties of one of the thermal plant of NTPC

Sample No.	FQA-1	FQA-2	FQA-3	BHU-1
$D_{10(F)}$ mm	0.32	0.3	0.18	0.11

$D_{15(F)}$ mm	0.35	0.36	0.24	0.14
$D_{90(F)}$ mm	10	10	10	4.9
% Passing 75µ	0	0	0	2

5.2 Analysis of test results

The grain size analysis of all tested ash samples indicate that the Bottom ash samples possess predominantly fine sand sizes followed by medium sand sizes. The grain size analysis of the Pond ash samples from the different plants indicate that it possess predominantly silt size particles. The plasticity index values of the tested ash samples indicate that all the ash samples (bottom ash and pond ash) possess non-plasticity characteristics. The laboratory permeability tests conducted on the Bottom ash samples indicate that Bottom ash materials possess the pervious drainage characteristics whereas as the Pond ash materials possess the semi-pervious drainage characteristics. It is observed that the material passing 75 µ sieve is less than 5% in the Bottom ash samples which are suitable to be used as filter materials for the construction of the ash dyke raisings. The Pond ash mostly fall under category-2 of base materials with percentage finer than 75 µ in-between 40% – 85%. The filter material suitability analysis shows that the Bottom ash samples of different NTPC plants satisfies the filter criteria as recommended by IS 9429. A typical filter material suitability analysis of one of the NTPC plant is presented in following Table. 4.

Table. 4. Typ. Suitability analysis of filter material (Bottom ash) w.r.t. base material(Pond ash)

Filter Criteria	Parameter	FQA-1		FQA-2		FQA-3		BHU-1		Remarks
For Min. $D_{15(F)}$, $D_{15(F)}/D_{15(B)} > 5$	$D_{15(F)}/D_{15(B)}$	12	PASS	12	PASS	8	PASS	5	PASS	-
Min $D_{15(F)} > 0.1$mm Max $D_{15(F)} \leq 0.7$mm	$D_{15(F)}$ (mm)	0.35	PASS	0.36	PASS	0.24	PASS	0.14	PASS	For Base Soil-Category-2
Min $D_{15(F)} > 0.1$mm Max $D_{15(F)} \leq ((40-A)x(4D_{85(B)}-0.7)/(40-15))+0.7)$	$D_{15(F)}$ (mm)	0.35	PASS	0.36	PASS	0.24	PASS	0.14	PASS	For Base Soil-Category-3
Self Healing	% passing 75µ	0	PASS	0	PASS	0	PASS	2.0	PASS	-
Limits of $D_{10(F)}$ and $D_{90(F)}$ for Preventing Segregation	For $D_{10(F)}$<0.5mm Max. $D_{90(F)}$<20mm	10	PASS	10	PASS	10	PASS	4.9	PASS	-

As per above analysis, all samples of Bottom ash are having $D_{15(F)}$>0.1mm, thus posses the required filter ability. Further, the corresponding ratio of $D_{15(F)}/D_{15(B)avg}$ are more than 5 for all bottom ash samples thus material posses the adequate drainage capacity. All samples of Bottom ash are having percentage of material passing 75μ < 5%, thus the material may self-heal in the event of any cracks formed in the filter zone due to differential settlement. The limits for preventing segregation is also fulfilled in bottom ash.

6 Conclusion

In the thermal power projects, huge quantity of ash is being produced as a result of burning of coal and this ash is to be disposed off as expeditiously as possible to avoid piling up at the plant. The utilization of ash is strongly related to economy of its use, which changes with time. There may not be users in sight today, but after some time there could be bulk users. The most economic and commonly used method to dispose ash is by hydraulic transport, in the form of slurry, to the ash disposal areas. At the disposal areas, storage space is created by constructing dyke embankments all around, within which ash particles will be allowed to settle and the decanted water is allowed to escape.

The suitability of bottom ash as filter material with respect to pond ash as base material has been established by NTPC for use in dyke embankment of its various plants. Based on laboratory tests, it is established that bottom ash possess the required filter ability, drainage capacity, self healing properties and does not segregate. The above have been successfully implemented and found to be safe under operating phase. During operating phase, it is also observed that cracks developed in the filter zone due to differential settlements do not stay open due to self healing property available in bottom ash. The bottom ash is a free issue material and contributes in ash utilisation. It's use reduces construction time of the dyke embankment and ensures early availability of lagoons for ash disposal to meet the operational requirement. This also saves time and cost over runs due to unexpected delays in procurement of natural sand and most importantly it is eco-friendly too.

References

1. Shenbaga R. Kaniraj[1] and V. Gayathri[2]: Permeability and Consolidation Characteristics of Compacted Fly Ash, Journal of Energy Engineering, ASCE (April 2014)
2. DOC.NO. QS-01-PEC-W-02: NTPC Guidelines for design of ash dykes in the ash disposal area, Noida (February 2018)
3. IS 9429: Code of practice for drainage system for earth & rock fill dams, New Delhi (1999)
4. Naresh D.N.: Management of Ash Disposal, IGC-2010, IIT Bombay (2010).