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Estimation of Fly ASH Availability in a Thermal Power Plant for Cement Manufacturers

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Abstract

The Indian coals are having 25 to 45% ash content and huge quantity of fly ash is being generated every day in the Indian thermal power plants. The fly ash so generated are being disposed by dry or wet mode from the power plant. The fly ash disposed in dry mode is lifted by the cement manufacturers and the fly ash disposed in wet mode is unattended. Most of the quantity of fly ash is collected in the ESPs. The particle size of fly ash collected in ESPs is finer compared to the fly ash collected in other parts of the power plant. For this reason the cement manufacturers prefer the fly ash from ESPs. The quantity of fly ash collected in the ESPs is not directly measurable on everyday basis as there are no well proven instrumental methods. Also the quantity of fly ash collected in ESPs fluctuates every day due to the varying load factor and coal quality. However, it is important to estimate the quantity of fly ash collected by ESPs on everyday basis so that the proportion of fly ash lifted by the cement manufacturers and the fly ash sent to the ash pond will be known. Presently power plants do not have a method to estimate the exact availability of fly ash and it is being theoretically calculated from the design value that the 80% of the total ash is fly ash and in that a fixed proportion (about 70% of total fly ash generated) is collected in the ESPs. However, the actual generation of fly ash would be different and this is influenced by the type of coal used, fineness of the input coal particles, boiler operating conditions, load factor, age of the power plant, etc. This uncertainty leads to disputes between cement manufacturers and the utility if there is a penalty clause in the agreement for not completely lifting the available fly ash (as theoretically calculated by the utility). In view of this it is imperative to formulate acceptable methods for determining the actual quantity of fly ash collected in the ESPs on daily basis. In the present work, a simple methodology was developed to quantity the average fly ash collected in ESPs in a 210 MWe coal fired power plant on every day basis through site measurements and routine power plant data. The amount of fly ash disposed in dry and wet mode has also been estimated through this method.

Keywords: Ash Disposal in Power Plants, Fly Ash, Cement Plants, Coal based Power Plants

1. Introduction

Fly ash is a by-product of coal combustion in thermal power plants. It has popular uses in engineering and construction such as concrete production, corrosion control, embankments, waste stabilization and solidification, to mention a few[1–4]. In addition it has been proved that the fly ash can be used in many novel applications like the fabrication of silica aero gel[5], carbon nanotubes[6], recovery of Rare Earth Elements[7], etc. The Indian coals used for power generation are having the ash content varies between 25 to 45%. In India the fly ash generated in the coal fired power plants is predominantly utilised by cement manufacturers. Fly ash generated in the power plant is separated from flue gas by Electro Static Precipitators (ESPs) and disposed in both dry and wet modes. While the dry fly ash is directly lifted by the cement manufacturers from the silos, the one disposed in the wet mode is sent to the ash pond and this portion is mostly unattended. The ash ponds cause ecological problems and cause severe distress to the local communities[8]. Due to this reason the power plants will take all the measures to dispose the fly ash in dry mode which can be directly lifted by the cement manufacturers and only in unavoidable situations, the fly ash is disposed in wet mode.

Generally the fly ash is constituting approximately about 80% of the total ash generated in the power plants.

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However, the exact value may vary based on the type of coal used, plant operation procedures and the life spent by the boiler unit. The flue gas generated in the boiler consisting of fly ash travels through economiser, Air Pre-Heater (APH), connecting ducts and Electrostatic Precipitators (ESP) and finally let out through the chimney to the environment. Most of the fly ash in the flue gas is collected in the ESP and part of the fly ash is collected in the hoppers associated with the economiser, air preheater and connecting ducts. The fly ash collected in the hoppers of economiser, APH and connecting ducts are coarser in nature compared to the fly ash collected in the ESPs. The cement manufacturers generally prefer the ash from ESPs due to its fineness. Due to this reason, the cement manufacturers preferably lift fly ash disposed from ESP. The quantity of fly ash collected in the ESPs makes the actual availability of fly ash to the cement manufacturers.

The quantity of fly ash collected at the ESPs is fluctuating every day and this is due to many reasons that include, the load factor, varying coal quality, boiler operating conditions, etc. The estimation of the quantity of fly ash collected in the ESPs is challenging at power plant level due to the above reasons and also there are no well proven instrumental methods to measure the quantity of fly ash collected in the ESPs. Also, in the event of mechanical issues like chocking of pipes or mechanical problems associated to the dry fly ash extraction devices, the fly ash is forced to be disposed in wet mode. There are no well-defined procedures to estimate the fly ash disposed through wet mode.

Presently power plants estimate the availability of fly ash through theoretical calculations. It is calculated from the design value that the 80% of the total ash is in the form of fly ash and in that a fixed proportion (about 70% of total fly ash generated) is collected in the ESPs. However, the actual generation of fly ash would be different and this is influenced by the type of coal used, fineness of the input coal particles, boiler operating conditions, load factor, age of the power plant, etc. This uncertainty leads to disputes between cement manufacturers and the utility if there is a penalty clause in the agreement for not completely lifting the available fly ash (theoretically calculated by the utility). In view of this it is imperative to formulate acceptable methods for determining the actual quantity of fly ash collected in the ESPs on daily basis.

In the present work, a simple methodology was developed to quantity the average fly ash collected in ESPs in a 210 MWe coal fired power plant on every day basis through site measurements and routine power plant data. The amount of fly ash disposed in dry and wet mode has also been estimated through this method.

2. Methodology

The selected 210 MWe power plant disposes the fly ash in both wet and dry mode. The fly ash is evacuated from the ESP through suction method and this will be diverted either to the dry ash silos in dry mode or to the ash pond in wet mode from a junction point. The fly ash sent in dry mode to the dry ash silos are lifted by trucks from cement manufacturers on every day basis. The amount of fly ash lifted is precisely measured by a calibrated weighing bridge by taking the weight of the empty truck and the same truck with ash load. The fly ash sent in wet mode to the ash pond goes as a waste and unattended by cement manufacturers.

The study carried out at the power plant for the period of 11 days and the data collected from the power plant are described as below:

2.1 Ash Level Measurement in the Silo

The level of dry fly ash in the silo was measured at 0:00 hrs of every day for a period of 11 days. This gives information on the quantity of ash available in the silo at that particular time. The quantity in tonnes is calculated from the volume of the cylindrical silo and the generalised bulk density of fly ash. The capacity of dry ash silo is 750 Tons. The shape of the silo is a uniform cylinder with equal area from bottom to top. The height of the silo is 13.5 m and the diameter is 9.15 m. The drawing of the silo is given in Figure 1. The ash availability per meter in the silo is 55. 56 Tons as per the design. The ash level was measured by lowering a rope connected to a weight from the top of the silo. The weight was enough to keep the rope straight. When the weight touched the ash level in the silo, the length of the rope lowered was measured and this was recorded as the height of empty space above ash level in the silos. The height of the ash occupied in the silo was then obtained by deducting the height of empty space from the total height of the silo. Multiplying 55.56 T with the height of the ash occupied in the silo yielded the amount of ash present in the silo at 0:00 hrs.

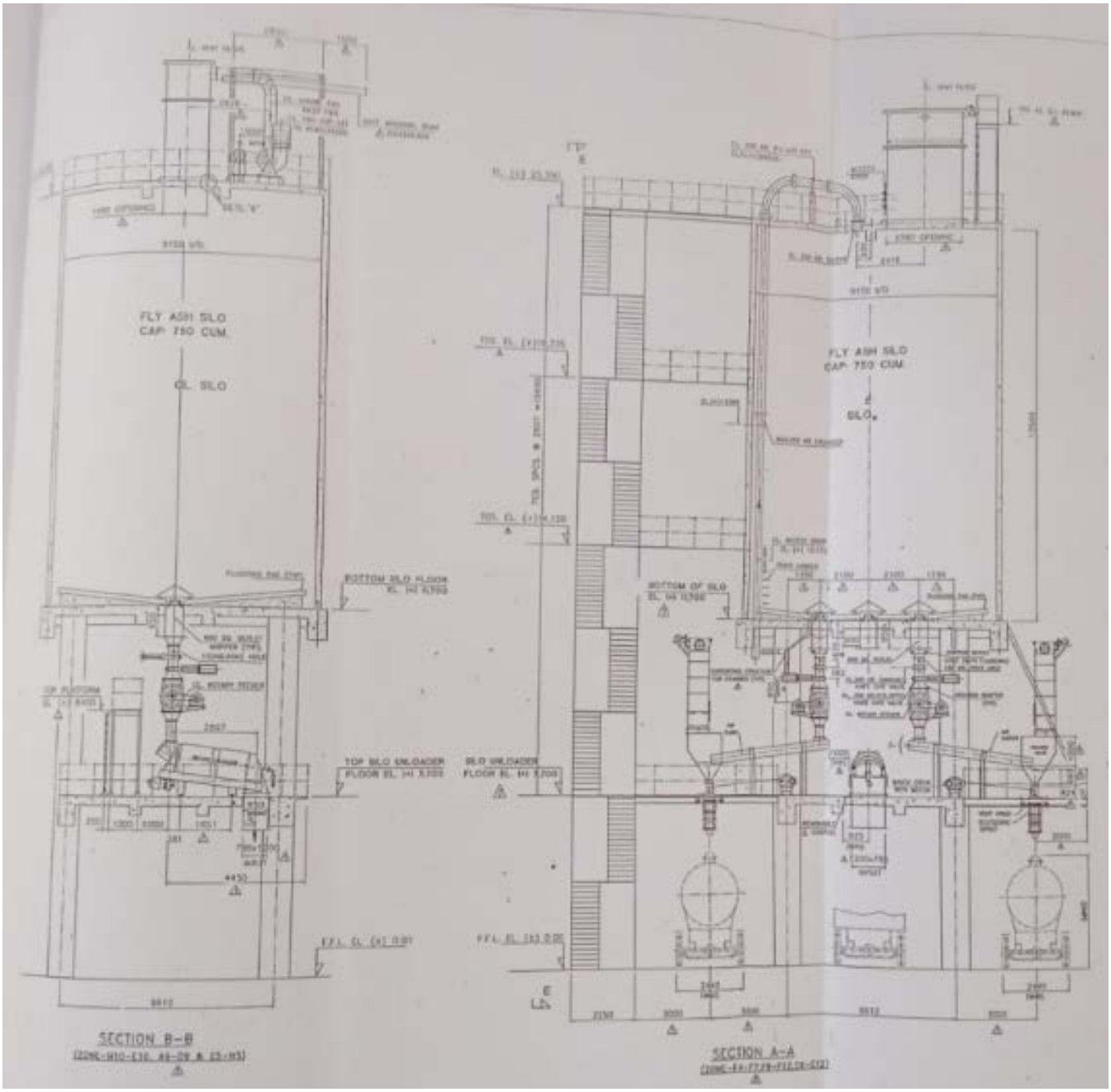

Figure 1. Drawing of dry ash silo.

2.2 Amount of Ash Lifted Every Day

Between 0:00 hrs to 0:00 hrs of every day, the ash lifted from the silo was calculated by adding the amount of ash lifted by each truck in the above duration. The amount of ash lifted by each truck was obtained from electronic weighing bridge data.

2.3 Fly Ash Evacuation Running Hours

The running hours of the evacuation of fly ash from ESPs through dry and wet mode and ideal operating hours were recorded in the log book by the Ash Handling Department of the Power Plant. These obtained data were used for calculating the amount of fly ash sent in wet mode by the procedure as given in the subsequent sections.

2.4 Estimation of Total Ash Generation

The total ash generated for a particular day in the power plant boiler was estimated from the parameters like the quantity of coal consumed in that day, property of the coal consumed on "as fired basis" (as fired coal is the coal just entering the boiler system), the quantity of mill rejects generated and the ash content of the mill rejects for that day. These data pertaining to the whole exercise period was obtained from the Fuel Management and Coal Handling divisions of the power plant. The determination of the quality of as fired coal is the routine procedure followed by the Fuel Management division of the power plant. The as fired coal is sampled from the conveyor belts leading to the bunkers on round the clock basis at equal intervals. The collected coal samples on 24-hour basis for a particular day is made as a composite and reduced as per IS: 436 method for assessing the total moisture, inherent moisture, volatile matter, ash content, fixed carbon and gross calorific value. The mill rejects are collected, sampled in the same way as given above and the quality with respect to proximate parameters is determined. The coal consumption data was obtained from the Coal Handling Plant (CHP). The CHP estimates coal consumption data on routine basis from RPM (Revolution per Minute) details of the coal feeders of the mills and fine tuning the same with the reconciliation of generation and average calorific value of the station coal for that day.

The strategy of the quantification of fly ash collected in the ESPs based on the site measurements and power plant data is given below:

1. The fly ash from ESPs is evacuated on continuous basis and no fly ash will be retained in ESPs for the duration more than few hours as the non-evacuation is dangerous which may lead to the collapse of ESPs.
2. The ESPs are evacuated through suction process and the suctioned ash either will go to the intermediate hopper in a dry mode or flushed by water on the way and diverted to ash pond. As the suction process is same in both the cases, the rate of evacuation is generally same in both the cases at any instant.
3. The uncertain quantity of fly ash which does not go either to dry fly ash silo or ash pond is negligibly low.
4. The data of ash level measurements before the start and after the completion of ash lifting in a day and the amount of total ash lifted by trucks on that day obtained from weighing bridge details, gives the

Table 1. Ash received in the silo every day

Date	Ash lifted in dry mode by the Trucks (MT)	Ash level measurement in the silo				Quantity of Ash available before and after lifting		Ash added to silos between before and after loading in Trucks (MT)
		Before unloading (m) (Empty above ash)	After unloading (m) (Empty above ash)	Before (m) (Ash height)	Before (m) (Ash height)	Ash quantity available before lifting (MT)	Ash quantity available after lifting (MT)	
Day-1	213.42	9.0	8.5	4.5	5.0	250.20	278.00	241.22
Day-2	287.72	8.5	8.0	5.0	5.5	278.00	305.80	315.52
Day-3	384.29	8.0	8.0	5.5	5.5	305.80	305.80	384.29
Day-4	591.62	8.0	8.0	5.5	5.5	305.80	305.80	591.62
Day-5	614.18	8.0	8.0	5.5	5.5	305.80	305.80	614.18
Day-6	621.74	8.0	10.0	5.5	3.5	305.80	194.60	510.54
Day-7	456.15	10.0	7.0	3.5	6.5	194.60	361.40	622.95
Day-8	698.98	7.0	6.0	6.5	7.5	361.40	417.00	754.58
Day-9	625.28	6.0	6.0	7.5	7.5	417.00	417.00	625.28
Day-10	714.94	6.0	8.0	7.5	5.5	417.00	305.80	603.74
Day-11	460.52	8.0	9.0	5.5	4.5	305.80	250.20	404.92
Total fly ash received in silo for the whole period								**5668.84**

amount of ash received by the silo from the plant during that particular day.

5. The amount of dry fly ash received by the silos for the study period of eleven days and the data on the running hours of fly ash evacuation in dry mode are used as the input for calculating the mass flow rate of fly ash during evacuation.
6. As the rate of evacuation by dry and wet mode is generally same, the reverse calculation of mass flow rate corresponding to the wet mode running hours yields the quantum of fly ash disposed in wet mode. The total quantity of fly ash evacuated in dry and wet mode yields the amount of fly ash collected by the ESPs from the boiler on every day basis.
7. The proportion of the fly ash collected at the ESPs with respect to the total ash generated is calculated from the power plant data collected during the study period.

Table 2. Running hours of ash evacuation in wet and dry mode from ESP.

Date	Wet mode running Hours (min)	Dry mode running hours (min)	Idle hours (min)
Day-1	437.25	762.75	240.00
Day-2	298.75	601.25	540.00
Day-3	336.75	579.25	524.00
Day-4	90.75	870.00	479.25
Day-5	336.75	579.25	524.00
Day-6	6.25	1200.00	233.75
Day-7	337.75	695.00	407.25
Day-8	0.00	1200.00	240.00
Day-9	210.00	1110.00	120.00
Day-10	280.25	919.75	240.00
Day-11	330.50	870.00	239.50
Total	**2665.00**	**9387.25**	**3787.75**

3. Results and Discussions

The details of the ash level measurements in the silos and the ash lifted by the cement manufacturers are given in Table 1.

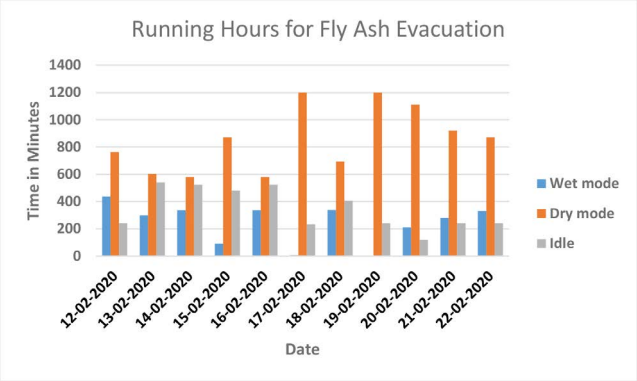

Figure 2. Running hours for the fly ash evacuation from ESPs.

Table 3. Coal consumption, mill rejects and ash generated in the boiler.

Date	Coal quantity (MT)	Coal ash %	Total ash from coal (MT)	Mill Rejects Quantity (MT)	Mill Reject Ash (%)	Ash discarded with Mill Rejects (MT)	Total Ash generated the boiler (MT)
Day-1	2909	38.79	1128.40	20.00	75.13	15.03	1113.38
Day-2	2746	43.21	1186.55	20.00	72.96	14.59	1171.95
Day-3	2871	42.87	1230.80	25.00	68.11	17.03	1213.77
Day-4	2817	39.52	1113.28	34.00	72.67	24.71	1088.57
Day-5	2686	40.85	1097.23	20.00	70.22	14.04	1083.19
Day-6	2794	40.05	1119.00	20.00	73.03	14.61	1104.39
Day-7	2707	38.66	1046.53	20.00	69.53	13.91	1032.62
Day-8	2820	38.88	1096.42	20.00	70.73	14.15	1082.27
Day-9	2971	38.74	1150.97	20.00	72.39	14.48	1136.49
Day-10	2676	40.91	1094.75	20.00	73.30	14.66	1080.09
Day-11	2669	42.37	1130.86	20.00	71.81	14.36	1116.49
Total	**30666.00**	**444.85**	**12394.77**	**239.00**	**789.88**	**171.56**	**12223.21**

The Table 2 gives the details on the running hours of evacuation of fly ash from ESP in both wet and dry mode. The coal consumption and total ash generated per day during the study period is given in Table 3.

The comparative plot on the running hours of wet and dry mode of disposal of fly ash is given in Figure 2.

With the above data the average fly ash collected for a period of 11 days is given in the following table.

3.1 Total Quantity of Parameters Obtained during the Work Period (11 days)

The total quantity of fly ash disposed in dry mode (A) = 5668.84 MT

The total time of evacuation by dry mode (B) = 9387.25 min

The total time of evacuation by dry mode (C) = 2665.00 min

The rate of evacuation of fly ash by dry mode (D) = 0.604 T/min

The total quantity of fly ash disposed in wet mode (E) = C X D = 1609.66 MT

The total quantity of fly ash received to ESPs (F) = 7278.50 MT

The total quantity of coal consumed in Unit # 7 (G) = 30666 MT

The total quantity of ash associated with coal (H) = 12394. 77 MT

The total quantity of mill rejects from Unit # 7 (I) = 239 MT

The total quantity of ash discarded with mill rejects (J) = 171.56 MT

The total quantity of ash generated in the boiler (K) = 12223.21 MT

The percentage of fly ash received to ESPs out of total ash (L) = (F x 100) / K= 59.55%

3.2 The Average Quantity of Parameters Per Day Basis

The average quantity of fly ash disposed in dry mode per day = 515.33 MT/day

The average quantity of fly ash disposed in wet mode per day = 146.33 MT/day

The average quantity of fly ash received to ESPs per day = 661.68 MT/day

The average quantity of coal consumption per day = 2782.81 MT/day

The average quantity of total ash generated per day = 1111.20 MT/day

The average maximum availability of fly ash from ESP is 59.55 % of the total ash

4. Conclusions

The site measurements were carried out for a period of 11 days in a 210 MWe coal fired power plants for estimating the quantity of fly ash collected in ESPs on daily basis. With the site measurements, routine plant data and the developed strategies, the fly ash collected in the ESPs, the quantity of fly ash disposed through dry and wet mode were calculated. The estimated average fly ash collected in the ESPs is 59.55 % of the total ash generated in the boiler. Among the total fly ash collected in the ESPs, about 77.9 % of fly ash was disposed in dry mode and 22.1% of the fly ash was sent in wet mode. The wet mode disposal was unavoidable due to maintenance issues. This study helped in understanding the actual fly ash which can be available on ground conditions to the cement manufacturers and the amount of fly ash actually disposed in wet mode in a typical coal fired power plant.

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