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Investigation into the characterization of fly ash collected from different thermal power stations of India

At present utilization of fly ash is carried out in the area of bricks, cement, concretes, agriculture and mine filling. The possibility may be investigated to utilize fly ash in quick isolation of fire affected area in underground coal mines by making mine seals. In view of above development of fly ash based composition suitable for construction of alternative mine seals in underground mines will have direct practical application and will provide an alternative to conventional seal as well as it will make control of fire easy and isolation of the area very quick during emergency. Five fly ash samples collected from different thermal power stations and analyzed in respect of their physical properties viz. colour, lumpiness, particle size, leaching behaviour, bulk density, moisture content and combustible material to find their suitability for use in making mine seals.

Introduction

Fly ash is finely divided residue resulting from the combustion of powdered coal or lignite and collected from the fuel gas of pulverized fuel fired boilers with the help of electrostatic precipitators in thermal power stations (TPS). It is generally grey in colour, abrasive, refractory and generally acidic in nature. Major chemical constituents of fly ash primarily composed of oxides of silicon, aluminum, iron, calcium and magnesium making up to about 95% of the total composition. The rest minor constituents are oxide of titanium, sodium, potassium, sulphur, phosphorus and manganese. Indian fly ash sample however contains higher amount of oxides of silicon, aluminum and un-burnt carbon as well as lower amount of oxide of sulphur. Several researchers [1-2] classified the fly ash on the basis of cementitious and pozzolanic properties and revealed that cemntitious fly ash is labelled as class C, with $SiO_2+Al_2O_3+Fe_2O_3$ making up at least 50 mass per cent. In pozzolanic fly ash, class F, $SiO_2+Al_2O_3+Fe_2O_3$ makes up more than 70 mass per cent of the composition of the fly ash. Studies [3] indicated that hundreds of millions of metric tonnes of fly ash that are produced annually on a worldwide basis, only a portion e. g. 20% to 40% of the fly ash is re-used for productive purposes, such as an additive or stabilizer in cement. As per the studies [4] use of fly ash in America in 2002 estimate that only 30% of the fly ash produced is used. Two thirds is used in the concrete industry, which has reached a maximum consumption figure.

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Thermal power stations using pulverized coal or lignite as fuel generate large quantities of ash as a by-product. There are about 82 power plants in India, which form the major source of fly ash in the country. With the commissioning of super thermal power plants and with the increasing use of low grade coal of high ash content, the production of ash will go up in the years to come and will pose serious ecological problems. Studies [5-6] in the United Kingdom approximately 50% of the fly ash produced is used and in India only 6%. Due to problem of coal ash disposal and environment impact, gainful utilization of fly ash is a prime necessity for the healthy growth of thermal power sector. In view of utilization of fly ash, many authors have proposed the utilization of fly ash in the area of fly ash bricks, fly ash cement, fly ash concrete, fly ash agriculture and mine felling. As per the studies [7-8] fly ash is a diverse substance. The characteristics of fly ash differ depending on the source of the coal used in the power plant and the method of combustion.

Now a day's sectionalization of the developed working by erecting series of stopping is a normal practice in underground coal mines. Some times it becomes necessary to seal off abandoned areas to eliminate the need to ventilate them. Stopping are also used to seal fire zones or the areas susceptible to spontaneous heating.

Significance of mine seals is well established. Increasing distance of workings in our mines needs better ventilation arrangements to provide comfortable working environment. Construction of normal brick stopping at distance in mines is not only difficult task but quite expensive particularly during emergency arising due to fire in the mine.

In view of the above, need for alternative mine seals have been felt since long back. Isolated effects in our country have been made with encouraging results. However, none of the technologies for alternative seals have so far been established in our country.

Development of comprehensive technology for alternative mine seals will therefore go a long way in solving the long standing problem for quick isolation of areas affected due to fire in mines and erecting stopping in far off districts of mines to provide adequate ventilation at workings. To achieve this target the main objectives are development of suitable fly ash based chemical composition for construction of alternative mine seals and laboratory studies in respect of air leakage, flame resistance, effect of temperature, decomposition products and strength of the developed product.

This paper deals with the characterization of fly ash collected from different thermal power stations. The properties considered for the selection of fly ash are particle size, leaching behaviour, bulk density, moisture content and combustible material.

Experimentation

Physical properties of fly ash

The physical properties of fly ash collected from different thermal power stations are shown in Table 1. Photographs 1-5 (in Fig.1)show the physical appearance of fly ash of different thermal power stations.

Compositional analysis of fly ash

The compositional analysis of the major chemical constituents of fly ash samples collected from the selected thermal power stations was carried out by chemical method. The results are given in Table 2.

Determination of moisture content

The moisture content of the samples of fly ash was studied. For this purpose one gram fly ash sample was taken and then heated in an air oven at 105±5°C for one hour and

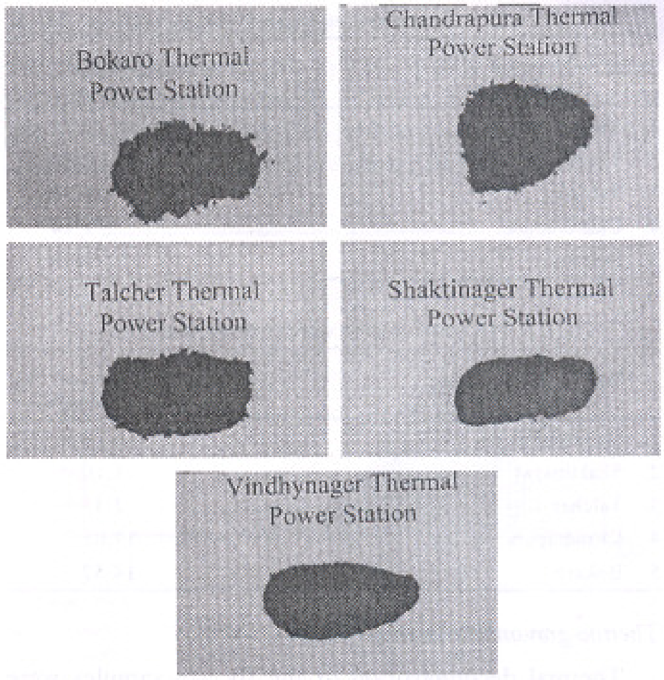

Fig.1

loss in weight after heating was calculated. This loss of weight when expressed as a percentage of the dry weight of the sample gave the % moisture content. The results shown in Table 3 revealed that the moisture content in the fly-ash of Bokaro thermal power station was found to be 2.08%, which was more than other fly ash at the same temperature. The moisture content of VTPS (Vindhyachal thermal power station) was 0.16%. The results are also shown in Table 3.

Determination of combustible content

The fly ash is residue left after the heating. Still there is some carbonaceous combustible material often present in it. This combustible material may be harmful while it is used in coal mines for different applications e.g. filling or stowing. Hence it is necessary to determine the combustible material of fly ash. The combustible content in the fly ash was studied using conventional method (high temperature furnace) and thermo gravimetic analyzer (TGA). The details of the experiments are given below:

Using high temperature furnace

A known amount of fly ash was heated in crucible at 875 ± 25°C in furnace for one hour in presence of oxygen. The weight loss was measured. The results are shown in Table 4.

Table 1: The physical properties of different thermal power stations

Name of thermal power station	Colour	Odour	Bulk density (g/cc)	Lumpiness
Vindhyachal	Light grey	Odourless	1.2585	Present
Talcher	Light grey	Odourless	1.1240	Not present
Shaktinagar	Light grey	Odourless	1.1120	Present
Chandrapura	Dark grey	Odourless	0.8605	Not present
Bokaro	Black	Odourless	0.7365	Not present

Table 2: Results of compositional analysis of different thermal power stations

Thermal power station	Chemical constituents (%)				
	CaO	MgO	Fe_2O_3	Al_2O_3	SiO_2
1. Vindhyachal	2.95	2.53	5.0	1.48	88.0
2. Shaktinagar	2.76	2.22	3.0	1.50	89.0
3. Talcher	2.78	2.53	3.0	2.50	85.0
4. Chandrapura	2.81	2.12	4.3	1.85	84.0
5. Bokaro	2.88	2.83	4.0	3.00	78.0

TABLE 3: THE MOISTURE OF DIFFERENT FLY ASH

Thermal power station	Moisture (%)
1. Vindhyachal	0.16
2. Shaktinagar	0.40
3. Talcher	0.33
4. Chandrapura	1.14
5. Bokaro	2.08

TABLE 4: THE COMBUSTIBLE CONTENT OF DIFFERENT FLY ASH

Thermal power station	Combustible content of fly ash (%)
1. Vindhyachal	0.74
2. Shaktinagar	1.10
3. Talcher	2.33
4. Chandrapura	11.01
5. Bokaro	14.57

Thermo gravimetric analyzer (TGA)

Thermal decomposition of the fly ash samples were investigated using thermo gravimetric analyzer (TGA, Model Mattler TC-11). Samples were evaluated for their ignition behaviour, decomposition in different temperature range and for residual matters.

10-20 mg of sample was taken and loaded in the sampler holder of TGA. The instrument was programmed for incremental heating at the rate of 20°C/min and up to 800°C. Thermo gram and differential thermo grams obtained from instruments were evaluated for ignition behaviour, decomposition in different temperature range and for residual matters. Thermo grams and differential thermo grams of decomposition with analysis of different fly ash are shown in Figs.2-5 and experimental parameters and step analysis are given in Table 5-6.

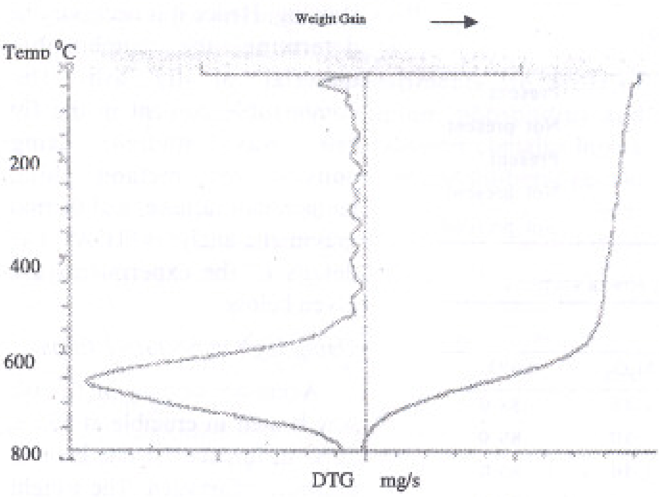

Fig.2 Thermogram and differential thermogram of Bokaro thermal power station

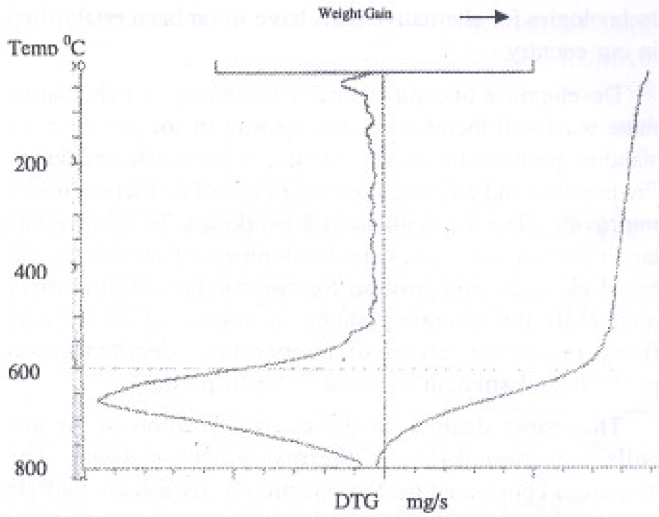

Fig.3 Thermogram and differential thermogram of Chandrapura thermal power station

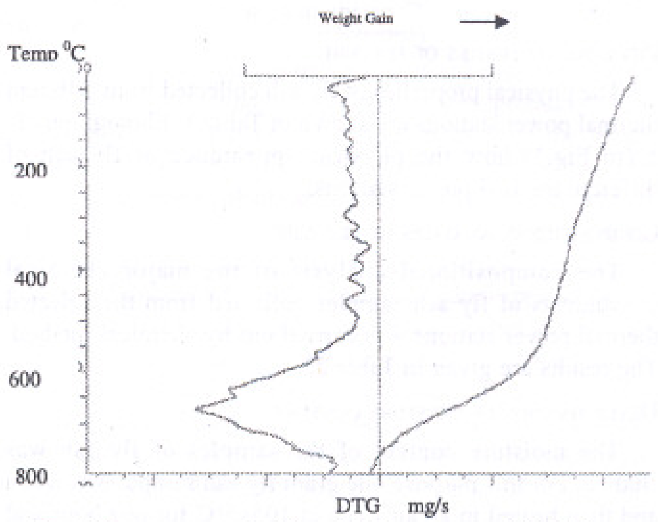

Fig.4 Thermogram and differential thermogram of Shaktinagar thermal power station

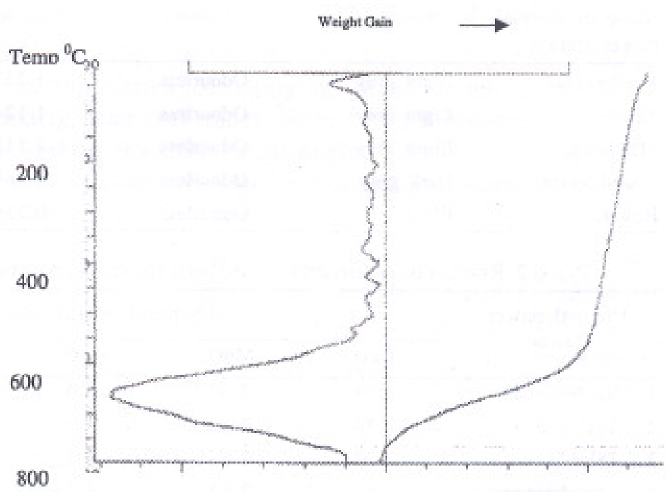

Fig.5 Thermogram and differential thermogram of Talcher thermal power station

Study of grain size

Particle size is important for application of fly ash in making blocks and bricks. Grain size of the fly ash samples were determined using "FRITSCH analysette – 22 larger particle size analyzer" in the laboratory. The results are given in Table 7. Crystallograph of different fly ash samples (Figs.6-11) show the grain size of fly ash crystals and their content in the samples.

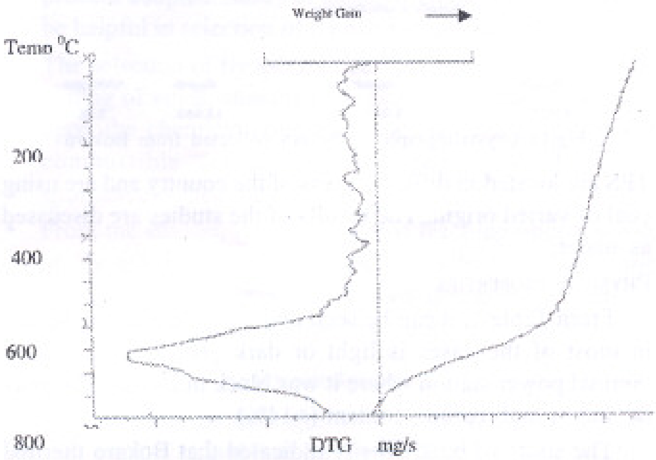

Fig.6 Thermogram and differential thermogram of Vindhyachal thermal power station

Table 5: Experimental parameters of TG Analysis

	Step analysis parameters	Screen parameters
1.	Dyn/ISO 1 or 2	1
2.	Auto limit 0 or 1	1
3.	Start temperature °C	25
4.	End temperature °C	800
5.	Baseline type	1
6.	Plot cm	10
7.	Plot mode	2091
8.	Mole mass gas	0
9.	Mol mass init.	0
10.	Sample ID. no.	As per the sample taken
11.	Rate of heating °C/Minute	20
12.	Weight mg	As per the sample taken
13.	End screen temperature °C	795-796

Study of leaching behaviour

The influence of fly ash on water quality was investigated by studying the effect on pH of water. For this purpose the pH of water before and after 24 hours of mixing of fly ash was measured. The results are shown in Table 8.

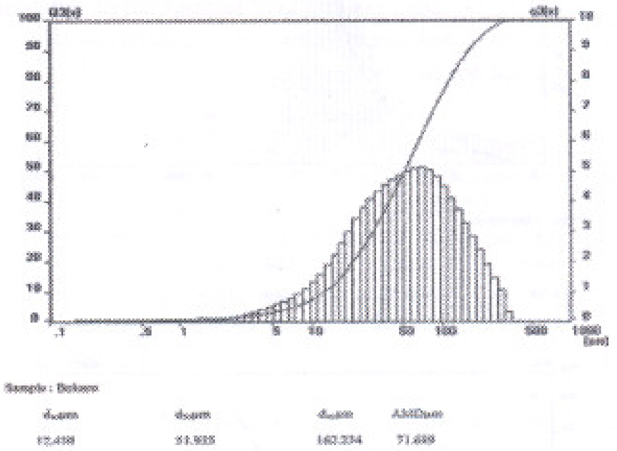

Fig.7 Crystallograph of fly ash collected from Bokaro

Table 7: The grain size of different fly ash

Thermal power stations		Particle size			
		$d_{10}\mu m$	$d_{50}\mu m$	$d_{90}\mu m$	AMDμm
1.	Bokaro	12.410	51.935	162.234	71.689
2.	Shaktinagar	1.536	11.646	43.175	17.895
3.	Vindhyachal	0.737	7.037	15.962	7.784
4.	Chandrapura	0.766	5.236	11.856	5.933
5.	Talcher	1.203	7.271	19.318	9.031

Table 8: Leaching behaviour of fly ash in water

	Name of thermal power station	pH of water without fly ash	Change in pH of water with fly ash sample (24hrs)
1.	Blank water sample	7.0	7.0
2.	Bokaro	7.0	6.2
3.	Shaktinagar	7.0	6.6
4.	Vindhyachal	7.0	6.7
5.	Talcher	7.0	6.8
6.	Chandrapura	7.0	7.2

Table 6: TG Studies on fly ash

	Bokaro TPS		Chandrapura TPS		Shaktinagar TPS		Talcher TPS		Vindhyanagar TPS	
	Temp. range (°C)	Weight loss (%)	Temp. range (°C)	Weight loss (%)	Temp. range (°C)	Weight loss (%)	Temp. range (°C)	Weight loss (%)	Temp. range (°C)	Weight loss (%)
1.	29-145	1.78	29-225	1.89	29-357	3.03	25-441	3.19	29-421	3.76
2.	225-329	0.85	225-513	1.77	357-437	0.53	505-793	14.91	421-481	0.5
3	329-457	1.04	513-793	21.59	437-493	0.4	795.3	81.67	481-789	13.87
4	513-793	29.02	795.7	74.43	493-781	8.47	-	-	795.7	81.49
5	795.7	65.81	-	-	795.7	87.03	-	-	-	-

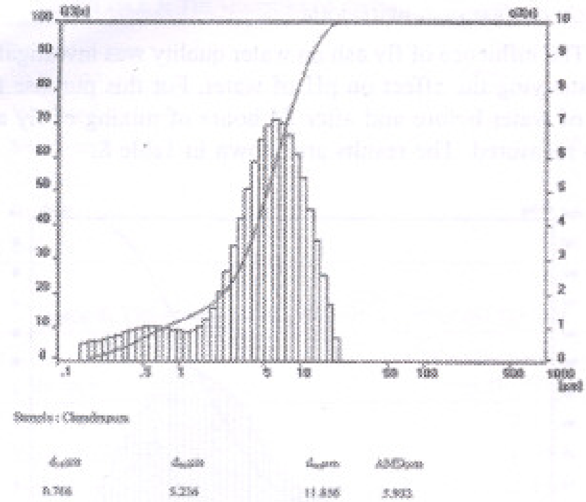

Fig.8 Crystallograph of fly ash collected from Bokaro

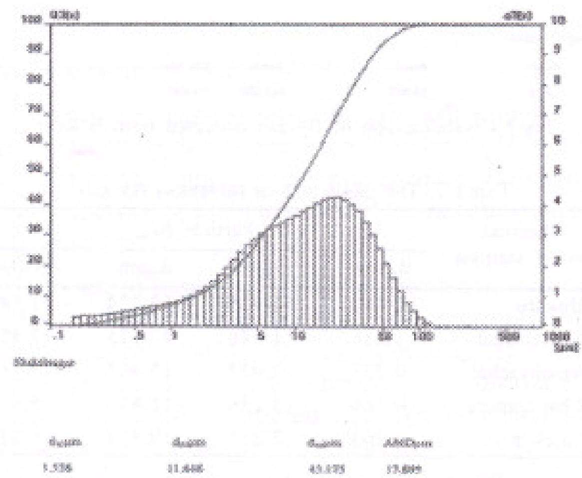

Fig.9 Crystallograph of fly ash collected from Bokaro

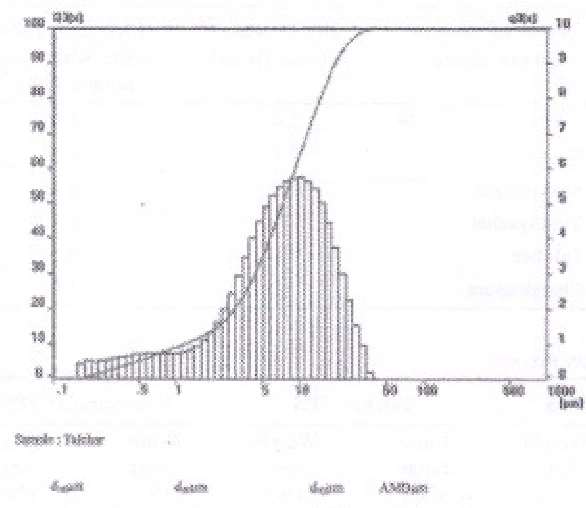

Fig.10 Crystallograph of fly ash collected from Bokaro

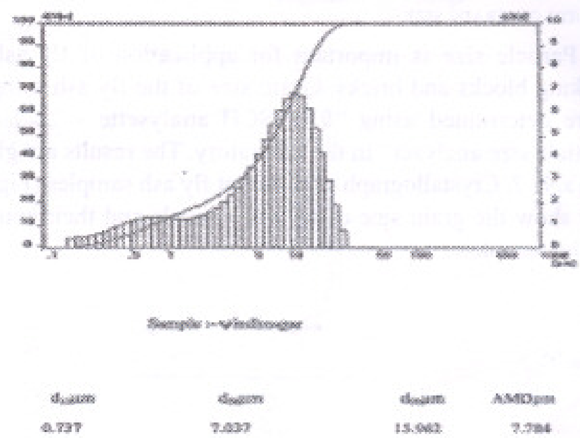

Fig.11 Crystallograph of fly ash collected from Bokaro

Results and discussion

Under study, samples from five TPS, viz. Vindhyachal, Talcher, Shaktinagar, Bokaro and Chandrapura were collected. These TPS are located in different parts of the country and are using coal of varied origin. The results of the studies are discussed as under;

Physical properties

From Table 1, it can be seen that the colour of the fly ash in most of the cases is light or dark grey except Bokaro thermal power station where it was black in colour. This may be due to high carbon content (>14%).

The study of bulk density indicated that Bokaro thermal power station fly ash is lightest. This may be due to variation of mineral content and particle size of fly ash.

Compositional analysis

From Table 2, the % of CaO, MgO, Fe_2O_3, Al_2O_3 and SiO_2 was analyzed. In the sample SiO_2 was found in the range of 78-89%, Al_2O_3 1.48-3.0%, Fe_2O_3 3.0-5.0%, MgO 2.12-2.83%, CaO 2.76-2.95%.

Moisture content

From Table 3, it can be seen that the moisture content in Vindhyachal, Shaktinagar and Talcher was found below 1% (0.16, 0.40 & 0.33% respectively) whereas in Bokaro and Chandrapura thermal power stations it was 2.08% and 1.14% respectively.

Combustible content

From Table 4, it can be seen that combustible content in Chandrapura and Bokaro was more than 10% (11.01 and 14.57) whereas in rest of the samples it was below 2.5%.

Grain size

From Table 7, it can be seen that average mean diameter (AMDμm) of all samples is below 18 except Bokaro where it was 71.69μm thus Bokaro fly ash is comparatively larger in size compare to other fly ash samples.

Leaching behaviour

From Table 8, it can be seen that fly ash when put in water there is no significant change in pH value of water thus there is no leaching of fly ash when kept in water. However, it was observed that initially there is slightly decrease in pH i.e. increase in acidity but within 24 hours time it attains the normal value i.e. pH 7.

Conclusions

From the results of the investigation, conducted on five fly ash samples collected from Vindhyachal, Shaktinager, Talcher, Chanderpura and Bokaro thermal power stations, the following conclusions may be made:

- The physical and chemical properties of fly ash samples collected from different thermal power stations vary significantly. It may be either due to the change in chemical constituents of coal used in that TPS or the combustion process adopted. Study of these parameters may therefore be helpful in selection of fly ash for specific uses.
- The selection of fly ash particularly for use in coal mines (filling of voids, stowing etc.) should be made depending upon the chemical composition of the ash specially the combustible content in it to reduce/avoid risk if spontaneous heating.
- From the studies, it is evident that leaching phenomenon of fly ash is very interesting. Initially it shows some leaching behaviour and pH goes down but within 24 hours time it attains normal pH values.

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References

1. Kruger, R. A. (1997): *Fuel*, No. 76 (8), pp.777-779.
2. Scheetz, B. E. and Earle, R. (1998): *Current opinion in solid state & Material Science*, No. 3, 5, pp.10-520.
3. Shackelford, C. D. (2000): *Journal of Hazardous Materials*, 76, pp. vii-viii.
4. Malhotra, V. M., Valimbe, P. S. and Wright, M. A. (2002): *Fuel*, No. 81, pp. 235-244.
5. McCarthy, M. J. and Dhir, R. K. (1999): *Fuel*, No. 78, pp. 121-132.
6. Satapathy, L. N. (2000): *Ceramics International*, No. 26, pp. 39-45.
7. Vassilev, S. V. and Vassilveva, C. G. (1996): *Fuel Processing Technology*, No. 47, pp. 261-280.
8. Helmuth, R. (1987): "Fly Ash in cement and concrete", Portland cement Association, Skokie, pp 36-61.

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3. Wachendorf, Jeff (2009): "Cast blasting around town", Proceedings of the 35th International conference on Explosives and Blasting Techniques, *ISEE*, Feb 8-11 '2009, Denver, CO, USA, pp 139-145.
4. Chironis, N. P. (1984): "Angled drilling aids casting", *Coal Age*, V84(b), January '84, pp 64-67.
5. Hartley, Rob (1993): "Rock blasting technique in opencast coal operations", *Quarry Management*, Sep '1993, pp 35-39.
6. Chiappetta, R. F., Bauer, A., Dailey, P. J. and Burchell, S. L. (1983): "The use of high speed motion picture photography in blast evaluation and design", 9th Intl. Conf on Explosives and Blasting Techniques, *ISEE*, Dallas, Texas, USA, Feb '1983, pp 258-309.
7. Tracy, J. M. (1985): "Increased production through cast blasting in surface coal mines", *Journal of Explosives Engineering*, V(3), Sep-Oct 1985, pp 16-23.
8. Chironis, N. P. (1980): "Casting overburden by blasting", *Coal Age*, May' 1980, pp 108-116.
9. Langefors, U. and Kihlstrom, B. (1967): "Modern Techniques of Rock Blasting", John Wiley & Sons, NY.
10. Worsey, P. N. and Giltner, S. G. (1986): "Economic and design considerations for explosive overburden casting", *International Journal of Mining and Geological Engineering*, V(5), pp 93-108.
11. Chironis, N. P. (1983): "Spoil-side stripping succeeds", *Coal Age*, April 1983, pp 48-53.
12. Chironis, N. P. (1986): "Spoil-side Dip-line stripping works well with cast blasting", *Coal Age*, August 1986, pp 40-45.
13. Dupree, P. D. (1987): "Applied drilling and blasting techniques for blast casting at Trapper Mine-Potential to save on overburden", *Journal of Mining Engineering*, Jan '87, pp 13-15.
14. Fording River Operations, MineReport, 1988.
15. Singhal, R K. and Naidu, Highwall G. (1989): "Cast Blasting in Canadian surface coal mines", *World Mining Equipment*, July-Aug '89, pp 33-36.
16. Ewart, D. L., Marston jr, R. R. and Pries Stripping, M. (1993): "Alternatives to Shovel/Truck overburden pre-stripping: Three case studies" Prc of Int Congress on Mine Design, Balkema, Aug 23-26 1993, pp 247-265.
17. Chung, S., Mcgill, Mike and Preece, D.S. (1994): "Computer cast blasting modeling", 20th Int Conf on Explosives and Blasting Techniques, *ISEE*, USA, pp.217-226.
18. Uttarwar, M. D. and Yerpude, R. R. (2009): "An appraisal of overburden cast blasting technique in Indian surface coal mines", 35th Int. Conf. on Explosives and Blasting Techniques, *ISEE*, Denver, CO, USA, Feb 8-11,2009, Vol II, pp 335-46.
19. Wachendorf, Jeff (2002): "Cast Blasting pays dividends for Spring Creek Coal", *Coal Age*, V107(2), Feb '02, pp 34-36.
20. Youdi, Zhang, Li, Kemin and Tao, Shang (2004): "Opencast method and its application prospect in Chinese surface mines". Mining Science and Technology, Eds Wang Ge & Guo, 2004, Taylor and Francis Group, London.