STUDY OF THE SETTLING CHARACTERISTICS OF FLY ASH-WATER SLURRY AND DESIGNING OF A SETTLING POND

A THESIS SUBMITTED IN PARTIAL FULLFILLMENT

THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

CHEMICAL ENGINEERING

BY

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DEPARTMENT OF CHEMICAL ENGINEERING

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CERTIFICATE

This is to certify that the report entitled **"STUDY OF THE SETTLING CHARACTRISTICS OF FLY ASH-WATER SLURRY AND DESIGNING OF A SETTLING POND"** being submitted by JYOTI RANJAN ROUT towards the fulfillment of the requirement for the degree of Bachelors of Technology in Chemical Engineering at Department of Chemical Engineering, NIT Rourkela is a record of bonfire work carried out by him under my guidance and supervision**.**

Prof. P. RATH

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Thanking you,

JYOTI RANJAN ROUT

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ABSTRACT

Fly ash is a very fine material which is produced by burning of pulverized coal in boilers of thermal power plants. Worldwide, more than 65% of fly ash produced from coal power stations is disposed off in landfills and ash ponds. The fly ash is sent to ash ponds in the form of slurry with water since it is economical. This fly ash being finer and lighter than river sand has lower settlement rate, which can be increased by adding a suitable polymer to the ash slurry in the pond. It is desired that the rate of of settling is fast, so that the water can be easily drained out form the ash pond. If the water height is built up for a long period of time, then it will result in the building up off the hydrostatic pressure which may damage the pond and lead to leakage of fly ash-water slurry from the pond causing various industrial hazards.

The objective of this report is to provide a detailed study of the settling rates of fly ash in ash pond for polymer (carboxy methyl cellulose) added, and at different concentration levels. This report also aims at suggesting the aspects to be considered while constructing an ash pond for the fly ash disposal. The turbidity of the fly ash-water slurry along with the polymer mixed to it is studied at some specific time intervals with the help of a Nephelo turbidity meter to determine the rate of decrease of turbidity of the clear liquid at the top of the fly ash-water slurry. This helps in determining the optimum concentration of polymer dosage for faster settlement of fly ash. From the experiments conducted and results obtained, it is concluded that the optimum concentration of the polymer solution to be added is 2ppm (2ml of 10-2 range polymer solution). The gravitational settling rate of the fly ash is calculated after the addition of the above concentration of the polymer. It is concluded that the settling rate of fly ash in ash pond of thermal power plants can be increased by the addition of the polymer of optimum concentration.

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CHAPTER 1

INTRODUCTION

OBJECTIVE

SPECIFIC OBJECTIVE

1.1 INTRODUCTION

Fly ash is a very fine material produced by burning of pulverized coal in a thermal power plant, and is carried by the flue gas and is collected by the electrostatic precipitators or cyclones. The high temperatures of burning coal turns the clay minerals present in the coal powder into fused fine particles mainly comprising aluminum silicate. Fly ash produced thus possesses both ceramic and pozzolanic properties. The problem with fly ash lies in the fact that not only does its disposal requires large quantities of land, water and energy, its fine particles, if not managed well, by virtue of their weightlessness, can become air-borne. Currently, 100 million tons of fly ash being generated annually in India, with 65000 acres of land being occupied by ash ponds. Such a huge quantity does pose challenging problems, in the form of land usage, health hazards, and environmental dangers. Both in disposal, as well as in utilization, utmost care has to be taken, to safeguard the interest of human life, wild life and environment.

The World Bank has cautioned India that by 2015, disposal of coal ash would require 1000 square kilometers or 1 square meter of land per person. Since coal currently accounts for 75% of power production in the country, the bank has highlighted the need for new and innovative methods for reducing impact on the environment. [14]

The physical, geotechnical and chemical parameters to characterize fly ash are the same as those for natural soils, e.g., specific gravity, grain size, atterberg limits, compaction characteristics, permeability coefficients, shear strength parameters and consolidation parameters. The properties of ash are a function of several variables such as coal source, degree of pulverization, design of boiler unit, loading and firing conditions, handling and storing methods. A change in any of the above factors can result in detectable changes in the properties of ash produced. The procedures for the determination of these parameters are also similar to those for soils.

1.2 OBJECTIVE

The objective of this study is “study of the settling characteristics of fly ash-water slurry and designing of a settling pond”. This objective involves the following specific objectives:-

1.2.1 SPECIFIC OBJECTIVES

- Studying the engineering properties of fly ash.
- Study of the settling characteristics of fly ash-water slurry.
- Use of a polymer solution to improve the settling rate of the fly ash and calculate the rate of settling of fly ash by gravitational settling method.
- Suggesting the aspects to be considered for the design and construction of an ash pond.

CHAPTER 2

LITERATURE REVIEW

GENERATION OF FLY ASH

COMPOSITION OF FLY ASH

PROPERTIES OF FLY ASH

CLASSIFICATION

FEATURES

HOW IS FLY ASH HAZARDOUS

FLY ASH MANAGEMENT

2.1 GENERATION OF FLY ASH

Fly ash is produced as a by-product in coal fired thermal power plants. Pulverized coal, when blown into the boiler, it is ignited and generates heat and is self converted to a molten residue. The heat is then extracted by the tubes of the boiler and the molten residue is thus cooled to form ash. The finer ash particles are carried away by the flue gas to the electrostatic precipitators and are referred as fly ash, whereas the heavier ash particles fall to the bottom of the boiler and are called as bottom ash. Different types of coal fired boilers are (a) Dry bottom boilers, (b) Wet bottom boilers and (c) Cyclone furnaces. Dry bottom boilers produce 80% ash as fly ash and 20% as bottom ash. Wet bottom boilers produce 50% each as fly ash and bottom ash respectively. Lastly, cyclone furnaces produce 20% as fly ash and 80% as bottom ash.

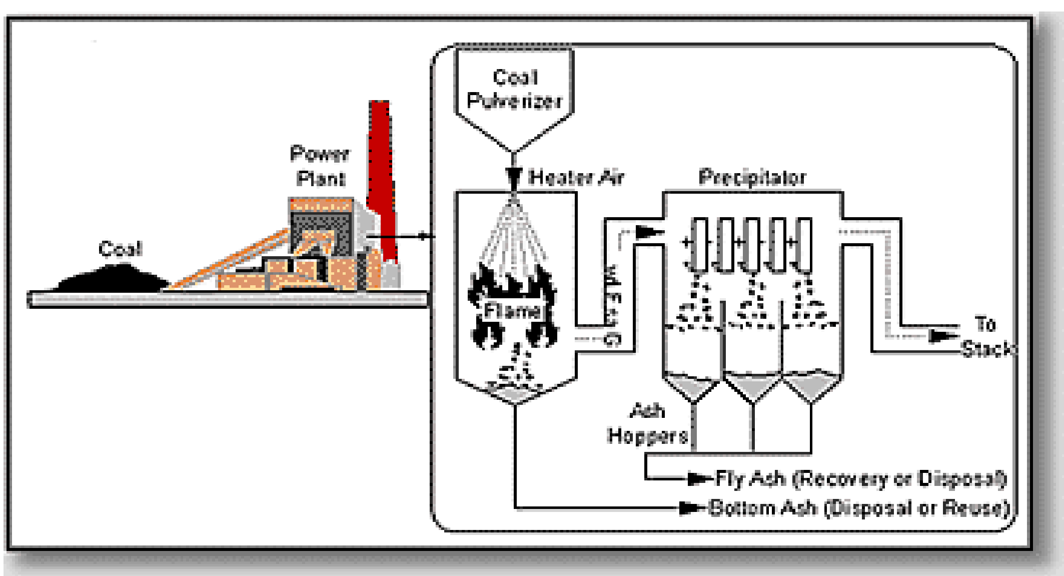

Fig. 2.1 Production of fly ash in a dry-bottom utility boiler with electrostatic precipitator.

In India coal/lignite based thermal power plants account for more than 55% of the electricity installed capacity and 65% of electricity generation. The ash content of the coal used at the thermal power plants ranges from 30-40%, with the average ash content around 38%. Since low ash, high grade coal is reserved for metallurgical industries. The thermal power plants have to use high ash, low grade coal. The thermal power plants ash generation has increased from about 40 million tones during 1993-94, to 120 million tons during 2005-06, and is expected to be in the range of 175 million tons per year by 2012.[16]

SL NO	Country	Annual ash production, MT	Ash utilization %
1	India	112	38
2	China	100	45
3	USA	75	65
4	Germany	40	85
5	UK	15	50
6	Australia	10	85
7	Canada	6	75
8	France	3	85
9	Denmark	2	100
10	Italy	2	100
11	Netherlands	2	100

Table 2.1 fly ash generation and utilization statistics [13]

2.2 COMPOSTION

Depending upon the source and makeup of the coal being burnt, the composition of fly ash and bottom ash vary considerably. Fly ash includes substantial amounts of silicon dioxide and calcium oxide which are the main ingredients of many coal bearing rocks.

Toxic constituents of fly ash depend upon the specific coal bed makeup, but may include one or more of the following elements in quantities or trace amounts to varying percentages: Arsenic, molybdenum, selenium, cadmium, boron, chromium, lead, manganese, mercury, strontium, thallium, vanadium, beryllium along with dioxins.

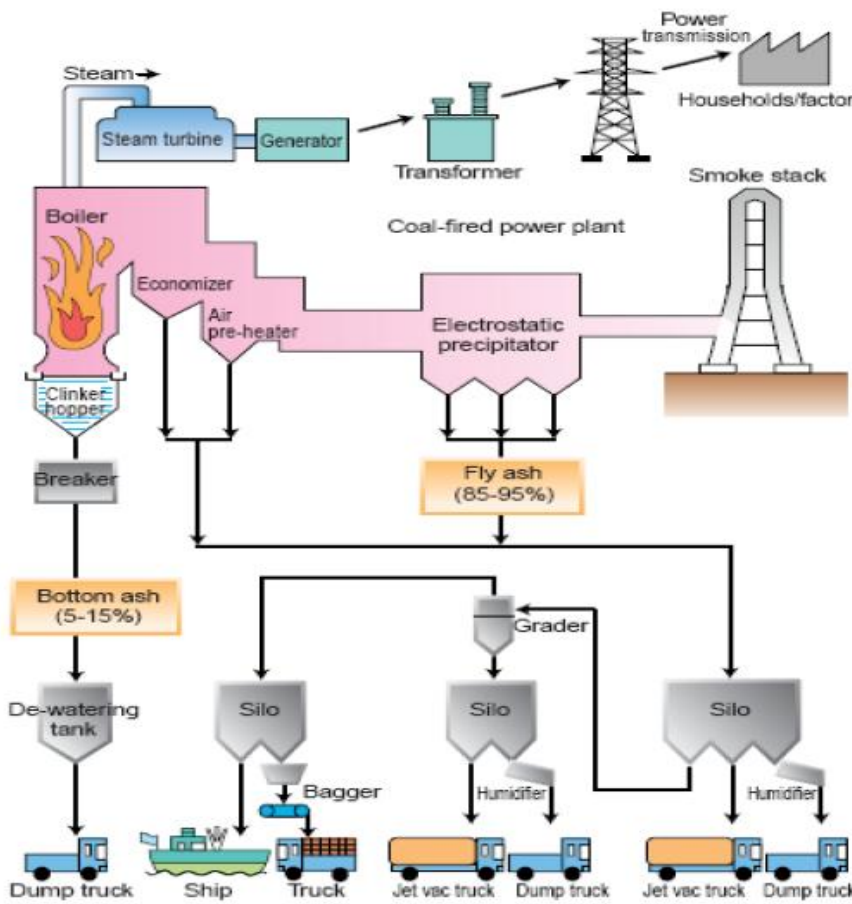

Fig. 2.2 ash generation from coal fired boiler

Fly ash is a fine, glass powder recovered from the gases of burning coal during the produtcion of electricity. The micron-sized earth elements consist of primarily of sillica, alumina and iron. When mixed with lime and water, the fly ash forms a cementious compound with properties very similar to that of protland cement. [13]

Component	Bituminous	Sub bituminous	Lignite
SiO_2	20-60	40-60	15-45
Al_2O_3	5-35	20-30	10-25
Fe_2O_3	10-40	4-10	4-15
CaO	1-12	5-30	15-40
MgO	0-5	1-6	3-10
SO_3	0-4	0-2	0-10
Na_2O	0-4	0-2	0-6
K_2O	0-3	0-4	0-4
LOI	0-15	0-3	0-5

Table 2.2 Normal range of chemical composition for fly ash produced from different coal types (expressed as percent by weight).

2.3 PROPERTIES OF FLY ASH

2.3.1 Physical

Fly ash consists of fine, powdery particles that are predominantly spherical in shape, either solid or hollow, and mostly glassy (amorphous) in nature. The carbonaceous material in fly ash is composed of angular particles. The particle size distribution of most bituminous coal fly ashes is generally similar to that of a silt (less than a 0.075 mm or No. 200 sieve). Although sub bituminous coal fly ashes are also silt-sized, they are generally slightly coarser than bituminous coal fly ashes. The particle size distribution of raw fly ash is very often fluctuating constantly, due to changing performance of the coal mills and the boiler performance.

The specific gravity of fly ash usually ranges from 2.1 to 3.0, while its specific surface area (measured by the Blaine air permeability method) may range from 170 to 1000 m^2/kg.

Engineering properties of Fly Ash	
Parameter	
Specific gravity	1.90-2.55
Plasticity	Non Plastic
Proctor compaction - Maximum dry density (gm/cc)	0.90-1.60
Optimum moisture content (%)	38.0-18.0
Angle of internal friction (O)	30^0-40^0
Cohesion (kg/cm ^{2})	Negligible
Compression index	0.05-0.4
Permeability (CM/SEC)	10^5-10^3
Particle size distribution	
Clay size fraction (%)	1-10
Silt size fraction (%)	8-85
Sand size fraction (%)	7-90
Gravel size fraction (%)	0-10
Coefficient of uniformity	3.1-10.7

Table 2.3.1 engineering properties of fly ash parameter.[7]

The color of fly ash can vary from tan to gray to black, depending on the amount of unburned carbon in the ash. The lighter the color, the lower the carbon content. Lignite or sub bituminous fly ashes are usually light tan to buff in color, indicating relatively low amounts of carbon as well as the presence of some lime or calcium. Bituminous fly ashes are usually some shade of gray, with the lighter shades of gray generally indicating a higher quality of ash.

2.3.2 Chemical

The chemical properties of fly ash are influenced to a great extent by those of the coal burned and the techniques used for handling and storage. There are basically four types, or ranks, of coal, each of which varies in terms of its heating value, its chemical composition, ash content, and geological origin. The four types, or ranks, of coal are anthracite, bituminous, sub bituminous, and lignite. In addition to being handled in a dry, conditioned, or wet form, fly ash is also sometimes classified according to the type of coal from which the ash was derived.

The principal components of bituminous coal fly ash are silica, alumina, iron oxide, and calcium, with varying amounts of carbon, as measured by the loss on ignition (LOI). The LOI for fly ash should be less than 6 %. Lignite and sub bituminous coal fly ashes are characterized by higher concentrations of calcium and magnesium oxide and reduced percentages of silica and iron oxide, as well as a lower carbon content, compared with bituminous coal fly ash. Very little anthracite coal is burned in utility boilers, so there are only small amounts of anthracite coal fly ash.

They consist mostly of silicon dioxide (SiO_2), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminum oxide

(Al_2O_3) and iron oxide (Fe_2O_3) Chemical composition of fly ash is as follows: SiO_2, 59.38; Fe_2O_3, 6.11; CaO, 1.94; MgO, 0.97; SO_3, 0.76; alkalis, 1.41; and unburnt sulphur and moisture, 3.74%. Fly ash contain following toxic metals Hg, 1; Cd, Ga, Sb, Se, Ti and V, 1-10; As, Cr, La, Mo, Ni, Pb, Th, U and Zn, 10-100; and B, Ba, Cu, Mn and Sr, 100-1000 mg/kg. Heavy metals like (As, Mo, Mn and Fe) show leaching with concentration above permissible limits. [16]

2.4 CLASSIFICATION

Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).

2.4.1 **Class C fly ash**

Fig. 2.4.1 class C fly ash

Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO_4) contents are generally higher in Class C fly ashes. Class C fly ash can be identified from its light brownish colour.

2.4.2 **Class F fly ash**

Fig 2.4.2 class F fly ash

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 10% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. Alternatively, the additions of a chemical activator such as sodium silicate (water glass) to a Class F ash can lead to the formation of a geopolymer. Class F fly ash can be identified by its dark brownish colour. [13]

2.5 HOW IS FLY ASH HAZARDOUS

Fly ash is a very fine powder and tends to travel far in the air. When not properly disposed, it is known to pollute air and water, and causes respiratory problems when inhaled. When it settles on leaves and crops in fields around the power plant, it lowers the yield. The conventional method used to dispose off both fly ash and bottom ash is to convert them into slurry for impounding in ash ponds around the thermal plants. This method entails long term problems.

The severe problems that arise from such dumping are:-

- The construction of ash ponds requires vast tracts of land. This depletes land available for agriculture over a period of time.
- When one ash pond fills up, another has to be built, at great cost and further loss of agricultural land.
- Huge quantities of water are required to convert ash into slurry.

During rains, numerous salts and metallic contents in the slurry can leach down to the ground water and contaminate it. [7]

2.6 MANAGEMENT OF FLY ASH

2.6.1 Recycling of fly ash

In 1996, approximately 14.6 million metric tons (16.2 million tons) of fly ash were used. Of this total, 11.85 million metric tons (13.3 million tons), or approximately 22 percent of the total quantity of fly ash produced, were used in construction-related applications.

Between 1985 and 1995, fly ash usage has fluctuated between approximately 8.0 and 11.9 million metric tons (8.8 and 13.6 million tons) per year, averaging 10.2 million metric tons (11.3 million tons) per year. Fly ash is useful in many applications because it is a pozzolan, meaning it is a siliceous or alumino-siliceous material that, when in a finely divided form and in the presence of water, will combine with calcium hydroxide (from lime, Portland cement, or kiln dust) to form cementitious compounds.

Applications	Quantity Used		Percent of Total Used
	Million Metric Tons	Million Tons	
Cement production and/or concrete products	7.2	8.0	60
Structural fills or embankments	1.9	2.2	17
Stabilization of waste materials	1.7	1.9	14
Road base or subbase materials	0.63	0.7	5
Flowable fill and grouting mixes	0.27	0.3	2
Mineral filler in asphalt paving	0.15	0.2	2
Approximate Total	11.85	13.3	100

Table 2.6.1 fly ash construction related applications (recycling)[16]

2.6.2 Difficulties in handling of fly ash

Many challenges are to be faced in the handling and utilization of fly ash. Some of these difficulties include:-

- The composition of fly ash depends on the quality of coal utilizers. So the costumer cannot be sure of the quality of fly ash available form a particular source.
- The unavailability of testing, labeling & packing facilities of fly ash results in unnecessary expenses to the costumers.

- The location of thermal power plants in remote areas creates difficulties in transportation and lifting for the user industries. [13]

2.6.3 Problems associated with disposal of fly ash

Primarily, the fly ash is disposed off using either dry or wet disposal schemes. In dry disposal, the fly ash is transported by truck, chute, or conveyor at the site and disposed off by constructing a dry embankment (dyke). In wet disposal, the fly ash is transported as a slurry through pipe and disposed off in impoundment called “ash pond”. Most of the power plants in India use wet disposal system and when the lagoons are full, four basic options are available:-

- Constructing new lagoons using conventional construction material.
- Hauling of fly ash from the existing lagoons to another disposal site.
- Raising the existing dyke using conventional construction material and
- Raising the dyke using fly ash excavated from the lagoon (ash dyke).

The option of raising the existing dyke is very cost effective because any fly ash used for constructing dyke would, in addition to saving the earth filling cost, enhance disposal capacity of the lagoon.

An important aspect of design of ash dyke is the internal drainage system. The seepage discharge from the internal surfaces must be controlled with filters that permit water to escape freely and also to hold particles in place and the peizometric surface on the downstream of the dyke. The internal drainage system consists of construction of rock toe, 0.5 meter thick sand blanket and sand chimney. After completion of the final section including earth cover the turfing is developed from sod on the downstream slope.

CHAPTER 3

STUDY OF SETTLING CHARACTERISITICS OF FLY ASH

OBJECTIVE OF THE STUDY

SAMPLE COLLECTION

EXPERIMENTAL PROCEDURE

RESULTS

DISCUSSION

3.1 OBJECTIVE OF THE STUDY

The objective of this study is to improve the settling rate of fly ash particles in a fly ash-water slurry as compared to the usual settling of fly ash in ash ponds of thermal power plants. For this purpose a polymer solution is added to the slurry which causes flocculation of the fly ash particles and allows them to settle at a faster rate.

3.2 SAMPLE COLLECTION

The sample collection of different types of ashes such as fly ash, bottom ash and pond ash has different procedures. The fly ash and the bottom ashes are generated at the power plant and can be collected directly from the discharge points. In most of the power plants sampling pipes are provided at places near the discharge point or near the storage point for collection of ash samples. The sample can be directly collected into a bucket or any other container and can be suitably packed for transportation. The sample used in this study was fly ash collected from the bottom of the electrostatic precipitator of NTPC Kaniha, Talcher, Orissa.

3.3 EXPERIMENTAL PROCEDURE

3.3.1 Requirements

1. Fly ash sample.
2. Digital Nephelo turbidity meter.

Fig 3.3.1.1 Nephelo turbidity meter

3. Jar apparatus (consists of a motor connected to a rotating shaft with a stirring blade at the base and arrangement for varying the rpm of the motor with the help of a voltage/current regulator)

Fig 3.3.1.2 Jar apparatus

4. Polymer (Carboxy methyl cellulose).

3.3.2 Procedure

1 gm of ash sample was added to 500ml of distilled water in a glass beaker to form a solution. A Polymer solution of 10^{-3} range was prepared by adding 1gm of polymer (CMC) with 1000 ml of distilled water in a separate beaker. 1ml of the polymer solution prepared was pipetted out and was added to the fly ash water solution and the resulting solution was stirred with the help of a jar apparatus for 5 minutes .The solution was then allowed to stabilize for the next 5 minutes and

to let some fly ash to settle down. The clear liquid at the top of the solution was taken out with the help of a dropper for the determination of its turbidity by the help of a Nephelo turbidity meter, at regular intervals of 10 minutes. The above procedure was repeated for 2 ml, 5 ml, 10 ml solution of the polymer. [1]

3.4 RESULTS

3.4.1 Turbidity of the clear solution at an interval of 10 minutes

Time (minutes)	Turbidity (NTU) for 1 ml polymer solution	Turbidity (NTU) for 2 ml polymer solution	Turbidity (NTU) for 5 ml polymer solution	Turbidity (NTU) for 10 ml polymer solution
10	503	495	508	523
20	482	470	446	496
30	457	426	458	498
40	432	389	467	486

Table 3.4.1 Rate of decrease in Turbidity with Time

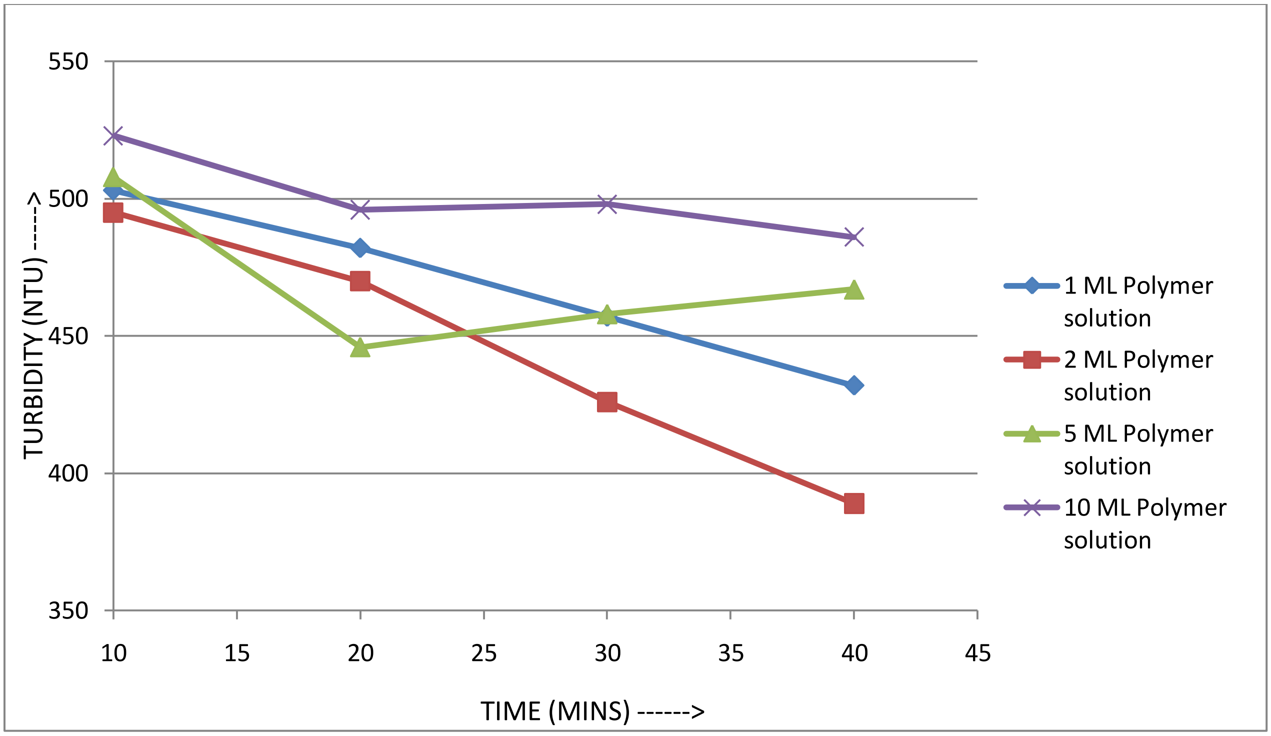

Fig. 3.4.1 Turbidity vs. Time Characteristics

3.4.2 Turbidity of the clear liquid for each fraction of polymer added

Fraction of polymer (ppm)	Turbidity (NTU) T1	Turbidity (NTU) T2	Turbidity (NTU) T3	Turbidity (NTU) T4
1	503	482	457	432
2	495	470	426	389
5	508	446	458	467
10	523	496	498	486

Table 3.4.2 Turbidity for each fraction of polymer

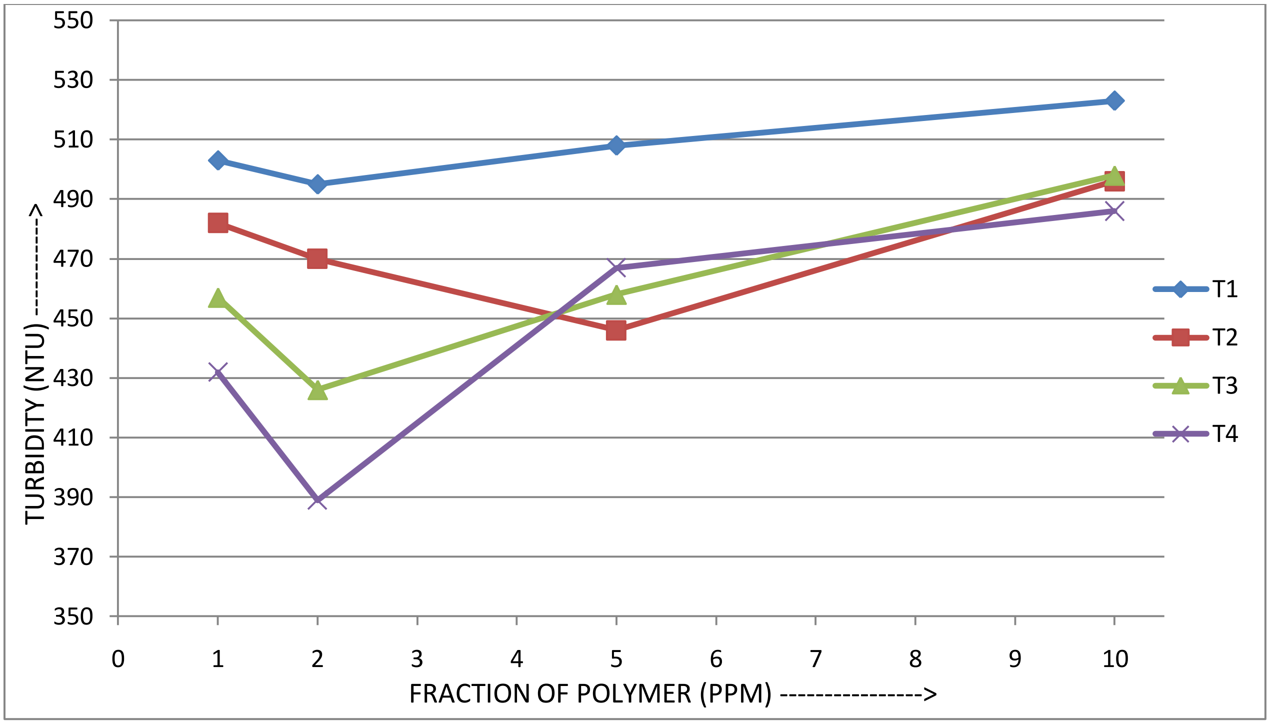

Fig 3.4.2 Turbidity vs. Fraction of polymer (ppm.)

3.5 DISCUSSION

Flocculation is the process of formation of larger agglomerates of particles in the suspension by the help of high molecular weight polymeric materials. The polymer added causes flocculation of the fly ash particles which results in settling down of the fly ash. Flocculation is affected by many factors such as: particle size distribution, chemical properties of solids suspended, molecular weight, temperature, ionic strength, polymer type and polymer dosage. [1]

From fig. 3.4.1, i.e,. turbidity vs. time characteristics, it is observed that the rate of decrease in turbidity is maximum for 2ppm (2ml of 10^{-3} range) polymer added. So, the rate of settling is faster in case of 2ppm polymer been added. For the case of 1ml polymer added, there is a gradual decrease in the turbidity of the clear liquid. For the case of 5ppm polymer added, the turbidity decreases initially and then the turbidity increases. But for higher concentrations of polymer being added, instead of decrease in turbidity, it will promote the increase in the turbidity of the clear liquid. Moreover, from fig. 3.4.2 i.e.,. Turbidity vs. fraction of polymer, it is observed that the turbidity is minimum for 2ppm of polymer added, where most of points lie. So from these observations, we can conclude that 2ppm is the optimum concentration of polymer to be added in order to fasten the rate of settlement of fly ash. The polymer used for the above experiment is not completely soluble in water and imparts come turbidity to its solution with distilled water. The addition of higher concentration of polymer adds to the turbidity of the solution instead of decreasing the turbidity of the solution. So, the plot of 10ppm polymer being added has a higher turbidity as compared to the lower concentrations added.

CHAPTER 4

SETTLING RATE OF FLY ASH

OBJECTIVE

SEDIMENTATION

PROCEDURE

RESULTS

DISCUSSION

4.1 OBJECTIVE

The objective of this study is to calculate the settling rate of the fly ash from the fly ash-water slurry. The settling is due to gravity in a cylindrical tube. The usual rate of settling of the fly ash is calculated and is compared with that of the rate of settling with polymer being added to the slurry.

4.2 SEDIMENTATION

Sedimentation involves separation of a suspension or a slurry into a supernatant clear liquid that is essentially free from particles and a thick sludge containing a high concentration of solids. It is thus a process of phase separation. The sedimentor is called thickener if the concentrated sludge is our primary desired product and it is called clarifier if the objective is to recover the clear liquid from the suspension.

Industrial sedimentation is conducted as a continuous process in thickeners or gravity sedimentation tanks that are usually shallow tanks several meters in diameter that receive the slurry at the centre or side, permit the overflow of the supernatant liquid (over weirs) and produce a thick sludge from the bottom. The tank bottom is often made conical to facilitate the discharge of the underflow sludge. The tanks are also fitted with rakes (which are rotating railings with fixed vertical plates) positioned slightly above the tank bottom. These rakes scrap or sweep the tank floor, thereby directing the sludge towards the central discharge. When a suspension containing very fine particles is being handled, the rate of sedimentation will be extremely low. The rate can be artificially increased by adding an electrolyte which causes precipitation of colloidal particles and the formation of flocs. The suspension may also be heated to lower the viscosity of the liquid. Slow agitation of the slurry can also help in reducing the apparent viscosity of the suspension as well as assist in the consolidation of the sediment.[18]

4.3 PROCEDURE

The method of calculating the settling rate of fly ash is gravitational settling. In this method, a vertical glass cylinder (2 litre) was taken graduated in milliliters and was cleaned thoroughly with distilled water. Water and fly ash were taken in the cylinder in such a way that the ratio remained 7:3 by weight (i.e., 1400 gms water and 600 gms fly ash). Little amount of potassium permanganate was added to the slurry to make it easy for demarcation of the height. The fly ash-water slurry was stirred continuously with the help of a stirrer for some time. The height of the settles fly ash was noted down. The above steps were repeated after adding 2ppm polymer solution (CMC) to the fly ash-water slurry. The results were obtained both for usual gravitational settling and gravitational settling under the influence of polymer.[13/18]

Fig 4.3.1 Graduated vertical cylinder

4.4 RESULTS

Time (in min)	Height of the fly ash settled (in cms)	
	Without Polymer	With Polymer
0	37	36.8
2	35	34.5
4	33	32.3
6	31	30.2
8	29.5	28.6
10	28	27
12	27	26
14	26	25
16	25.2	24.5
18	24.4	23.6
20	23.8	23.1
22	23.2	22.7
24	22.7	22.1
26	22.3	21.7
28	21.9	21.3
30	21.5	21
32	21.2	20.7
34	20.8	20.4
36	20.5	20.1
38	20.2	19.7
40	19.9	19.5
42	19.6	19.3
44	19.3	19
46	19.1	18.9
48	18.9	18.7
50	18.6	18.4
52	18.4	
54	18.2	
56	18	
58	17.8	
60	17.6	
71	17	
80	16	
90	15.2	

Table 4.4.1 Height of fly ash settled with respect to time (with and without polymer)

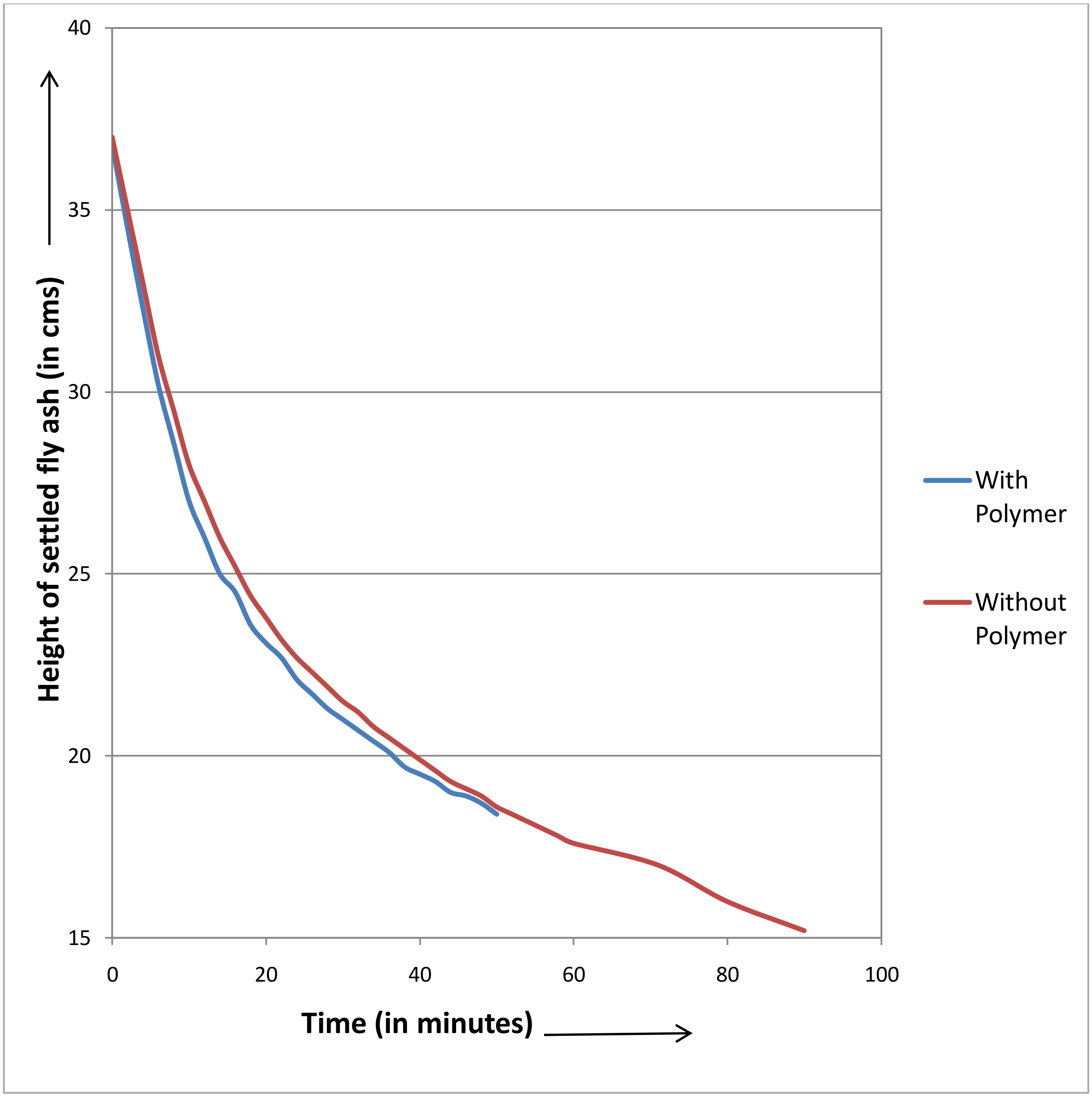

Fig 4.4.1 Height of settled fly ash vs. time

Time (in min)	Rate of settling of fly ash (in cms/min)	
	Without Polymer	With Polymer
2	1	1.15
4	1	1.1
6	1	1.05
8	0.75	0.8
10	0.75	0.8
12	0.5	0.5
14	0.5	0.5
16	0.4	0.25
18	0.4	0.45
20	0.3	0.25
22	0.3	0.2
24	0.25	0.3
26	0.2	0.2
28	0.2	0.2
30	0.2	0.15
32	0.15	0.15
34	0.2	0.15
36	0.15	0.15
38	0.15	0.2
40	0.15	0.1
42	0.15	0.1
44	0.15	0.15
46	0.1	0.05
48	0.1	0.1
50	0.15	0.15
52	0.1	
54	0.1	
56	0.1	
58	0.1	
60	0.1	
71	0.05	
80	0.11	
90	0.08	

Table 4.4.2 Rate of settling of fly ash with respect to time

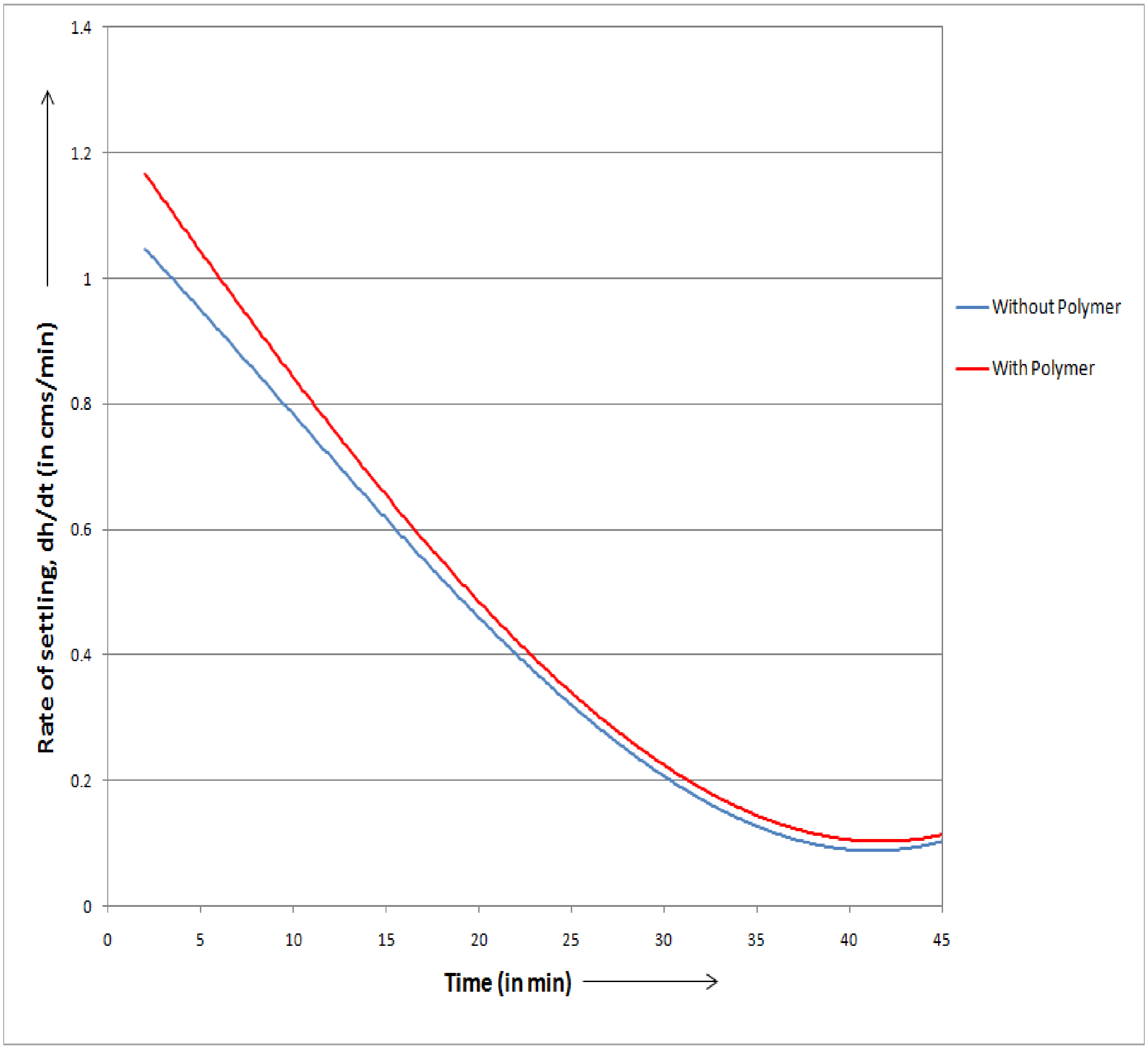

Fig. 4.4.2 Rate of settling vs. time

4.5 DISCUSSION

Buoyancy occurs in gravitational settling systems, and the main reason of sedimentation or gravitational settling is the difference in density of solids and liquids. If the densities of the suspended solids and the suspending liquid are close, then the sedimentation would not occur effectively. The objective of this method is to separate the solids from the liquid either because the solid/liquid are valuable or the two phases have to be separated before disposal. The time taken for settling is known as the residence time of the settling.

The advantage of the gravitational settling is it's low cost. But if the particle size is fine and/or the difference in density of solids and liquid is low, the residence time and the size of vessel required for the effective settlement would become excessive and uneconomic.

Sedimentation equipments are classified into:-

- Batch settling tanks
- Continuous operated units.

Batch settling tanks are simpler and have lesser use. These batch settling tanks are used for treating very small quantities of liquid. Continuous operated units are used extensively in various sedimentation operations. [18]

From fig. 4.4.1, i.e,. height of settled fly ash vs. time, it is observed that at any instant of time, the height of the settled fly ash is less for the case in which polymer is added, as compared to that of the case in which polymer is not added. So, the decrease in height of the settled fly ash is faster after the polymer of 2ppm concentration is added.

Moreover, from fig. 4.4.2, i.e,. rate of settling vs. time characteristics, it is observed that the rate of settling of fly ash at any instant of time is greater for the case in which polymer is added as compared to that of the case in which polymer is not added. Initially, there is a significant difference between both the rates of settling, but at the later part, the difference diminishes gradually. With passage of time, as the settling process proceeds, the concentration of the fly ash particles continuously increases in the settled slurry. As a result of which, the inter-particle attraction forces increases which results in diminishing the rate of settling process.

CHAPTER 5

METHODOLOGIES OF ASH POND DESIGN AND MAINTENANCE

INTRODUCTION

ASH POND LAYOUT

DESIGN OF BUND

MAINTENANCE OF ASH POND

STABILISATION OF SOILS

5.1 INTRODUCTION

Fly, a waste of thermal power plants ,has its production per annum having crossed the 100 million tones limit is causing several challenges. The thermal power plants do not always pay much attention towards the maintenance of ash ponds because of it being a waste. There are various ways for disposing off the fly ash produced in thermal power plants. Out of these ways disposing the fly ash in ash ponds in the form of slurry with water is one of the best alternatives. Fly ash form the electrostatic precipitator and bottom ash from the bottom of the boiler are mixed together and is subsequently mixed with water in a ratio varying from 1 part ash and 4 to 20 parts of water. The slurry is then pumped into the ash ponds which are located within or outside the thermal power plant. Depending on the distance and elevation difference, energy required for pumping is very high and requires booster pumps at intermediate locations.

No well design procedure or codal provision exists for the ash pond construction and maintenance. There are several examples of failures in ash ponds which resulted in leakage of fly ash-water slurry into the surrounding areas including water bodies and creating environmental hazard. The ash pond is designed economically and proper procedures are adopted to avoid any kind of leakage form the ash ponds. Hydrostatic pressure over the full height of the bund is minimized by decanting the water which travel away from the bund forming a sloping beech and only the ash being settled close to the bund.

5.2 ASH POND LAYOUT

Following points should be considered while selecting the location and layout of an ash pond:-

- The ash pond area should be close enough to the thermal power plant to reduce the pumping cost.

- Provisions for vertical and horizontal expansions should be made considering the life of the power plant.
- The area should be far away from any water bodies like river, lake etc. to avoid environmental hazard due to any leakage of fly ash-water slurry.
- In coastal areas where the ground water is already saline, the water form ash pond should be preferably drained through the bottom of the ash pond and this type of pond has greater stability.

In interior areas, it is preferable to have a fairly impervious stratum to prevent migration of ash water into the ground water to prevent its pollution.

In hilly terrain region, a suitable valley can be identified for forming the ash pond. In tsuch case the hill slopes will serve as the dyke for the pond and the cost would be less for construction.

In most of the ash ponds, the total area can be divided into compartments and while one is operational other can be evacuated off the deposited ash for reuse. The deposited fly ash can be used to increase the height of the embankment which ultimately increases the amount of fly ash slurry containing capacity of the pond. If the area consists of a single pond , the it is not possible to increase the height while the pond is in operation. Each pond should have a minimum area to ensure that there is adequate time available for settlement of ash particles while the slurry travels from the discharge point to the outlet. This distance should be a minimum of 200m to ensure that only clear water accumulates near the outlet point.

5.3 DESIGN OF BUND

The cost of construction of a single ash pond is generally high. But this cost can be reduced by constructing the ash pond in stages by various methods like a) upstream construction method, b) downstream construction method and c) centre line construction method. Each stage has an increasing or incrementing height of 3-5m. The above methods are described in brief and their advantages & disadvantages:-

5.3.1 Upstream construction method

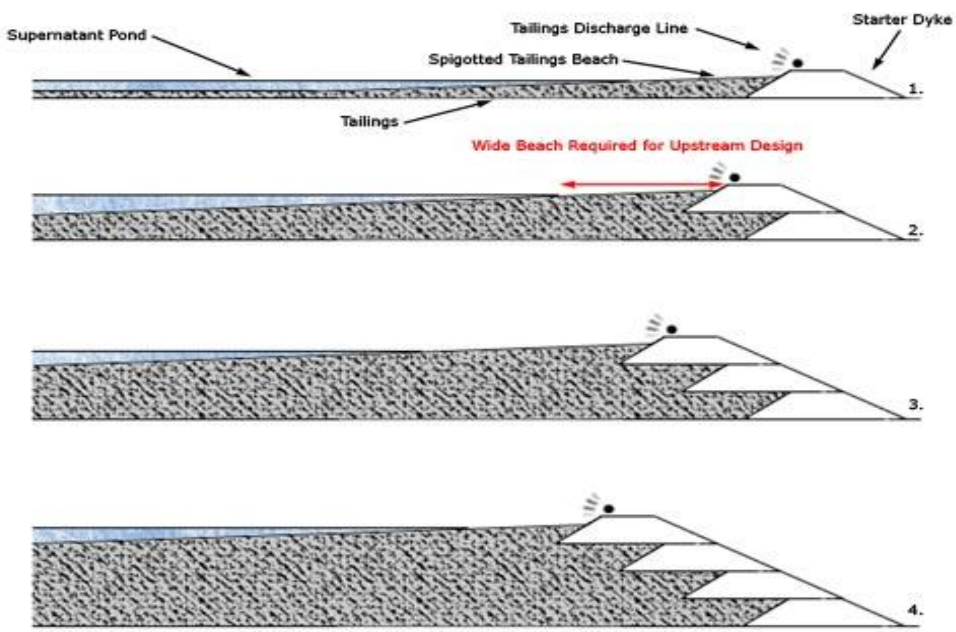

Fig 5.3.1.1 upstream construction method

This is the best design of raising the height of the dyke since it involves the least earthwork quantity. The above construction method has the minimum cost involved in it.

Following are the disadvantages of upstream construction method:-

- Since the total weight of the new construction is supported by the deposited ash, the ash deposition should be perfect in order to have adequate load bearing capacity.

- As the height of the pond increases, the area of the ash pond goes on decreasing and beyond certain stage, it becomes uneconomical to raise further height of the dyke.
- The drain at the upstream face should be well connected to the drain of the earlier segment, else ineffective drainage can result in reducing the stability of the slope.
- The ash pond cannot be operational while raising the height of the dyke by this method of construction. The pond needs to be dried to initiate the construction work.

5.3.2 Downstream construction method

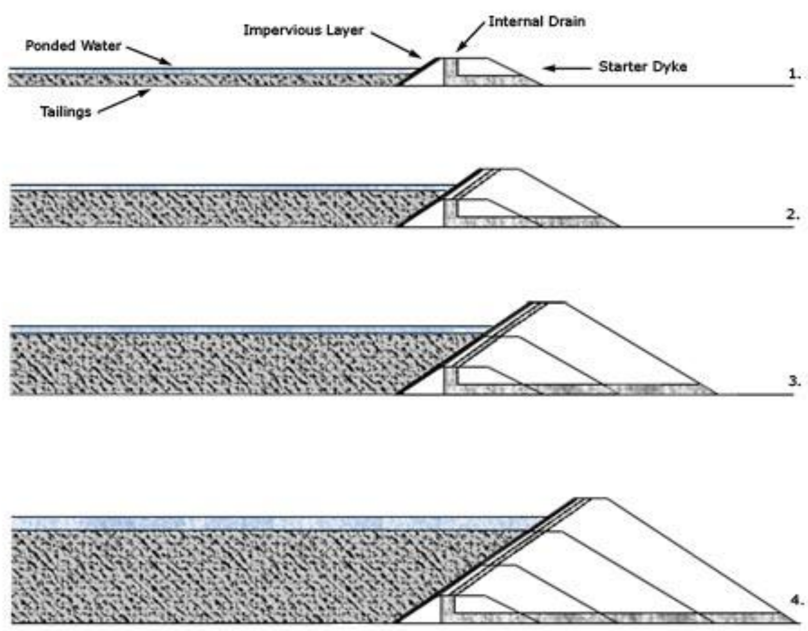

Fig. 5.3.2.1 Downstream construction method

After the pond gets filled upto the first stage, the pond height is increased by depositing the fly ash or earth on the downstream face of the dyke as shown in the figure. The advantage of this method of construction of ash pond is that the height of the dyke can be raised even if the pond is operational. Disadvantage of this method is that it involves approximately the same cost and amount of construction as in single stage construction.

5.3.3 centre line construction method

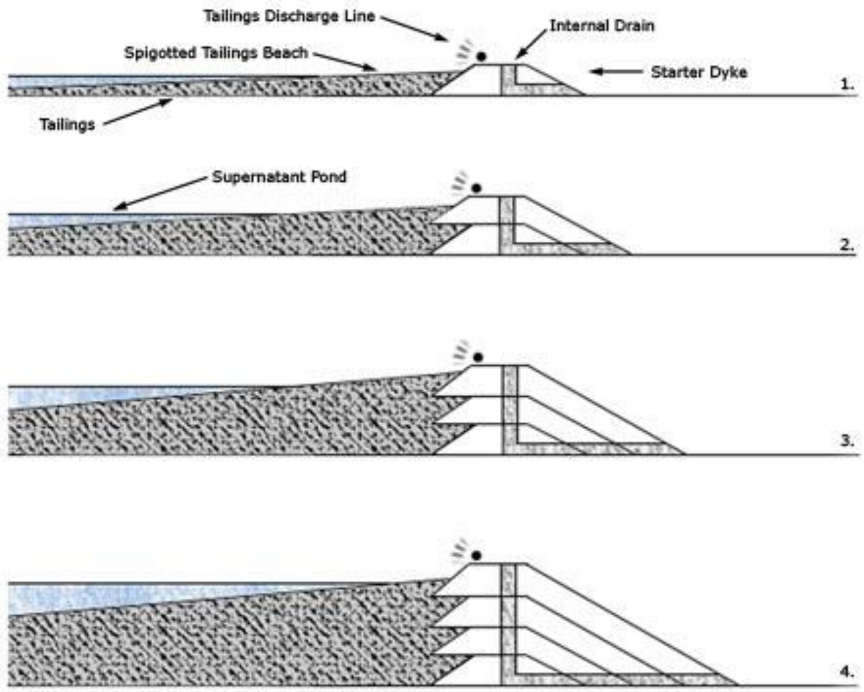

Fig. 5.3.3.1 Centre line construction method

In this method, after the pond gets filled upto the first stage, earth or fly ash is deposited on either side of the centre line of the dyke so that the centre line of the dyke remains at the same location as shown in the figure above. The amount of material required for raising the height of the dyke is less as compared to the downstream construction method. The construction cannot be initiated while the pond is operational.

Following aspects should be considered for this method of construction of bund:-

- The deposited particles should support the additional weight.
- Upstream face should be pitched or stone lined or precast lined to prevent erosion due to wind.
- The downstream should be grass turfed to prevent erosion due to rain.
- Proper decantation facilities should be provided to prevent the free water inside the pond to pile up to a large height. After decantation the clear water shall be drained successfully so that the suspended particles in the clear water remains within a maximum permissible limit of 100ppm.

5.4 MAINTENANCE OF ASH POND

The following guidelines should be followed for the proper maintenance of the ash pond:-

1) Method of slurry discharge:-

   For ash ponds, it is most important that the discharge points are uniformly distributed over the entire perimeter of the ash dyke. The coarser particles settle near the discharge point whereas the finer particles get carried away from the discharge point. Uniformly distributing discharge points provides adequate bearing capacity to the dyke being constructed on the existing segment of the ash pond. It is better that the discharge shall be simultaneously made from all the discharge points for more uniform beach formation along the perimeter. When the freeboard in the reservoir is less than 0.5m, then further discharge should be diverted to the other pond which should be ready. A minimum of 50m beach should be formed to maintain the stability of the downstream slope.

2) Decanting system:-

The quality of the decanted water should be satisfactory with total suspended solids less than 100 ppm. If the elevation of the outlet is low, then the suspended solids will increase. A delay in raising the outlet elevation will result in high concentration of ash. On the other hand, early raising will result in increased area of decanted water pond and reduce the beach length.

3) Raising of ash dyke:-

The pond already filled up with ash should be allowed to dry without any further discharge of slurry for minimum 1 month till the construction work for raising the height of the dyke hasn't begun. This type of pond should be provided with water sprinklers at regular intervals to prevent dust pollution. Too much of water spraying makes the surface of the ash pond swampy.

4) Maintenance of ash dyke:-

Following aspects should be considered for maintenance of the ash dyke:-

- Wet patches on the downstream slope formed due to inadequate beach length or choked drain should be prevented.
- Gulley formation on the slope due to rain should be prevented.
- Rat or animal holes should be covered.
- Growth of plants should be plugged.
- If the free board gets reduced due to erosion, then additional earth fill is provided on the top of the dyke.

- Total inflow and outflow to the ash dyke should be recorded.

5) Other general recommendations:-
   - The area of the ash dyke should be provided with fencing and unauthorized entry should be prohibited.
   - The entire dyke perimeter should have accessible roads.
   - A site office should be constructed with a full time engineer responsible for inspection and monitoring of the dyke. [19]

5.5 STABILISTION OF SOILS

Stabilization in a broader sense incorporates the various methods employed for modifying the properties of soil to improve its engineering performance. The soil used for the construction of the dyke shall compact and having good load bearing capacity. Mechanical stabilization involves a) changing the composition of soil by addition or removal of certain constituents or b) densification or compaction.

Other kind of stabilization includes cement stabilization, lime stabilization, bitumen stabilization, and chemical stabilization, thermal and electrical stabilization.

Following are the various methods of compaction:-

1) Compaction by vibroflotation.
2) Compaction by deep blasting.
3) Compaction by vacuum.
4) Compaction by vibration.[15]

6 CONCLUSIONS

The generation, composition, properties and classification of fly ash were studied in this report. Different recycling methods along with the difficulties in handling and disposal problems of fly ash were discussed which comes under the management of fly ash.

The experiment for determination of rate of decrease in turbidity of the clear liquid at the top of the fly ash-water solution, after the addition of the suitable polymer, concluded the following:-

- The rate of decrease in turbidity of the clear liquid was maximum for 2ppm concentration of the polymer solution added to the fly ash-water solution.
- The minimum of turbidity of the clear liquid was plotted for the fraction of polymer as 2ppm.

So it can be concluded that 2ppm is the optimum concentration of the polymer solution to be added, which results in the faster settlement of fly ash particles.

From the experiment for the determination of the rate of settling of fly ash after the addition of 2ppm polymer solution, it can be concluded that the rate of settling was faster as compared to the usual gravitational settling of fly ash in ash ponds.

The design of an ash pond involved mathematical approach towards dam construction which is out of the scope of this report. So the aspects to be considered during layout and design of an ash pond are provided in the report.

But the experiment conducted for the determination of optimum concentration of polymer is at low scale and the optimum concentration determined has lesser effect on the settling of fly ash in industrial scale. The above concentration used in the the determination of settling rate signifies a very small difference in the rate of settling as compared to the usual settling process in thermal power plants.

7 FUTURE WORK

The report comprises of the experiment carried out on one sample of fly ash from NTPC, kaniha and with the use of one polymer sample (CMC). Future works can be carried out using the bottom ash and fly ash samples from various other thermal power plants. Moreover, other suitable polymers like chitosan, guar gum, acryl amide, polyethylenimine etc. can be used as flocculants for the faster settling of fly ash particles.

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