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Effect of ClayContent on the Hydraulic Conductivityof Silty Soils

Shahid Noor[1], Chitra R[2]., Manish Gupta[3], Amardeep Singh[4]

[1]*Scientist 'C', Central Soil and Materials Research Station, MoWR, RD & GR, New Delhi, India.*
[2,3]*Scientist 'E', Central Soil and Materials Research Station, MoWR, RD & GR, New Delhi, India.*
[4]*Scientist 'D', Central Soil and Materials Research Station, MoWR, RD & GR, New Delhi, India.*

Abstract- Hydraulic conductivity or Permeability is one of important engineering property of soils which is used in the design of embankments, filters, clay liners and other water retaining structures. The permeability of soil depends upon the various soil characteristics likeparticle size, particle shape, void ratio, soil structure and permeate properties. The present study was carried out for the construction of starter dykes for the ash dykes of a thermal power project. The construction of the statter dyke was proposed with the locally available soil. Since the permeability of locally available construction material (soil) was high, which can not be used for the construction of Ash dyke. The Clay (Bentonite) was used to reduce the permeability of soil. The paper presents the effect of clay on the Permeability of the soil.
Key Words: Earthen Dam, Particle Size Distribution, Void Ratio, Permeability, Standard Proctor Compaction, Bentonite

I. INTRODUCTION

The present study was carried out for the construction of starter dykesfor the ash pondsfor a coal based Thermal Power Project, Tanda Thermal Power Project at Tanda, Uttar Pradesh. The coal based thermal power project generate large quantities of ash as by-product. In India,there are over 145 thermal power plants with an installed power capacity of 1,38,916 MW and generate about 185 Million tonnes of fly ash per year. The utilisation of this fly ash poses a big challenge before the thermal power projects. At present, the fly ash utilization for different purposes is 102.54 Million tonnes and percentage of fly ash utilization is 55.7 %.

There are two types of ash disposal system practiced by thermal power plants in India – wet disposal system and dry disposal system. In the wet disposal system, the ash is mixed with water to make slurry which is then pumped to the ash disposal lagoons through pipelines. At the disposal area, dykes are constructed to form ash ponds, into which the ash slurry is discharged. Most thermal power plants in India dispose ash by the wet disposal system. The present study was carried out for the construction of a starter dykes for the new ash ponds with local available soil and use of the clay (Bentonite) to achieve the desired permeability (less than 10^{-7} cm/sec.) of soil.

II. TANDA THERMAL POWER PROJECT

Tanda Thermal Power Project is located in Ambedkar Nagar district in the state of Uttar Pradesh. The power project is one of the coal based power projects of NTPC. The coal for the power Project is sourced from North Karnpura Coal Fields. Source of water for the power project is from Tanda Pump Canal on Saryu River. The power project comprises of 6 units with a total generation capacity of power project is 440 MW. The NTPC Ltd. has planned to increase the power generation capacity of project and Stage II has been started under which, it is proposed to set up the unit 5 and 6 with a power generation capacity of 1320 MW.

The scheme for ash disposal system envisages construction of one storage lagoon with sedimentation basin at Ash Dyke-1 location and two storage lagoons & a common over flow lagoon at Ash dyke-2 location at the ash disposal areas. The proposed ash dyke is within 5 km from the project boundary. The total length of the starter dyke for both the dykes is estimated to be about 11.0 km. The layout plan of the starter dyke for the ash pond-1 and ash pond-2 are presented in Figures 1 &2 and the cross section of the starter dyke is presented in Figure 3.

III. BOROW AREAS

A total of four borrow areas in the vicinity of the power project were identified and onesoil sample from each borrow area was collected for ascertaining their suitability as construction material. The soil samples were collected from a depth of 1.00 m to 1.50 m.

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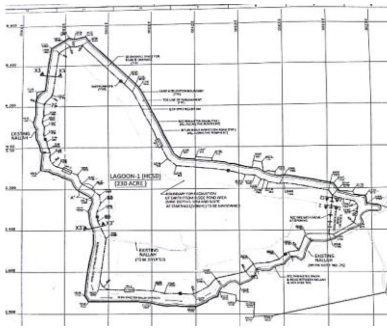


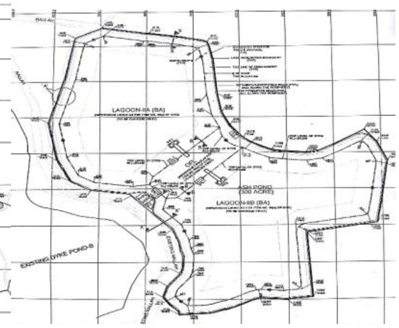


Figure 1:Layout Plan of Ash Pond-1 Figure 2: Layout Plan of Ash Pond-2

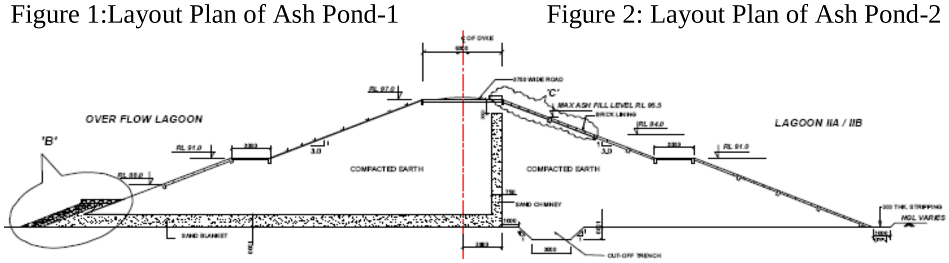


Figure 3 :Cross section of Starter Dyke at Tanda Thermal Power Project

IV. THE INVESTIGATION METHOD

The laboratory investigations was carried out on the all soil samples and it was found that the soil samples collected from the borrow areas namely village Samharia and village Khattegaon possess impervious drainage characteristics and the values of Coefficient of Permeability were found to be 5.14 x 10^{-7} cm/sec and 6.50 x 10^{-7} cm/sec respectively and the soil samples from these borrow areas can be used for the construction of the ash dyke. While the remaining two soil samples collected from the borrow areas namely Near Jaganpur Turn of old ash dyke and Beside the road towards village Ladanpur and Kakrahi possess the semi pervious drainage characteristics and the values of Coefficient of Permeability were found to be 6.87 x 10^{-6} cm/sec and 8.18 x 10^{-6} cm/sec respectively.

Since the soil samples from the borrow areas namely Near Jaganpur Turn of old ash dyke(Sample A) and Beside the road towards village Ladanpur and Kakrahi(Sample B)possess the semi pervious drainage characteristics, it was proposed that the Clay (Bentonite) shall be mixed with these soils to achieve the impervious drainage characteristics ($k < 1\times10^{-7}$ cm/sec.).

The bentonite was mixed with both the soil samples A & B in proportion of 3%, 5% , 7% and 9% by volume and a total of 6 nos. blended soil samples are prepared as detailed below in Table 1.

Table -1: Details of the Blended (Soil + Bentonite Mix.) Soil Samples

S. No.	Sample No.	Bentonite, % by volume
1	Sample A	0 %
2	Sample B	0 %
3	Sample 1	Sample A+ 3% Bentonite
4	Sample 2	Sample A+ 5% Bentonite
5	Sample 3	Sample A+ 7% Bentonite
6	Sample 4	Sample B + 3% Bentonite
7	Sample 5	Sample B + 5% Bentonite
8	Sample 6	Sample B + 7% Bentonite

V. LABORATORY INVESTIGATIONS

To characterize the borrow area material (Sample A & Sample B) and Clay (Bentonite), the various laboratory tests viz. Mechanical Analysis, Atterberg's Limits, Standard Proctor Compaction Test, Laboratory Permeability Testwere conducted on the all the threesoil samples. The blended soils samples (Soil+ Bentonite mix.) were subjected to the Standard Proctor Compaction test and Laboratory Permeability test to assess the effect of clay on the soil permeability characteristics.

5.1 Mechanical Analysis

5.1.1 Soil

The grain size analysis of the both the soil samples (Sample A and Sample B) indicate that the tested soil samples possess fine sand sizes followed by the silt sizes and clay sizes. The coarse sand sizes and gravel sizes were absent in both the tested soil samples. The grain sizes of the tested soil samples indicate that the clay sizes vary from 2.4 % to 8.6 %, silt sizes vary from 20.4 % to 39.3 %, fine sand sizes vary from 57.9 % to 70.7 % and medium sand sizes vary from 0.3 % to 0.4 %. The coarse sand sizes and gravel sizes were absent in both the tested soil samples. The plasticity index values of the tested soil samples indicate that both the soil samples exhibit non plastic characteristics.

Based on the results of grain size distribution and Atterberg limits tests both the tested soil sample fall under SM (Silty Sand) group of Bureau of Indian Standard soil classification system. The graphical representation of grain size distribution of the tested soil samples is presented in Figure 4.

5.1.2 Bentonite

The grain size analysis of the tested Clay (Bentonite)sample indicate that soil samples possess predominantly clay sizes followed by the silt and sand sizes. The coarse sand sizes and gravel sizes were totally absent in the tested soil sample. The grain sizes of the tested Bentonite sample indicates that the clay sizes was 90.9 %, silt sizes 8.0 %, fine sand sizes 0.9 % and medium sand sizes 0.2 %. The coarse sand sizes and gravel sizes were absent in the tested soil sample. The plasticity index value of the tested Clay (Bentonite) sample indicates that the tested soil sample possesses the high plasticity characteristics.

Based on the results of grain size distribution and Atterberg limits tests, the Clay (Bentonite) sample falls under CH (Clay with High Compressibility) group of Bureau of Indian Standard soil classification system.The graphical representation of grain size distribution of the tested soil samples is presented in Figure 3.

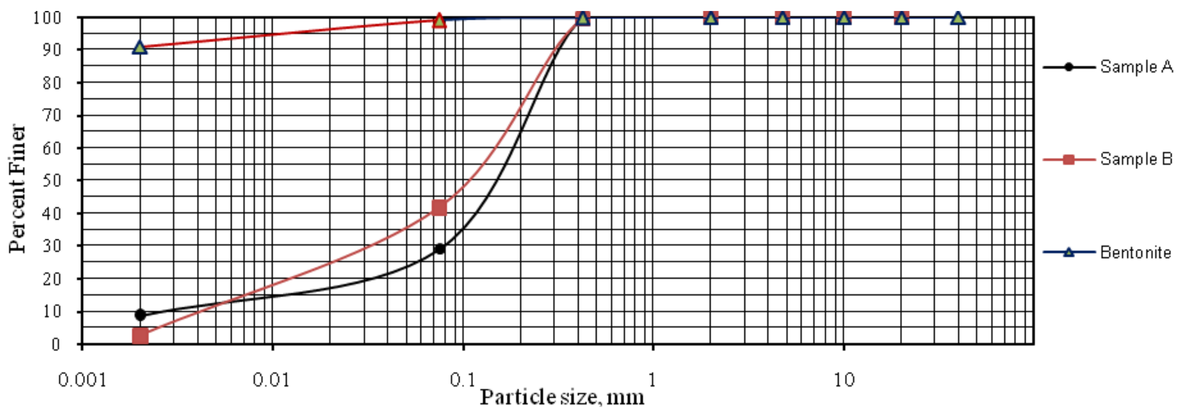


Figure 4: Grain Size distribution of BorrowAreas Soil and Bentonite

5.2 Standard Proctor Compaction Test

All the 8 soil samples (2 soil samples + 6 blended soil samples) were subjected to Standard Proctor Compaction test. The values of Maximum Dry Density and Optimum Moisture Content of the tested blended soil samples vary from 1.730 g/cc to 1.861 g/cc and 10.5 % to 16.9 % respectively and the graphical representations of the Standard Proctor Compaction tests of the tested materials are presented in Figure 5.

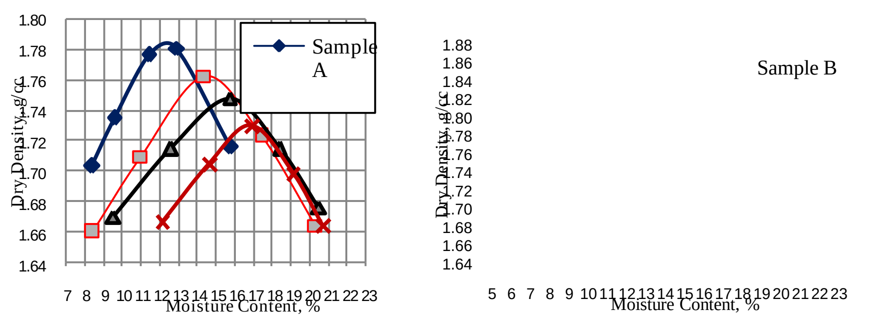


Figure 5: Standard Proctor Compaction Curves of Blended Soil Samples A and B

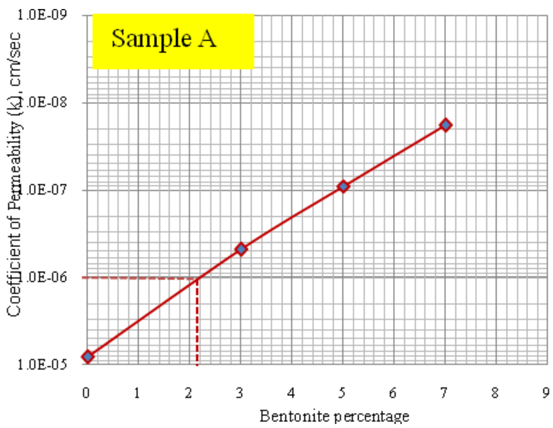
5.3 Laboratory Permeability Test

All the 8 soil samples (2 soil samples + 6 blended soil samples) weresubjected to the laboratory permeability test using falling head method. The soil samples were compacted at 98% of the maximum dry density. The values of the Coefficient of Permeability (k) for soil samples vary from 6.87×10^{-6} cm/sec to 8.18×10^{-6} cm/sec and for blended soil samples vary from 2.61×10^{-9} cm/sec to 4.82×10^{-7} cm/sec and presented in Table 2.

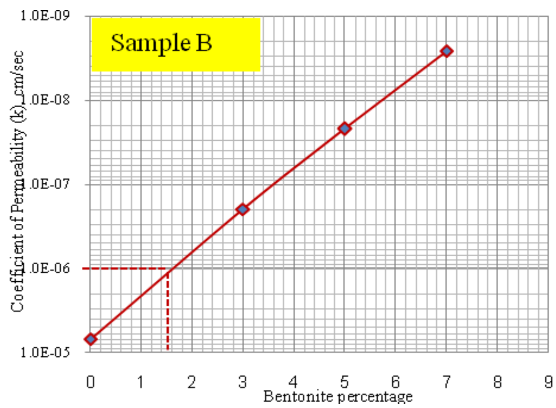
Table -2: Coefficients of Permeability for the Blended (Soil + Bentonite Mix.) Soil Samples

Sample No.	Bentonite, % by Volume	Coefficient of Permeability (k) cm/sec	Drainage Characteristics
Sample A	0 %	8.18×10^{-6}	Semi pervious
	3 %	4.82×10^{-7}	Impervious
	5 %	9.03×10^{-8}	Impervious
	7 %	1.83×10^{-8}	Impervious
Sample B	0 %	6.87×10^{-6}	Semi pervious
	3 %	1.97×10^{-7}	Impervious
	5 %	2.21×10^{-8}	Impervious
	7 %	2.61×10^{-9}	Impervious

The results of laboratory permeability test indicate that tested soil samples (Samples A & B) possess semi pervious drainage characteristics and blended soil samples possess impervious drainage characteristics and the results are presented in Table - 2. The graphical representations of the Laboratory Permeability test results of the tested blended soil samples are presented in Figure 6.



(Sample A)



Sample B

Figure 6: Coefficient of Permeability(k) Vs. Bentonite Percentage for Blended Soil Samples A and B

VI. CONCLUSIONS

Based on the findings of the laboratory investigations carried out on the blended soil samples for construction of starter dyke for Ash Pond -1 and Ash Pond - 2 at Tanda Thermal Power Project, Stage – II, Tanda, Uttar Pradesh, the following conclusions have been arrived at.

- ❖ The grain size analysis of the tested soil samples indicate that both soil samples possess fine sand sizes followed by the silt sizes and clay sizes. The coarse sand sizes and gravel sizes were absent in both the tested soil samples.
- ❖ The grain size analysis of the tested Bentonite sample indicates that sample possesses predominantly clay sizes followed by the silt and sand sizes. The coarse sand sizes and gravel sizes were absent in the tested Bentonite sample.
- ❖ The plasticity index values of the tested soil samples indicate that both the tested soil samples exhibit non plastic characteristics.
- ❖ The plasticity index value of the tested Bentonite sample indicates that the tested soil sample possesses the high plasticity characteristics.

- Based on the results of grain size distribution and Atterberg limits tests, both the tested soil samples fall under SM (Silty Sand) group of Bureau of Indian Standard soil classification system.
- Based on the results of grain size distribution and Atterberg limits tests, the Bentonitesample falls under CH (Clay with High Compressibility) group of Bureau of Indian Standard soil classification system.
- The values of Maximum Dry Density and Optimum Moisture Content of the tested soil samples (Sample A & B) vary from 1.784 g/cc to 1.861 g/cc and 10.5 % to 12.4 % respectively.
- Based on the Standard Proctor Compaction tests, it is inferred that the tested soil samples are capable of achieving very good compaction densities.
- The values of Maximum Dry Density and Optimum Moisture Content of the tested blended soil samples vary from 1.730 g/cc to 1.823 g/cc and 12.8 % to 16.9 % respectively.
- Based on the Standard Proctor Compaction tests, it is inferred that the tested blended soil samples are capable of achieving very good compaction densities.
- The values of the Coefficient of Permeability (k) of the tested soil samples (Sample A & B) vary from 6.87×10^{-6} cm/sec to 8.18×10^{-6} cm/sec.
- The results of laboratory permeability test indicate that that both the tested soil samples possess the semi pervious drainage characteristics.
- The values of the Coefficient of Permeability (k) of the tested blended soil samples vary from 2.61×10^{-9} cm/sec to 4.82×10^{-7} cm/sec.
- The results of laboratory permeability test indicate that that all the tested blended soil samples possess the impervious drainage characteristics.

VII. RECOMMENDATIONS

- The impervious drainage characteristics of soil from borrow area A (Sample A) can be achieved with a Bentonite percentage of 2.2 %. But, for the practical consideration, a dosage of 3.0 % Bentnite is recommended.
- The impervious drainage characteristics of soil the borrow area B (Sample B) can be achieved with a Bentonite percentage of 1.6 %. But, for the practical consideration, a dosage of 2.0 % Bentonite is recommended.

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