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# STUDY OF HYDRAULIC CONDUCTIVITY AND STRENGTH PROPERTIES OF FLYASH MIXED WITH CEMENT FOR STABILIZATION OF SLOPES AND EMBANKMENTS

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**ABSTRACT**

***Earthen embankments are the commonly seen structures which are susceptible to failure. One of the most frequently seen ways of failure is the failure due to seepage. Almost one third of the failure cases are due to seepage. So the aim of the present study is to solve out the problem using fly ash. The particle size distribution of fly ash collected from NALCO· was studied and compared with soil. To add more resistance to permeability and binding ability cement was added to fly ash with different percentage (5, IO and I 5%). The permeability of fly ash and its mixtures with cement were studied by falling head method and compared with that of soil. It was seen that soil has higher value of hydraulic conductivity than that of fly ash and the fly ash having highest percentage of cement had the lowest value of hydraulic conductivity. The addition of cement had decreased the permeability of the fly ash. The strength properties were also studied by analysing the unconfined compressive strength and cohesion. The Universal Testing Machine was used to perform the unconfined compression test at UTM laboratory, CAET, OUAT. The cylindrical samples which were used for hydraulic conductivity test were subjected to unconfined compression test. It was seen that fly ash had higher value of unconfined compressive strength than that of soil. The unconfined compressive strength was increased with increase in the percentage of cement. The cohesion decreased when coefficient of permeability increased. The fly ash specimen with J 5% cement had the highest strength and the lowest value of hydraulic conductivity as the best replacement of soil.***

*KEYWORDS:* **Flyash, Hydraulic Conductivity, Cement, Stabilization, Slopes**

## INTRODUCTION

Slopes and embankments are the most ancient and commonly seen structures in India. The main reason for it is that it can be built with naturally available materials with very less use of equipments for construction. In the older days the construction cost of the earthen embankments was higher however the modern developments in the earth moving equipments has reduced significantly the cost of construction of the earthen embankment. Simultaneously the cost of embankments in gravity dams has increased because of the increase in the cost of concrete, masonry etc. In this scenario earthen embankments in dams has become the best choice as these are cheaper, can utilize locally available materials and especially these require less skilled laborers.

Earthen embankments are not very rigid. Therefore these are susceptible to failure. And one of the most important causes of its failure is seepage. Almost one third of the earthen embankments fail due to seepage (Garg, 2014). Concentrated seepage through the embankment body or through its foundation leads to piping or sloughing and the subsequent failure of the dam occurs. Piping is the process of progressive erosion and subsequent removal of soil particles from within the embankment structure and sloughing is the removal of the soil particles from the wet downstream face. These phenomena occur due to the following causes (Suresh, 2009)

- The flow of seepage water causes an erosive force, which leads to dislodge the soil particles from the soil mass. These dislodged particles are migrated into voids of the filter materials, downstream side. Then clogging occurs, which results in the failure of the drainage system.
- The seepage flow causes a differential pore pressure. The pore pressure tends to lift up the soil mass which causes boiling action.
- Piping is the reason of the internal erosion occurring inside the embankment structure due to the flow of seepage water.
- Due to the development of the pore pressure the soil mass becomes weak; as a result failure of the earthen embankment occurs.

- When water level inside dams in high more seepage water flow into the embankment. So the embankment body gets saturated. Thus the embankment becomes weak to withstand the pore water pressure and the saturated portion of the embankment is dislodged. This results in the complete failure of the structure.

Fly ash is a material that can be taken for consideration as a low permeable mass, in the construction of different hydraulic structures. And fly ash when mixed with cement gives lower permeability than soil.(Gupta *et al,* 2004). Therefore this makes it one of the desirable materials for use in the earthen embankments.

Fly ash is a byproduct that is released from the thermal power plants. it is produced from the combustion of the pulverized coal. It is discharged into the atmosphere after the dust collection system removes it from the combustion gases. The term "Fly Ash" was first used in the electrical power industries in USA in 1930. The first comprehensive data on its use in concrete was reported in 1937 by Davis et al. Its major practical action was in Hungry Horse Dam, USA in 1948.Worldwide acceptance of fly ash was in I 970s when the energy costs were rapidly increased.(Ramezanianpour, 2014)

The diameter of fly ash particle usually varies between I µm to I 50µm. The type of dust collection system determines its size. The chemical composition of fly ash is determined by the amount of incombustible matter in the coal. However more than 85% of most fly ash ashes comprise chemical compounds and glasses fonned from the elements silicon, aluminium, iron, calcium & magnesium. The chemical analysis of fly ash shows that SiO2, Al2O3, Fe2O3 and CaO are the major constituents of fly ash. the minor components of it are MgO,Na2O,K2O,SO3,MnO,TiO2 and C (Ramezanianpour, 2014).

The production of fly ash in India was around 160 million tons in the year 2014 and is expected to rise to 225 million tons by the year 20 I 7. And only 60% of it is used properly. So it is very important to use the fly ash properly. If left unchecked the storage of fly ash produced from I MW plant will require an area of I acre (Rengaswamy and Mohan, 1999). Moreover it is hazardous to the environment of an area. Therefore if its proper management will not be undertaken properly this will result in the degradation of land, water and atmosphere.

## REVIEW OF LITERATURE

Chakraborti *et al.* (2009) studied to evaluate changes in suspended particle- size distribution as a function of variations in mixing conditions. Suspensions were taken from Lake Erie near Buffalo, N.Y., and mixed in a standard jar apparatus using six different mixing intensities. These suspensions were monitored for changes in particle size and shape using a noninvasive image analysis technique. A relationship was derived between suspended particle sizes and mixing intensity, based on estimates of energy dissipation rates. The regression was also compared with mixing of suspensions taken from two other systems in the Buffalo, N.Y. area, a small lake on the University at Buffalo campus, and the Buffalo River (Buffalo, N.Y.). Samples from all three sites behaved similarly in terms of particle size as a function of mixing conditions. Estimates for dissipation rates in natural systems were then used to relate the laboratory data to field conditions. Dissipation rates produced at slow mixing speeds in the jar were similar to those calculated for more energetic riverine and estuarine environments. Results of this study should be useful for understanding suspended particle-size distributions under a variety of mixing conditions, and is of direct interest in a wide range of sediment and contaminant transport problems.

Shanthakumar *et al.* (2010) studied on how particle size of the fly ash governs its utilization in various engineering projects. This could be obtained by either conducting dry- and wet-sieving or hydrometer analysis. Though, fora material with a particle size less than 75micron, the hydrometer analysis is best suited, difficulties associated with it are well known. This necessitates application of advanced techniques such as laser particle analysis, soft imaging, etc. However, not only are these techniques cost intensive, but they also fail to yield reliable results, particularly, if the material is heterogeneous and the particles are coarser. This calls for resorting to dry or wet sieving for accurate determination of particle-size distribution characteristics. However, not many studies have been conducted that critically evaluate and compare the results obtained from these methodologies in relation to those obtained from the hydrometer tests. With this in view, investigations were conducted on different fly ashes by conducting dry sieving. In addition, the fraction of fly ash retained on 45micron sieve was determined by employing wet sieving. Results obtained from these methodologies are critically examined. It has been demonstrated that dry-sieving with plastic balls yields reliable results in less time as compared to the wet sieving and hence this methodology would be better suited for pozzolanic materials.

Wang *et al.* (2013) focused on the effects of particle size distribution on shear strength of accumulation soil. A series of direct shear box tests and tri-axial tests were performed to characterize the shear strength of the accumulation soil. Results from the direct shear tests indicate that the range of the angle of shearing resistance of the accumulation soil is 33.5-54.6°, and those from the tri-axial tests indicate that the angle is 37.2-50.7°. The basic properties of the soil, such as median particle diameter, coefficient of uniformity, and gravel content, were used to analyze the effects. The angle of shearing resistance is generally increasing with increasing median particle diameter and gravel content and decreasing with increasing coefficient of uniformity.

Singh (2014) discusses grain size analysis, distribution, and grading. In grain size analysis, grain sizes are divided into class intervals, and the relative frequency or proportion is determined for each class interval. The grading entropy theory is used to define particle migration criteria, explain the particle breakage process, and construct the transfer function between soil physical properties and the grading curve. The concept of grading entropy can be explained from a geometric point of view in terms of the concept of simplex. The chapter discusses some properties of the entropy diagram analytically, especially for the maximum and minimum boundaries, as they are important in different applications of the grading entropy, including construction of transfer functions.

## MATERIALS AND METHODS

### 1.1 Collection of Samples

The fly ash sample was collected from NALCO thermal power station, Anugul. It was collected from the fly ash dump yard of the power plant station. And the soil sample was collected from the farm of Odisha University of Agriculture & Technology.

Both the samples were kept in the soil and water conservation laboratory of College of Agricultural Engineering and Technology as the experiments had to be done in that laboratory itself.

### 1.2 Sieve Analysis

Sieve analysis is a procedure used to find out the particle size distribution of a granular material. It is an important procedure as the particle size distribution gives an idea about how a material behaves in use. As hydraulic conductivity is an important aspect of the research so it becomes essential to find out the particle size distribution.

Before taking the samples for sieve analysis oven drying was done to remove access moisture from the sample. The samples were highly sticky due to moisture. So it was necessary to remove moisture from it to perform sieve analysis. For oven drying the sample were kept at 105°C for 24 hours inside the hot air oven.

500g of each of both soil and fly ash the oven dried samples were taken for analysis. The weighing was done by the digital weighing balance. Different set of sieves were selected for soil and fly ash as the sizes of soil and fly ash were very different.

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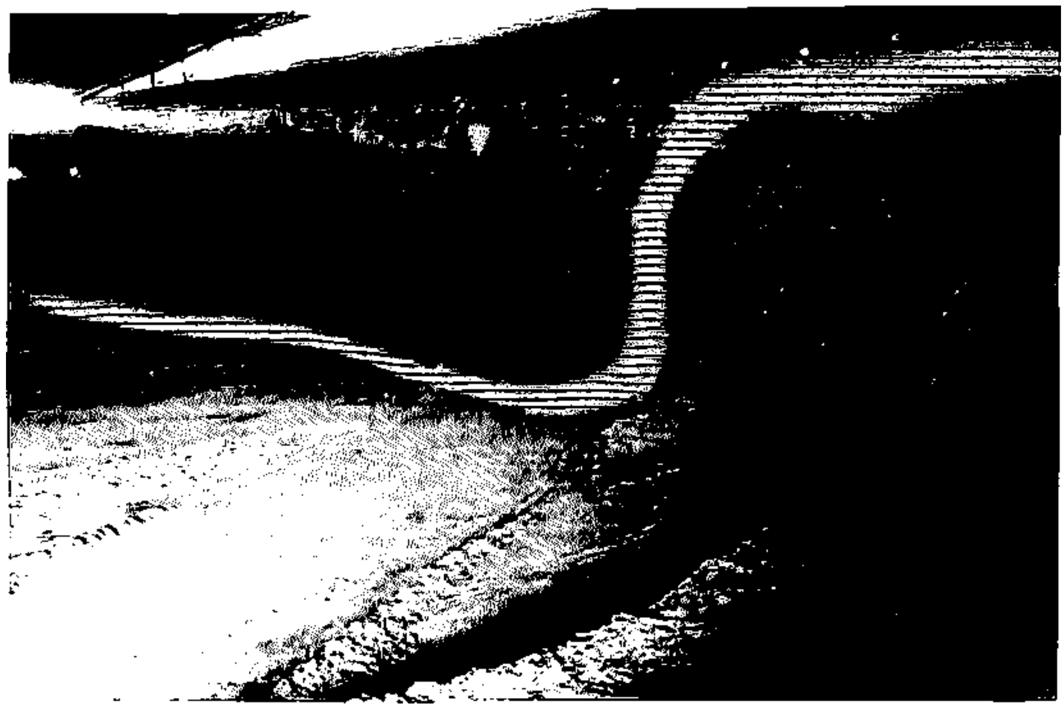


**Fig. 3.1 Sample collection site**

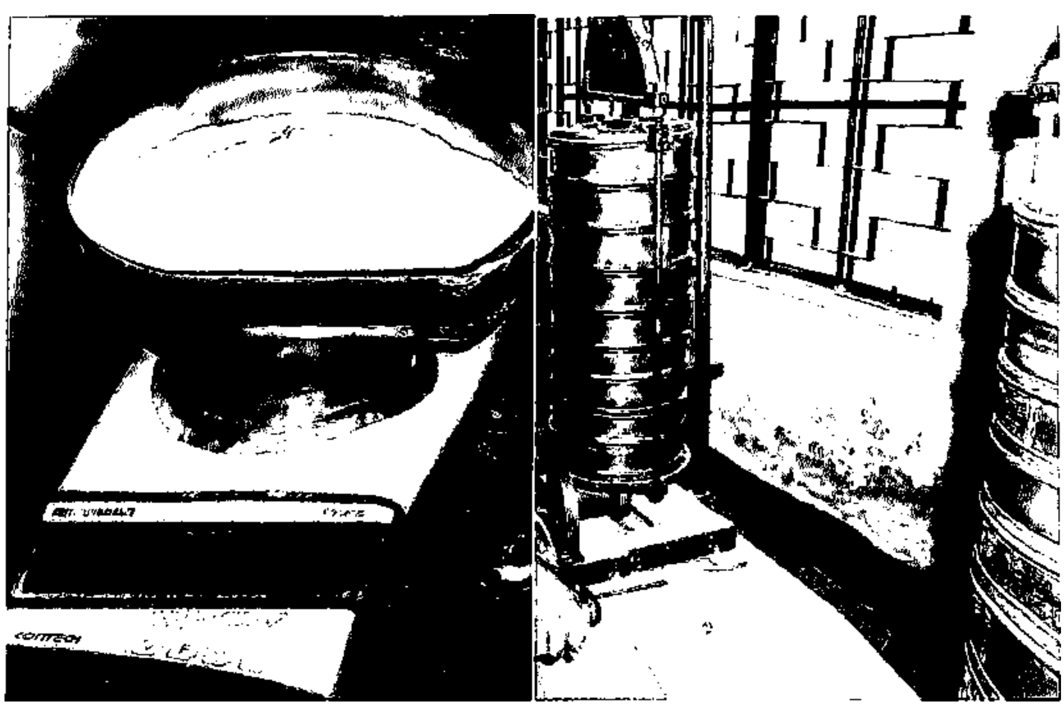


**Fig. 3.2 Sample weighing & sieve analysis**

**Table 3.1 Set of sieves for soil and fly ash**

| IS sieve size in mm | |
|---|---|
| soil | Fly ash |
| 1.180 | 1.180 |
| 1 | 0.600 |
| 0.710 | 0.180 |
| 0.500 | 0.090 |
| 0.355 | 0.075 |
| 0.212 | 0.063 |
| 0.150 | 0.045 |
| Pan | 0.025 |
| | pan |

Mechanical sieve shaker was used for sieving operations. The sieves were arranged in descending order from the top to bottom and fitted to the set up. 500g sample was kept on the top of the sieve and shaking was done. 20 minutes of hand shaking was given to the sample. Same procedure was followed for both fly ash and soil with the respective set of sieves. After the shaking process the mass of sample retained in each sieve is measured by weighing and the percentage of them with respect to total mass was calculated. Subsequently the percentage finer and cumulative percentage finer were calculated for analysis.

### 3.3 Determination of Specific Gravity

The specific gravity of all the samples was determined using the 200ml cylindrical flask available in the laboratory. At first the samples were dried in the oven for 24hours at 10s·c. The dried sample is cooled to ambient temperature. Empty weight of the flask was taken. Then the flask is partially filled with the sample and the subsequent weight is measured. The weight of flask filled with water up to the 200ml mark and weighed. The specific gravity is determined using the following formula

$$G = \frac{W2-W1}{200-(W3-W2)}$$

Where, $W_1$= weight of empty flask in gm

Wz=weight of flask with dry sample in gm

$W_3$=weight of flask with water and dry sample in gm

G= specific gravity of the sample

### 3.4 Determination of Hydraulic Conductivity

Hydraulic conductivity is otherwise known as the coefficient of permeability. Permeability is defined as the property of porous material which permits the passage of water through its interconnecting voids. The Darcy's law (1856) of flow of water through soil states that the rate of flow of water is directly proportional to hydraulic gradient and cross sectional area i.e.,

$$q = k.i.A$$

Where, q = discharge per unit time

i= hydraulic gradient

A= area of cross section

k== coefficient of permeability

The coefficient of permeability can be determined by the following methods:-

!. Laboratory methods
   - Constant head permeability test
   - Falling head permeability test
2. Field methods
   - Pumping-out test
   - Pumping-in test
3. Indirect methods
   - Computation from grain size or specific surface
   - Horizontal capillarity test
   - Consolidation test data

Falling head permeability test was used to determine the hydraulic conductivity of soil and fly ash samples. A stand pipe of known cross section area A is fitted over the permeameter and water is allowed to run down. The water level in the stand pipe constantly falls and water flows. Observations are taken when after steady state flow is reached. The head at any instant t is equal to the difference in the water level and in the stand pipe and bottom Of the tank. h1 and h2 are the heads at time intervals $t_1$ and $t_2$ respectively. Lis the length of the sample enclosed between the porous plates.

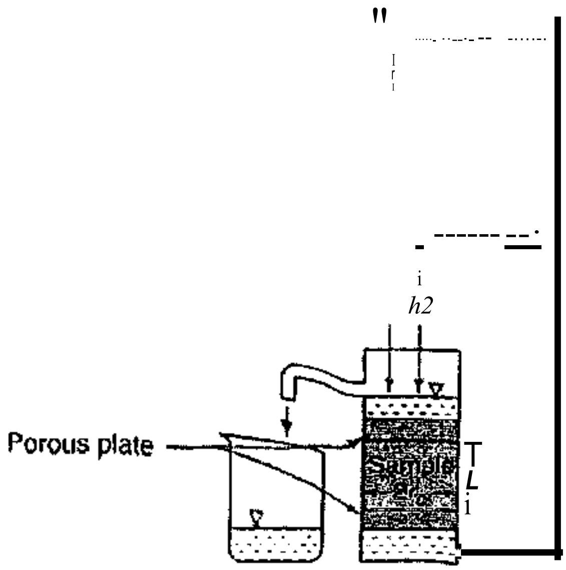



**Fig. 3.3 Falling head permeability test**

In the research Jodhpur permeameter was used to determine the hydraulic conductivity of the samples. It consists of permeameter mould, water inlet nozzle, air release valve, dynamic compaction base plate, perforated base plate, static flanged end-plugs, compaction collars and split collars, pad of filter paper, flexible tubing and stand pipe.

**Table 3.2 Dimensions of Jodhpur permeameter**

| | |
|---|---|
| Height of the mould (L) | 16.4cm |
| Diameter of the mould (D) | 10cm |
| Diameter of the stand pipe (d) | 5cm |
| Volume of the mould $M = (\frac{\pi D^2 \times L}{4} - v)$ | 1285.5 $cm^3$ |
| Volume of projection of the perforated base plate (v) | 3.1176 $cm^3$ |
| Area of the stand pipe (a) | 19.63 $cm^2$ |
| Area of the mould (A) | 78.57 $cm^2$ |

The pad filter was provided below the sample so that no material could pass with water. The sample was compacted in three layers. The mould is tightened. Water was allowed to flow in the stand pipe. Heads were measured at different time intervals and time readings were taken with the help of a stop watch.

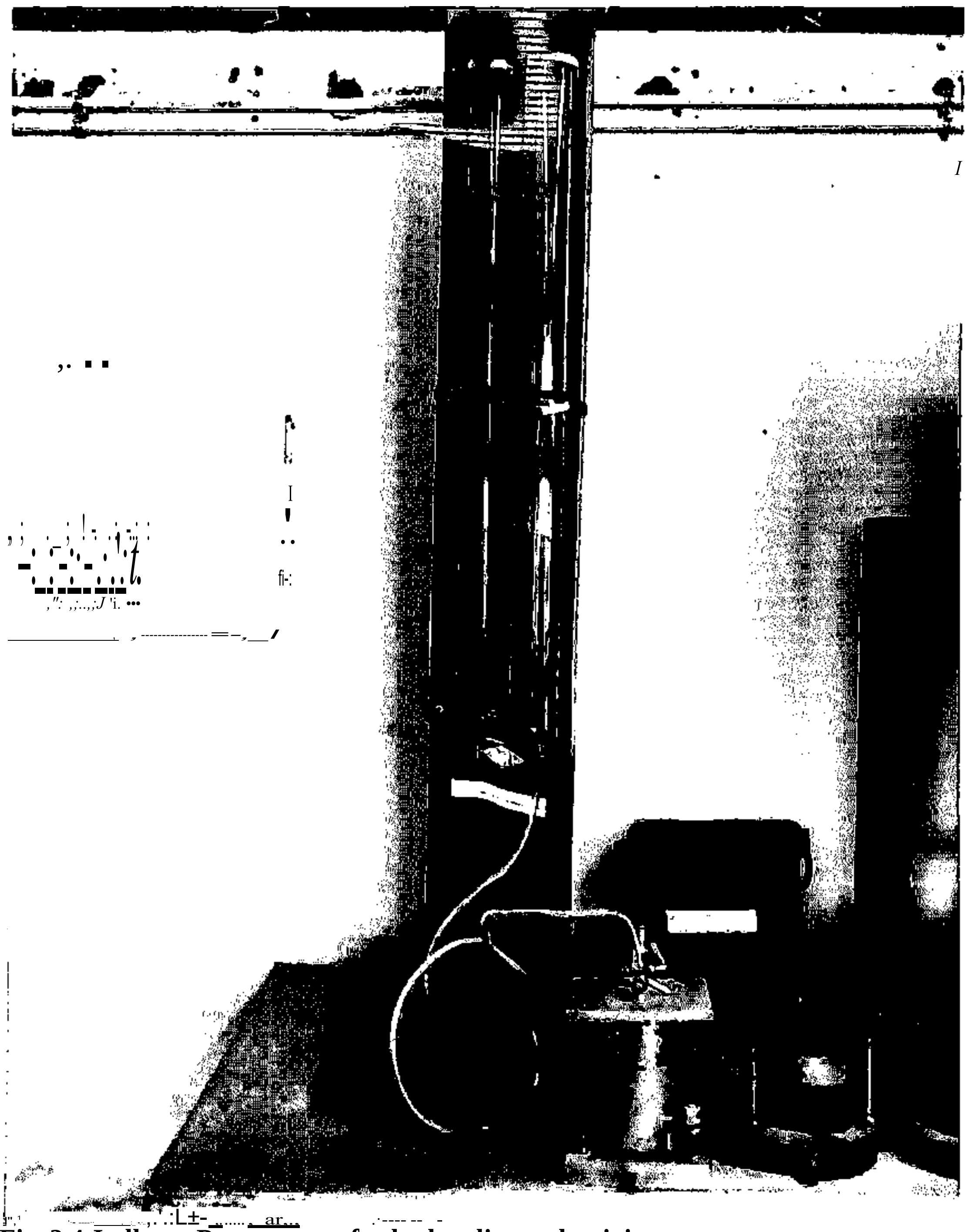


**Fig. 3.4 Jodhpur Pemeameter for hydraulic conductivity test**

The hydraulic conductivity is measured by the following equation

$$k = \frac{aL}{At} \ln \frac{h_1}{h_2}$$

Where, a= cross sectional area of the stand pipe in $cm^2$

A= cross sectional area of the mould in $cm^2$

L= height of the mould in cm

T= time of flow in second

h1= initial water level in cm

h2= final water level in cm

k= hydraulic conductivity in emfs

The hydraulic conductivity of fly ash was done with the same procedure except the mould was replaced with uPVC mould. The uPVC mould is a self detachable one. The self detachable mould was used here because the sample was further taken for strength test. The uPVC mould is of 100mm diameter and its volume is equal to the volume of the steel mould.

### 3.5 Hydraulic Conductivity of Fly Ash Mixed With Cement

The hydraulic conductivity of fly ash mixed with cement was also determined. Cement was added to the fly ash in volume basis. Three types of sample were taken where the percentage of cement were kept at 5%, 10%, 15% of the total volume of the mixture. The cement used was PPC type. The uPVC mould was used to determine the hydraulic conductivity of the samples.

**Table 3.3 Volume of fly ash and cement in the mould**

| Cement percentage | Fly ash (cm3) | Cement (cm3) |
|---|---|---|
| 5 | 1221.23 | 64.27 |
| 10 | 1156.95 | 128.55 |
| 15 | 1092.68 | 192.82 |

**Table 3.4 Specifications of UTM**

| | | |
|---|---|---|
| Capacity | Up to S kN | |
| Column Material | Aluminium Extrusion | |
| Base Material | Mild Steel | |
| Stiffness | 7 kN/mm | |
| Height | 1168 mm | |
| Width | 467mm | |
| Weight | 46 kg | |
| Maximum Noise Level | 18 db | |
| Maximum Data Processing Rate | 168 MHx | |
| Data Acquisition Rate | 1000 Hz | |
| External PC connectivity | USB | |
| Force Measuring Device | Strain Gauge Based Load Cell | |
| Load Cells | S N,lON, 2SN, SON, 100N, 2S0N, SOON, lkN, 2.SkN, SkN | |
| Accuracy | ±0.2% of applied force across load cell force range | |
| Calibration Standard(Force measurement) | ±0.5% to ISO 7500-1 ASTM E4 | |
| Internal Sampling Rate (Force measurement) | 1000 Hz | |
| Resolution | 0.lμm | |
| Accuracy | ±lOμm | |
| Calibration Standard (Extension measurement) | ISO 9513, ASTM E83 | |
| Test Speed | 0.001 mm/min to lO00mm/min | |
| | 0.00lmm/min to S00mm/min | |
| Power requirement & Frequency | Supply Voltage | 110/240 |
| | Frequency | 50/60 Hz |
| | Power | 530 W ±10% |
| Temperature & Humidity | 10-40° C and 10-90% Respectively | |

The specimen was fixed in the UTM by the piston arrangement. Then Load was applied on the top part of the specimen. The speed at which load applied was kept at O.lmm/min. The speed was kept constant throughout the experiment. Load is applied till the specimens failed. First the unconfined compressive strength of specimen made of soil was tested. Then the specimen made of fly ash and fly ash with 5%, 10% and 15% of cement were tested. The data recorded during the measurements were imported to Excel sheet and studied.

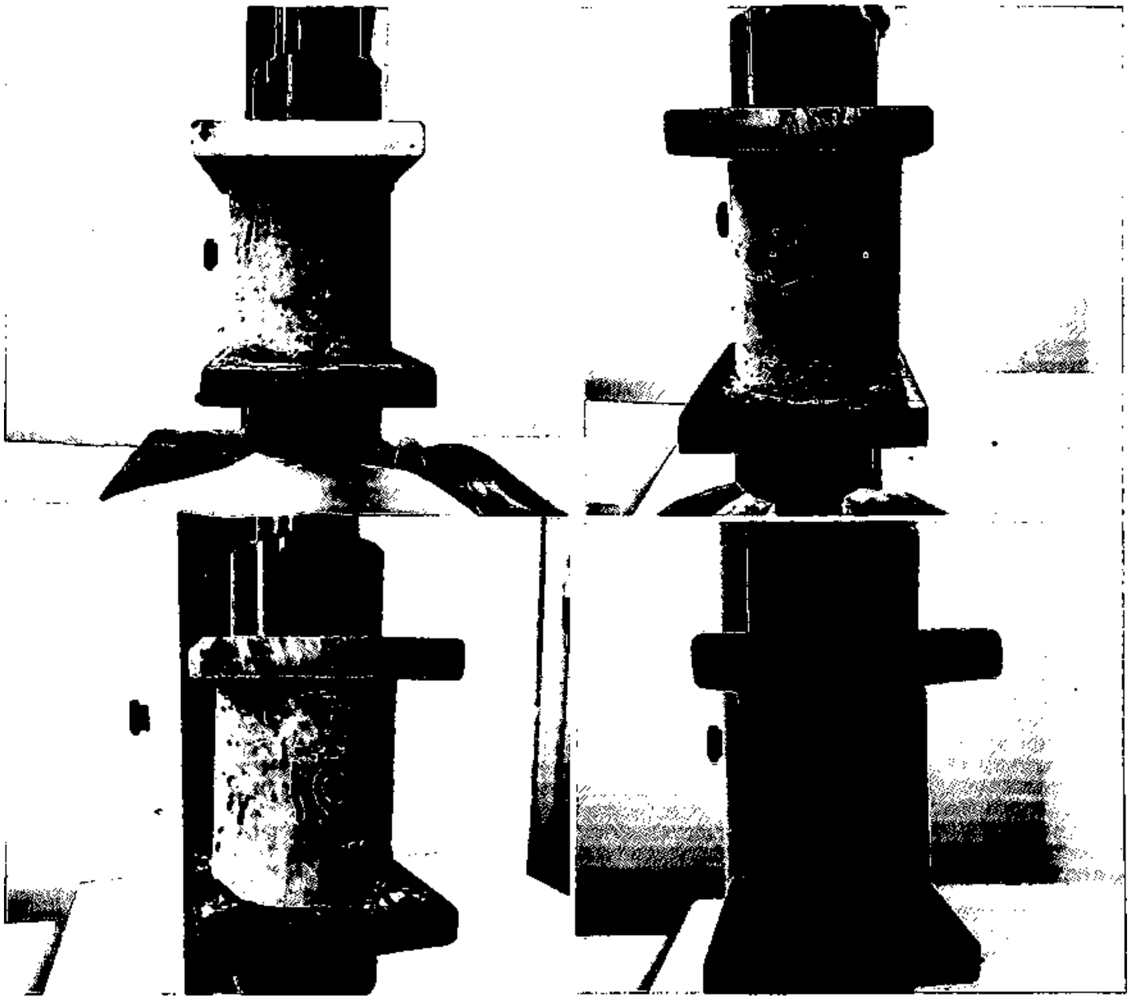


**Fig. 3.8 Testing of different specimens in UTM**

## RESULTS AND DISCUSSION

### 4.1 Specific Gravity

The value of specific gravity of soil was found to be 2.07 and that of fly ash was found to be 1.64 from the experiment.

### 4.2 Sieve Analysis

From the sieve analysis the mass retained in each sieve was weighed and its percentage, cumulative percentage, cumulative percentage finer was found out. A graph known as gradation curve was plotted in the semi log graph. In the X- axis the particle size was taken in log scale and in the Y-axis the cumulative percentage finer was taken. Subsequently from the curve the d10, dso, dao values were found out and the uniformity co efficient was calculated. The results obtained from the sieve analysis are shown in table 4.1 and 4.1..

**Table 4.1 Sieve analysis of soil**

| Sieve size in mm | Mass retained in gram | % retained | Cumulative % retained | Cumulative % finer |
|---|---|---|---|---|
| 1.18 | 20.5 | 4.1 | 4.1 | 95.9 |
| 1 | 21 | 4.2 | 8.3 | 91.7 |
| 0.71 | 70.3 | 14.06 | 22.36 | 77.64 |
| 0.5 | 68.1 | 13.62 | 35.98 | 64.02 |
| 0.355 | 88.2 | 17.64 | 53.62 | 46.38 |
| 0.212 | 138.6 | 27.72 | 81.34 | 18.66 |
| 0.15 | 63.3 | 12.66 | 94 | 6 |
| pan | 30 | 6 | 100 | 0 |

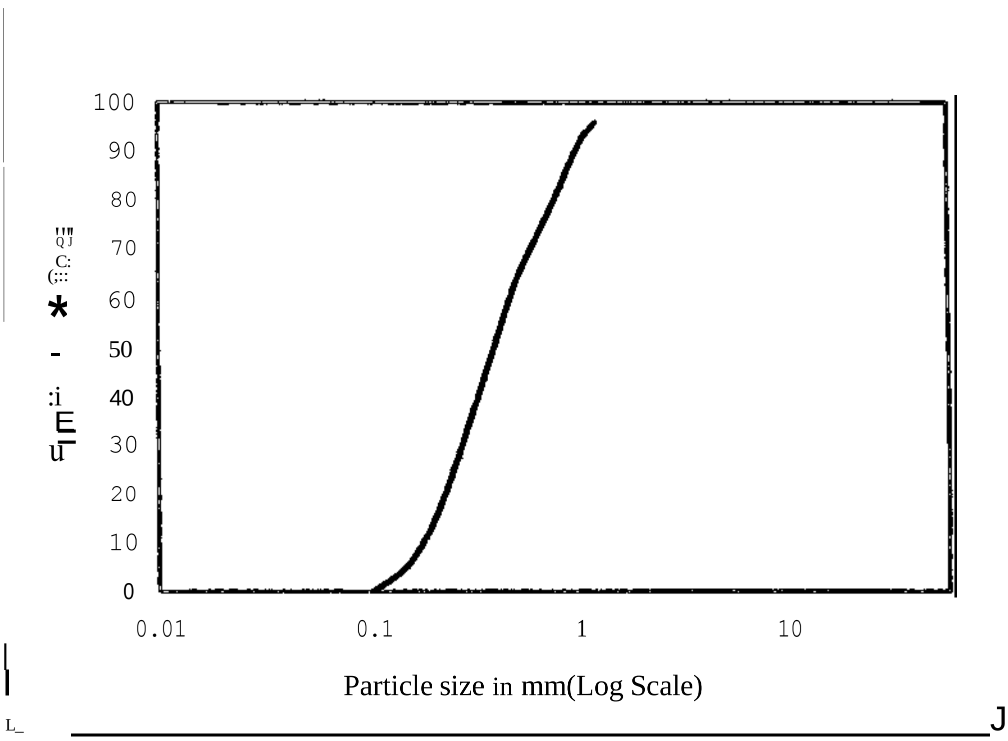


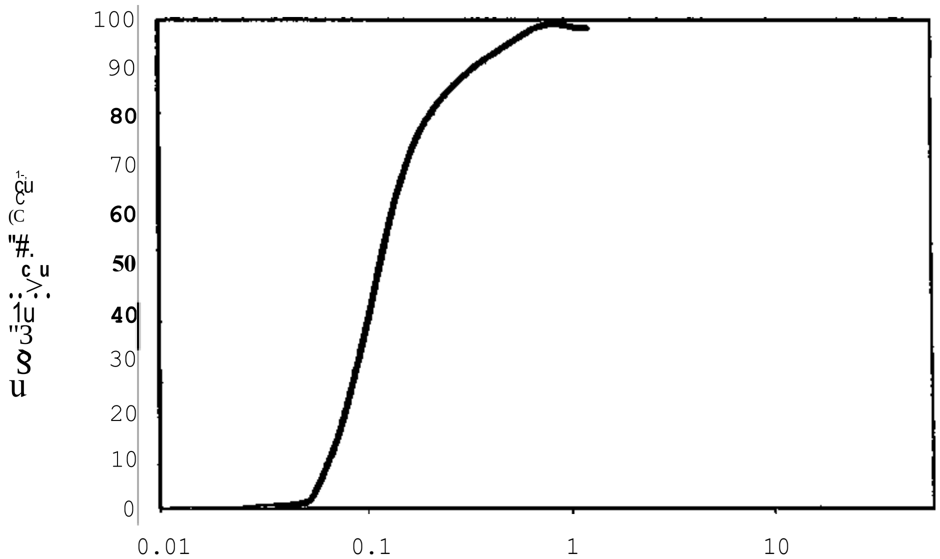

**Fig. 4.1 Gradation curve of soil**

From the sieve analysis of soil the gradation curve was prepared. From the gradation curve the values of d10, dso, and dso were found out. Here the $d_{10}$ value was found to be 0.167 mm and dso value was found to be 0.462 mm. The $d_{50}$ value which represents the mean particle size of the soil sample was found to be 0.380 mm. The uniformity coefficient, Cu which is equal to $d_{60}/d_{10}$ was found to be 2.77. Thus it can be said that the soil is uniformly graded as Cu < 3 i.e., the soil particles are almost of identical types.

The experiment of sieve analysis was repeated with fly ash. The mass retained with each sieve was weighed. The percentage of mass retained, cumulative percentage of mass retained and cumulative percentage finer were calculated. The gradation curve was drawn where the particle size was taken in theX axis and cumulative percentage finer in y axis. The $d_1$o. dso and d50 values were calculated from the graph.

**Table 4.2 Sieve analysis of Oy ash**

| Sieve size in mm | Mass retained in gram | %of mass retained | Cumulative % retained | Cumulative % finer |
|---|---|---|---|---|
| 1.18 | 8.1 | 1.62 | 1.62 | 98.38 |
| 0.6 | 4.1 | 0.82 | 2.44 | 97.56 |
| 0.18 | 101.4 | 20.28 | 22.72 | 77.28 |
| 0.09 | 234.8 | 46.96 | 69.68 | 30.32 |
| 0.075 | 63.7 | 12.74 | 82.42 | 17.58 |
| 0.063 | 44.5 | 8.9 | 91.32 | 8.68 |
| 0.053 | 33.1 | 6.62 | 97.94 | 2.06 |
| 0.045 | 6.2 | 1.24 | 99.18 | 0.82 |
| 0.025 | 4.1 | 0.82 | 100 | 0 |




!Fig. 4.2 Gradation cw-ve offty ash

From the sieve analysis of fly ash the gradation curve was prepared and shown in Fig. 4.2. The d10 value of fly ash sample was found to be 0.070 mm. The mean particle size $d_{50}$ value was 0.120 mm and doo was equal to 0.139. The value of uniformity coefficient Cu was found to be 1.98. Here the value of uniformity coefficient is very less and it is less than 4. So the fly ash particles are poorly graded or uniformly graded. The particles are of identical size.

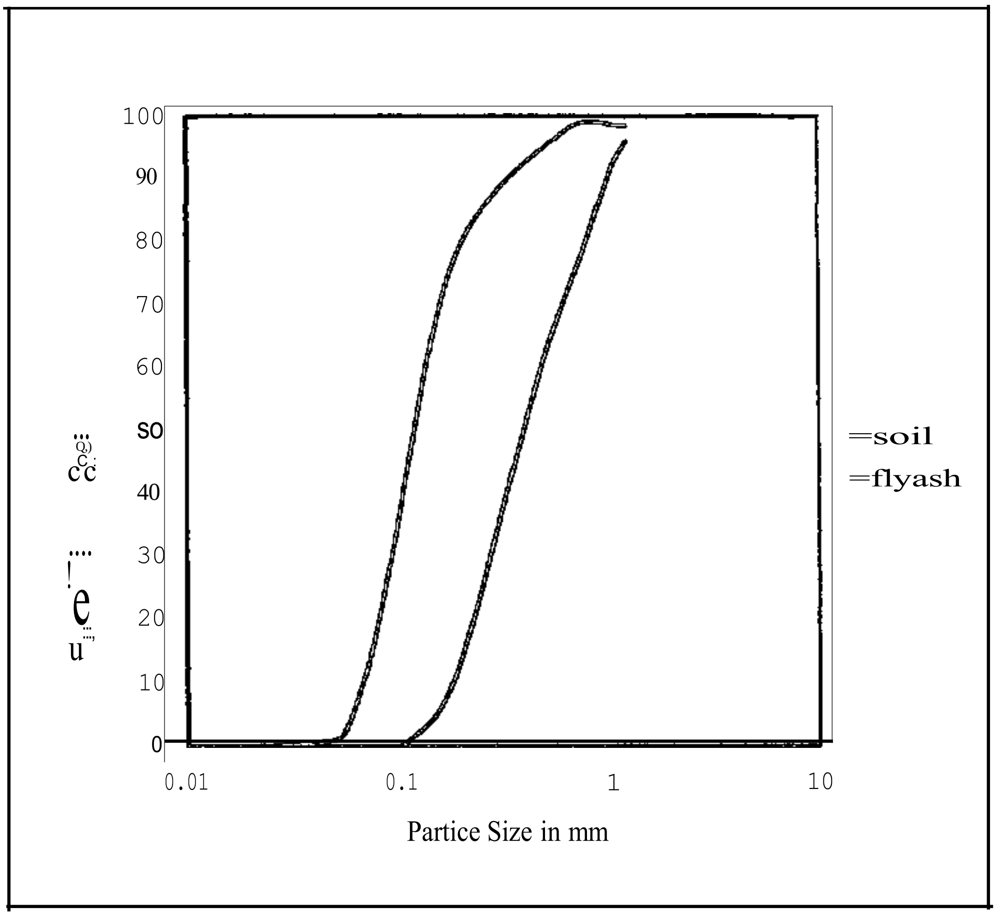



**Fig. 4.3 Gradation curve of Soil and fly ash**

## 4.3 Hydraulic Conductivity of Soil, Fly Ash and Fly Ash Mixed With Cement

The hydraulic conductivity value of soil, fly ash and fly ash mixed with 5%, I0% and 15% cement as observed from the laboratory test were presented in table 4.3.

**Table 4.3 Hydraulic conductivity values of soil and fly ash**

| Material | h1 incm | h2 in cm | tins | kinmis |
|---|---|---|---|---|
| Soil | 59.4 | 41.2 | 269 | 5.55xl0-3 |
| Fly ash | 69.2 | 65.7 | 4070 | 6.12xI0-5 |
| Fly ash mixed with 5% cement | 65.4 | 61.2 | 5139 | 5.27xl0-5 |
| Fly ash mixed with 10% cement | 62 | 59.1 | 5281 | 3.71x10-5 |
| Fly ash mixed with 15% cement | 67 | 65.7 | 6921 | l.16x10-5 |

After calculating the value of hydraulic conductivity of the above samples it is evident that fly ash is less permeable than soil. The soil specimen was almost 100 times more permeable than fly ash. And when cement is added with fly ash the permeability further reduced. With the increase in the percentage of cement the •k' value was reduced. The variation of fly ash and fly ash mixed with cement with hydraulic conductivity is shown in the Fig. 4.4.

**Table 4.4 Values from the UC test**

| Material | Length inmm | Depth of compression in mmat 300 N load | Effective area in 10-3m2 | Load in N | Unconfined compressive Strength InkPa | Cohesion in kPa |
|---|---|---|---|---|---|---|
| Soil | 72 | 6.03 | 1.24 | 37.85 | 30592.87 | 15296.44 |
| Fly ash | 60 | 2.11 | 2.93 | 302.40 | 103208.19 | 51604.09 |
| Fly ash with 5% cement | 60 | 0.89 | 2.87 | 459.50 | 160104.52 | 80053.26 |
| Fly ash with 10% cement | 60 | 0.79 | 2.86 | 974.00 | 340559.44 | 170279.72 |
| Fly ash with 15% cement | 60 | 0.59 | 2.85 | 2382.50 | 835964.91 | 417982.46 |

## SUMMARY AND CONCLUSION

### 5.1 Summary

The research was undertaken for solving the problem of earthen embankment failure due to seepage. Therefore study of hydraulic conductivity and strength property of fly ash and fly ash mixed with cement was carried out as the replacement material for soil in the core of earthen embankments .. The fly ash sample was collected from NALCO thermal power station, Anugul and soil from OUAT farm house. The samples were dried in the oven and their sieve analysis was done to find out the particle size distribution. Specific gravity of both the samples was measured by cylindrical flask method. For the test of hydraulic conductivity, falling head method was selected. The Jodhpur permeameter was used for the test of hydraulic conductivity. PVC moulds were prepared for the test replacing the iron mould. The hydraulic conductivity of soil, fly ash, fly ash with 5%, 10% and 15% cement was found out by the test and the specimens were subjected for unconfined compression test. Before the compression test the specimens were undergone a curing period of 21 days where the moisture loss of the specimens were prevented. The unconfined compression test was carried out with the help of Universal testing machine. The specimens were subjected to unconfined axial load and the load is applied till the failure of the specimens. The results were analyzed and the variations of hydraulic conductivity and unconfined compressive (UC) strength with percentage of cement, relationship of permeability with strength etc were studied.

### 5.2 Conclusion

After processing the data from the experiments and analyzing it the following conclusions were drawn.

1. The mean particle sizes (dso) of soil and fly ash were found to be 0.380 mm and 0.120 mm respectively. Both soil and fly ash were uniformly graded as the Cu for soil was 2.77 and that of fly ash was 1.98.
2. The specific gravity of soil was 2.07 and that of fly ash was 1.64.

3. The hydraulic conductivity (k) of fly ash was ($6.12x10^{-5}$ *mis)* about 100 times less than that of soil ($5.55x10^{-3}$mls). As cement is added to fly ash the k value further decreases. Amongst the samples of fly ash, the one having 15% has the least k value, whereas the pure fly ash having no cement has the highest k value. The relationship with which the k value varies with percentage of cement is **y= -1.644x+8.175** having $R^2$ value of 0.949 where y is hydraulic conductivity and x is percentage of cement content up to 15%.
4. From the UC test it was observed that soil has the least load bearing capacity and fly ash with 15% cement has the highest value. Addition of cement to fly ash has increased the load bearing capacity. The load bearing capacity of fly ash increases with increase in the percentage of cement. The relationship with which the load varies with percentage of cement is y = **132.8 e**$^{0.694}$x having an $R^2$ value of 0.976 where y is the maximum load at which the specimen fails and x is the percentage of cement content up to 15%.
5. The depth of compression of soil was higher than that of fly ash and fly ash mixed with cement. Fly ash having the higher percentage of cement has the lower value of depth of compression when compared at a fixed load. So the soil specimen was softer than that of the fly ash ones. Increase in the percentage of cement in fly ash the softness decreases.
6. The unconfined compressive strength of fly ash at failure is higher than that of soil. When percentage of cement in fly ash increases its value also increases. The relationship of its variation with percentage of cement is y **= 45167 e**$^{\mathbf{0.103}}$**x** with $R^2$ = 0.978, where Y is the unconfined compressive strength at failure in Pa and xis the percentage of cement content up to 15%.
7. The permeability reduces with increase in the cohesion or cohesive strength of fly ash i.e., when cement is added to fly ash its cohesion increases and permeability decreases. Fly ash having highest k value has the least cohesive strength and vice versa. The relationship of cohesion with permeability varies as **y= -221 In(x) + 452.5** with an $R^2$ value of 0.99, where y is the cohesion in kPa.

## REFERENCES


1. Akhtar J N and Alam J. 2008. The influence of permeability on steel fiber reinforced fly ash concrete at different ages, *The Indian society for hydraulics journal of hydraulic engineering,* **14(2):** 59-71.
2. Bachus R and Santamarina J. 2014. Geotechnical Properties and Diagenesis of Ponded Fly Ash. *Geo-Congress 2014 Technical Papers:* pp. 326-333.
3. Benson C and Othman M. 1993. Hydraulic Conductivity of Compacted Clay Frozen and Thawed In Situ, *Journal ofGeotechnical Engineering*, **119(2):** 276-294.
4. Benson C, Gunter J, Boutwell G, Trautwein S, and Berzanskis P. 1997. Comparison of Four Methods to Assess Hydraulic Conductivity, *Journal of Geotechnical and Geoenvironmental Engineering*, **123(10):** 929-937.
5. Benson C, Jo H, and Musso T. 2015. Hydraulic Conductivity of Organoclay and Organoclay-Sand Mixtures to Fuels and Organic Liquids, *Journal of Geotechnical and Geoenvironmental Engineering,* **141(2):** 1240-1246.
6. Chakraborti R. Atkinson J, and Kaur J. 2009. Effect of Mixing on Suspended Particle- Size Distribution, *Journal of Environmental Engineering,* **135(5):** 306-316.
7. Chetia A and Sekharan S. 2014. Study of the influence of Fly Ash Addition on water Retention Characteristics of Soils. Geo-congress 2014 Technical Papers,297- 306
8. Copeland K. Obla K. Hill R. and Thomas M. 2001 Ultra Fine Fly Ash for High Performance Concrete. *Construction and Materials Issues 2001:* pp. 166-175.
9. Das sand Yudhbir 2005. Geotechnical Characterization of Some Indian Fly Ashes, *Journal of Materials in Civil Engineering,* **17(5):** 544-552.
10. Daven A and Pekrioglu A. 2005. Material Properties of High Volume Fly Ash Cement Paste Structural Fill, *Journal of Materials in Civil Engineering,* **17(6):** 686