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EXPERIMENTAL DETERMINATION OF VARIABILITY IN PERMEABILITY OF SANDY SILT SOIL MIXED WITH FLY ASH IN PROPORTIONATE

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ABSTRACT

This paper presents the experimental determination of variability in permeability of sandy silt soil by blending with fly ash. The grain size, porosity, structure of the soil, specific gravity of the soil, viscosity and temperature are important factors in varying the permeability of the soil. Permeability is the flow conduction property of the soil. The void ratio with in the soil plays a vital role in varying the permeability. By blending with finer grains like fly ash in the soil with sandy silt the permeability will vary. This phenomenon can be observed through experimentation in the laboratory. The variation in the drainage property of the soil also observed. This paper includes all the variation in the flow property of the soil (sandy silt soil) by adequate mixing of the fly ash. Fly ash is a major solid by-product of the combustion of pulverized coal in thermal power plants. Five soil samples with different mixes of sandy silt and fly ash were obtained for comparison. Rigorous laboratory tests were performed to determine the individual properties. Tests such as Specific Gravity Test, Atterberg Limit Test (Liquid Limit, Plastic Limit and Plasticity Index), Relative Density Test, Particle Size Analysis, and Permeability Test were performed. From the results of these tests, it is observed that increase in fly ash content in soil Maximum Dry Density (MDD) decreased and Optimum Water Content (OMC) increased. Permeability is decrease with increase in fly ash in sandy silt soil. The decrease in permeability of sandy silt soil helps in stabilizing this soil and consequently increases the shear parameters of the sandy silt soil.

KEYWORDS: fly ash, laboratory test, optimum water content, permeability, specific gravity.

INTRODUCTION

The stability of any civil structure depends on the physical properties of soil. For designing any structure, it is very important to get the information of the soil and its properties at which the structure would be built. The soil properties directly or indirectly affect the design of the foundation of structure. So it is necessary to determine all the properties of soil before construction. If the soil is poor to bear the load of the structure then mitigation/ improvement of the soil properties can be made.

Permeability is a very important engineering property of soils Permeability; flow property of soil can influence the strength property of the soil the function of the permeability to provide drainage capacity in the soil and also to provide void ratio for stabilization of the soil required for the foundation work. The sandy silt soil is considered high permeable soil. Its permeability can be deceased by mixing with fly ash in proportionate.

In this paper the coefficient of permeability of sandy silt soil is to be determined. Then the different percentages of fly ash are mix and after this compare the result of coefficient of permeability. Here we obtain that the permeability of soil is decreases 30% approximately.

Fly ash is defined as the material extracted from the flue gases of a furnace fired with coal. Fly ash can be classified as non-plastic fine silt by unified soil classification system. There are two major classes of fly ash; class F fly ash is normally produced from burning anthracite or bituminous coal whereas class C fly ash is produced from burning

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lignite and sub-bituminous coal. Both classes of fly ash are pozzolans which are defined as silica and aluminous materials. Fly ash can be effectively used as compacted or flow able fill material in the construction of structural fills for building. Foundations, embankments, base and sub base courses for highways and railroads, dikes, levees, bridge abutments, and landfill cover in lieu of conventional earth materials.

Previous researchers have explained the reason behind variation in MDD and OMC in soil-fly ash mixed samples at various percentages on laboratory experiments as revealed by Ramaiah et al. (1972) Osinubi (1998), Kalkan and Akbulut (2004), Kumar and Sharma (2004), and Kumar (2004).Jyothi and Sastry (1991) investigated the behavior of expansive soils treated with lime. It was observed that, in general, the coefficient of consolidation increases whereas both the compression index and swelling index decrease with increase in lime content. Kumar et al. (2007) presented paper on, by way of comparison, the effect of fly ash on the volume change of two different types of clay, one a highly plastic expansive clay and the other a non-expansive clay, also of high plasticity. Also from the hydraulics view points, the most suitable ratio in the base layer reinforced by geotextiles is proposed 20% at most. Rao et al. (2014) studied the compressibility behavior of black cotton soil admixed with lime and rise husk. It was observed that the coefficient of consolidation increases as the percentage of admixture increases. 1:1 mix is more effective and economical among all the admixtures in reducing compression index.

METHODOLOGY

Fly ash contains silt sized particles and posses good permeability. To find out the effect of fly ash on soil varying amounts [100% soil, soil +5 % fly ash, soil + 10% fly ash, soil + 15% fly ash, soil + 20% fly ash] is utilized. Each soil mix underwent rigorous laboratory test: particle sieve analysis to find out the Type and Class of the soil, Specific Gravity , Atterberg Limits Tests to determine Liquid Limit , Plastic Limit and Plastic Index of soil, Standard Proctor test which determine the Maximum Dry Density and Optimum Water Content, Falling Head Permeability test by which coefficient of permeability is obtained.

Coefficient of permeability is known as the most variable soil property its value can vary over an order of magnitude even in case of relatively homogenous layers. So determining this value, it is a complicated and complex engineering task. There is a vast number of laboratory and in situ tests to determine the permeability coefficient. Each method has its own advantages, drawbacks and limitations, so different methods should be preferred in different situations. The permeability coefficients of sandy silt layer have been determined by means Khafagi Probe, Menard Probe, Water Filtration Method, Constant Head Laboratory Test and Falling Head Laboratory Test. The permeability coefficients have also been estimated by the equation proposed by Hazen (1895).

Here we use the variable head permeability test which is also called as falling head permeability test. First of all, tests are done on soil only. Then 5% of fly ash is mixed with soil and test performed on this mix. Then add 10% fly ash and test are performed and so on. At the end we compare the coefficient of permeability of soil and all the mixes. Then result is come out is that increasing in proportion of fly ash in soil, permeability decreases (30% approximately).

MATERIALS AND EXPERIMENTAL RESULTS

3.1 Materials

Local soil is collected from Lashkar Gwalior. Soil sample is yellow in color and sandy in nature.

Fly ash is collected from **Parichha Thermal Power Station** is located at Parichha in Jhansi district in the Indian state of Uttar Pradesh, about 25 km from Jhansi on the bank of Betwa River. The power plant is owned and operated by Uttar Pradesh Rajya Vidyut Utpadan Nigam.

The fly ash is in grey color and pozzolanic in nature the most common composition of fly ash are SiO2, Al2O3, Fe2O3, MgO, CaO, SO3, organic carbons and others. And local available soil , Parichha thermal power plant fly ash samples and soil mixed samples containing fly ash of 5, 10, 15, 20 % on the basis of dry weight.

3.2 Experimental results

Following experiments have been performed. These entire tests were conducted both on local soil and fly ash mixed soil for determining physical properties and engineering properties. The test are-

(1) Grain Size Analysis.

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(2) Specific Gravity Test.
(3) Liquid Limit and Plastic Limit Test.
(4) Standard Proctor Compaction Test.
(5) Falling Head Permeability Test.

3.2.1) Grain Size Analysis

Wet sieving the soil is to be sieved is mixed with water until it becomes a suspension. To reduce surface tension and facilitate passage of the material and few drops of tenside can be added. Then set of sieves are arranged according to IS code and the sieving test has been performed.

3.2.2) Specific Gravity Test

The object of the test is to determine the specific gravity of soil fraction passing 4.75mm IS Sieve. Specific gravity is the ratio of weight in air of a given volume of soil samples to the weight in air of equal volume of distilled water at 4 degree Celsius. It is an important factor which is used in computing other soil properties. Pycnometer Bottle is used for the determination of specific gravity of sandy silt soil.

3.2.3) Liquid limit and Plastic Limit Tests

The liquid limit (LL) is arbitrarily defined as the water content, in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2 in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit (PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling.
This testing method is used as an integral part of several engineering classifications systems to characterize the fine-grained fractions of soils and to specify the fine-grained fraction of construction materials. The liquid limit, plastic limit and plasticity index of soils are also used extensively, either individually or together, with other soil properties to correlate with engineering behavior such as compressibility, permeability, compactibility, shrink swell and shear strength.

3.2.4) Standard Proctor Compaction Test

In the Standard Proctor Test, the soil is compacted by a 5.5 lb hammer falling distance of one foot into a soil filled mold. The mold is filled with three equal layers of soil, and each layer is subjected to 25 drops of the hammer. The Modified Proctor Test is identical to the Standard Proctor Test except it employs, a 10 lb hammer falling a distance of 18 inches, and uses five equal layers of soil instead of three. This laboratory test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified compactive effort. The compactive effort is the amount of mechanical energy that is applied to the soil mass.

3.2.5) Falling head permeability test

The falling head permeability test is conducted in laboratory for local soil. The falling head permeability test involves flow of water through a relatively short soil sample connected to a standpipe which provides the water head and also allows measuring the volume of water passing through the sample. The diameter of the standpipe depends on the permeability of the tested soil. The test can be carried out in a Falling Head permeability cell or in an oedometer cell.

RESULTS AND DISCUSSION

4.1 Results

Experimental test data regarding the physical and engineering properties of locally available soil mixed with fly ash at different percentage by dry weight presented .The variation in MDD-OMC, Permeability and consolidation are observed experimentally. Experimental test results on physical and engineering properties of soil and fly ash are shown in table 1 to table 6. The maximum dry density vs. optimum moisture content curve of soil and soil mixed fly ash in different percentages are shown in fig.1 to fig.3.

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Table 1 Physical and Engineering Properties of Soil

Physical Properties	Test Results
Grain Size Sand (%) Silt (%) Clay (%)	 64.2 33.6 2.2
Color	Yellow
Uniformity Coefficient (Cu)	18.5
Coefficient of curvature (Cc)	0.38
Classification of Soil	SM
Name of Soil group	Gap graded coarse soil
Specific Gravity	2.6
Liquid limit (%)	12
Plastic limit (%)	Non Plastic
Plasticity	Non Plastic
Coefficient of Permeability, K cm/s	3.92x10-5
Engineering Properties	Test Results
Compaction Maximum Dry Density MDD (KN/m³) Optimum Water Content, OMC (%)	 19.5 10

Table 2 Physical and Engineering Properties of fly ash

Properties	Test Results
Grain Size Sand (%) Silt (%) Clay (%)	 32.2 62.6 5.2
Class	Sandy Loam
Color	Grey
Specific Gravity	2.2
Plastic Index	Non Plastic
Maximum Dry Density MDD(KN/m³) Optimum Water Content OMC (%)	16.2 24
Coefficient of Permeability K (cm/s)	1.8x10-6

The tests are now performed on soil blending with fly ash at different proportion.

Table 3 Specific gravity (G) of Soil, Fly Ash, soil + Fly Ash mix

Soil Properties	Soil	Fly Ash	Soil + 5% Fly Ash	Soil + 10% Fly Ash	Soil + 15% Fly Ash	Soil + 20% Fly Ash
G	2.6	2.2	2.54	2.47	2.41	2.34

Table 4 Liquid Limit of Soil, Fly Ash, soil- Fly Ash mix

Soil Properties	Soil	Fly Ash	Soil + 5% Fly Ash	Soil + 10% Fly Ash	Soil + 15% Fly Ash	Soil + 20% Fly Ash
LL	12	21	15	18	18.5	19

Table 5 Maximum Dry Density and Optimum Moisture Content of Soil, Fly Ash, soil- Fly Ash mix

Soil Properties	Soil	Fly Ash	Soil + 5% Fly Ash	Soil + 10% Fly Ash	Soil + 15% Fly Ash	Soil + 20% Fly Ash
MDD (KN/m3)	19.5	16.2	19.4	19	18.6	18.1
OMC	10	24	12	12	14	16

Table 6 Coefficient of Permeability of Soil, Fly Ash, soil - Fly Ash mix

Soil Properties	Soil	Fly Ash	Soil + 5% Fly Ash	Soil + 10% Fly Ash	Soil + 15% Fly Ash	Soil + 20% Fly Ash
K (cm/s)	**3.92x10-5**	**1.8x10-6**	**2.87x10-5**	**2.2x10-5**	**8.95x10-6**	**4.9x10-6**

4.2 Discussion

The discussions are based on the laboratory tests conducted on different geotechnical parameters and its results. Effects of fly ash on soil and its engineering properties and physical properties are discussed here. Also the effects of these properties of soil are directly or indirectly correlated with the permeability of soil and mixture of fly ash and soil. Hence here we discussed that how specific gravity, compaction characteristics of soil, Atterberg limits and coefficient of permeability changes on blending fly ash with soil. And how, coefficient of permeability depends on these properties.

4.2.1 Grain size

According to results soil is not well graded, soil is sandy silt and soil is impervious in nature. Soil comes in SM class, but as fly ash is added it change its class from SM to ML.

The coefficient of permeability of a soil is proportional to the square of the particle size (D).the permeability of coarse grain size is very large as compared to that of fine grained soil. Hence our local soil is sandy silt in nature and it is high permeable. When we add fly ash in it, then its coefficient of permeability is reduced because fly ash is silty loam in nature. Table 1 and fig. 1 summerizes the values of percentage finer and grain size analysis.

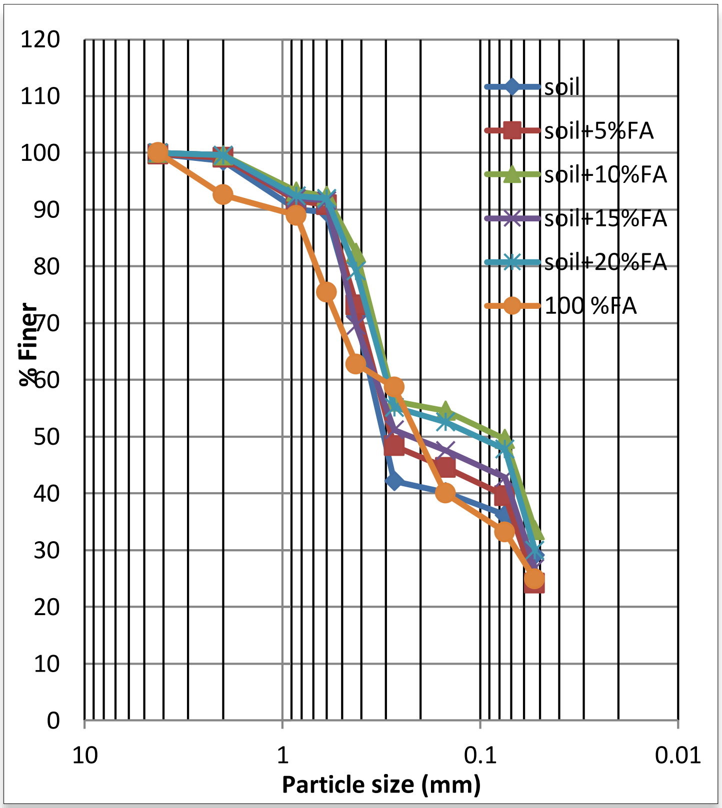

Fig 1. Grain Size Distribution of Soil

4.2.2 Specific Gravity

According to table 3, Specific gravity of soil is 2.6 and specific gravity of fly ash is 2.2. Hence after mix different percentage of fly ash in soil the specific gravity of soil is decreases from 2.6 (0% FA) to 2.34 (20%FA). Fly ash particles are hollow, thin walled cenosphere, having low weight than conventional soil, so in mixed samples the overall weight become less.

The greater the void ratio, the higher is the value of coefficient of permeability. Hence as the specific gravity is decreased the water content of soil is increased and permeability is decreased.

4.2.3 Atterberg limits

These limits are used to denote the degree of firmness of a soil.

The soil is sandy silt so it is non plastic in nature. Also the fly ash is non plastic. Hence the plastic limit and plastic index cannot be determined. Hence when compare the sandy silt soil and mixture of soil – fly ash having same plastic limit (non plastic), it is found that as the liquid limit is increases, the permeability is decreases.(According to table 4)

4.2.4 Compaction characteristics

The results of dry unit weight and Optimum Moisture Content of soil and soil-fly ash mix at various percentages are shown in Fig. 2. Table 5 summarizes the Maximum Dry Density and Optimum Moisture Content. The soil has a Maximum Dry Density of 19.5 kN/m³ at Optimum Moisture Content 10 %. Fly ash exhibit maximum dry density of 16.2 kN/m³ at Optimum Moisture Content 24 %. The 5, 10,15, 20% fly ash-soil mixture exhibit a decrease of Maximum Dry Density with increasing Optimum Moisture Content .The results show that as the fly ash content increases, the Maximum Dry Density decrease and the Optimum Moisture Content increase, it is due to lower specific gravity of fly ash particles. Fabio Santos et al. 2011 illustrated that the decrease in Maximum Dry Density with increase in fly ash is associated with the notion that fly ash is light compared to soil only. The higher Optimum Moisture

Content associated with higher fly ash content follows from the need of hydration reaction for cementitious fly ash, and to release the capillary tension from the greater exposed surface of the finer fly ash particles. The maximum dry density and the Optimum Moisture Content show a significant dependence upon the fly ash content. The Maximum Dry Density values of fly ash soil mixture are lower than those of soil, which is typically range from 18.1 to 19.5kN/m3.

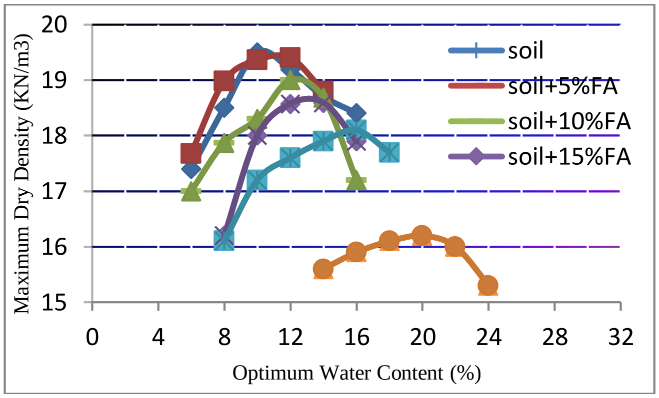

Fig 2 Dry density vs. Moisture content curve of soil

4.2.5 Permeability's coefficient

The coefficient of permeability/hydraulic conductivity (k) values of soil samples, fly ash and soil-fly ash mixed samples are presented in Fig 3. According to table 6, The hydraulic conductivity for the local sandy silt- soil is 3.92×10-5 cm/sec. With the increase of fly ash contents in mixed samples, the rate of permeability decreasing. The hydraulic conductivity values are within the range of 3.92 ×10-6 and 4.9×10-6 with percentages of fly ash 5,10,15 and 20% respectively. Increase in silt size particles in soil due to addition of fly ash make the mixed samples comparatively coarser and increases permeability. Researchers like, Ghosh and Subbarao (1998) in stabilization of a low lime fly ash with lime and gypsum, Osinubi (1998) in Hekinan and Matsushima fly ash for direct falling head permeability, and Porbaha et al. (2000) in conducting indirect calculation from consolidation observed similar trend. Similar trend was also observed in compacted fly and bottom ash mixtures with increasing fly ash content by Show et al. (2003), Kim et al. (2005) in high volume fly ash cement paste composite formed of various combinations of fly ash, cement, lime, silica fume, and chemical admixtures, Kalkan and Akbulut (2004) in application of silica fume for natural clay liners.

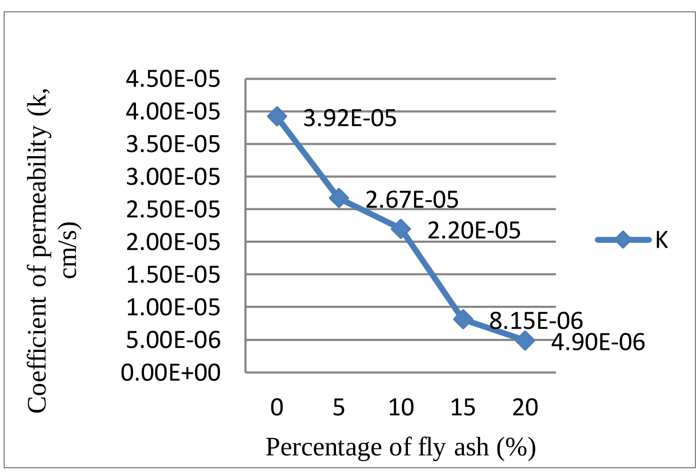

Fig 3 Coefficient of Permeability Vs percentage of Fly ash

CONCLUSIONS

Following conclusions may be made based on the above test results and discussions:

1. The specific gravity of sandy silt soil is decreases as we increase the percentage of fly ash in this soil.
2. The liquid limit of sandy silt soil is increases when percentage of fly ash is increased in that soil.
3. The sandy silt soil is non plastic, remains non plastic when fly ash is added because fly ash is also non plastic.
4. Soil-fly ash mixtures exhibit well-defined moisture density relationship, varying the mixture percentage. As the fly ash content increases optimum moisture content increases and maximum dry density decreases. The dry unit weight for soil-fly ash is lesser than those of typically compacted soil.
5. The higher silt content and lesser plasticity of the fly ash result in lesser volume change of the soil.
6. The rate of permeability of sandy silt soil decreases with increase of fly ash in sandy silt soil.
7. Fly ash with high percentage silt content can be mixed in local sandy silt soil; this material may be used as land filling and embankments in the field of geotechnical engineering construction. This can also be useful in stabilizing the soil.

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