Soil-Fly Ash Mix Effect on the Stability of Rigid Pavement Subgrade

Arun Singh Majhal[1] Dr. Rakesh Gupta[2]
[1]M.Tech Scholar [2]Assistant Professor
[1,2]Department of Civil Engineering
[1,2]SRMIET, Bhurewala, Ambala, Haryana, India

Abstract— The stabilization of sub grade soil is one of the principal and major processes in the construction of any highway. The aim of this thesis is to investigate the effect of soil-fly ash mix on the stability of rigid pavement sub grade. In this regard a laboratory experimental program will be considered to study the effect caused by the action of fly ash stabilization on the geotechnical trademarks of expansive sub grade soils. Expansive soil treated with different percentages of fly ash i.e. 15%, 20%, 25% and 30% will be taken into account. The initial values for this study includes Liquid Limit (LL), Plastic Limit (PL), Maximum Dry Density (MDD), Plasticity Index (PI), Optimum Moisture Content (OMC) & Unconfined Compressive Strength (UCS) with the fraction of fly ash added (F.A in %) in sub grade soil.

Key words: Fly Ash, Subgrade Soil

I. Introduction

A. General

Fly ash is a substantive industrial by-product that comes from the combustion of coal. In our country, only a small percentage of fly ash is used for the construction of technical projects while the rest is dumped which causes severe problems to the accessible environment. It has been found that stabilization with fly ash increase the mechanical and engineering characteristics of soil, so it is a better option to use fly ash as a modifier. Stabilization of soils and pavement base courses with coal fly ash is earning popularity among pavement engineers.

B. Rigid Pavements

Rigid pavements normally use Portland cement concrete as the prime structural element. It has a high degree of rigidity. Depending on conditions, engineers may design the pavement slab with plain, lightly reinforced, continuously reinforced, pre-stressed, or fibrous concrete. The concrete slab usually lies on a compacted granular or treated base course, which is supported, in turn, by a compacted sub grade. The base course provides uniform stable support and may provide subsurface drainage.

1) Concrete Slab (Surface Layer)

The concrete slab provides structural support to the aircraft, provides a skid-resistant surface, and prevents the infiltration of excess surface water into the sub base.

2) Base Course

The base course provides uniform stable support for the pavement slab. It also serves to control frost action, provide subsurface drainage, control swelling of subgrade soils, provide a stable construction platform for rigid pavement construction, and prevent mud pumping of fine-grained soils. Rigid pavements generally require a minimum base course thickness of 4 inches (100 mm). All new rigid pavements designed to accommodate aircraft weighing 100,000 pounds.

3) Subgrade

The subgrade is the compacted soil layer that forms the foundation of the pavement system. Subgrade soils are subjected to lower stresses than the surface and base courses. These stresses decrease with depth. The soils investigation should check for these conditions. The pavement above the subgrade must be capable of reducing stresses imposed on it to values that are low enough to prevent excessive distortion or displacement of the subgrade soil layer.

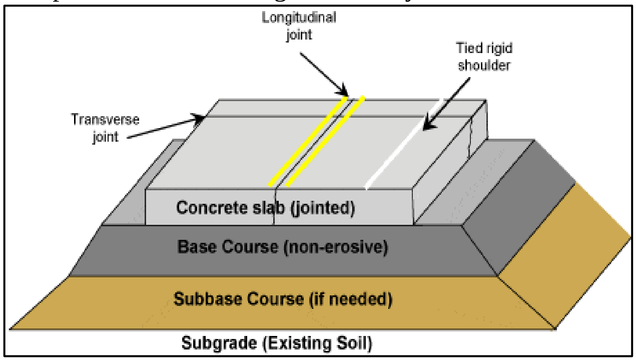

Fig. 1:

II. Methodology

A. Materials

- Soil sample: Dispersive soil
- Stabilization material: Fly ash
- Fly ash Source: Thermal Power Plant, Yamuna Nagar

Fig. 2: Sample of Soil

B. Soil

Soil is a mixture of organic matter, minerals, gases, liquids and organisms. The geological components are mixed with organic materials to form soils. There are two components of soil, rock particles and organic matter. The formation of the soil is either by physical weathering or chemical weathering. Gravel and sand is a result of physical weathering and clay and silt is a result of chemical weathering. Gravel and sand is most used in civil construction. They have low permeability and is avoid to use where permeability is to be controlled.

C. Different Types of Soils

According to USCS soils are classified into three broad categories

a) Coarse grained soils i.e sand and gravel
b) Fine grained soils i.e silt and clays
c) Organic soils i.e peat.

Soils are also classified as expansive soils, dispersive soils, highly compressive soils and low compressive soils, high plastic and low plastic soils.

D. Fly Ash

It is also known as pulverised fuel ash. It is a coal combustion product that is comprised of the particulates (fine particles of burnt fuel) that are driven out of coal-fired boilers together with the fuel gases. Ash that falls to the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the fuel gases reach the chimneys. Depending upon the source and composition of the coal being burnt, the components of the fly ash vary considerably but all fly ash includes substantial amount of silicon dioxide (SiO_2), Aluminium oxide (Al_2O_3) and calcium oxide (CaO).

Fig. 3: Fly Ash Sample

E. Classification of Fly Ash

According to IS 3812-1981 there are two types of fly ash.

1) Grade I fly ash, which is derived from bituminous coal having fractions SiO2+Al2O3+Fe2O3 greater than 70 %.
2) Grade II fly ash, which is derived from lignite coal having fractions SiO2+Al2O3+Fe2O3 total of which is greater than 50 %.

According to ASTM C618 there are also two categories of fly ash.

Class C and Class F depending on the type of coal and the resultant chemical analysis.

Class C fly ash, normally produced from the combustion of lignite or sub bituminous coals, contains CaO higher than 10 percent and possesses cementitious properties in addition to pozzolanic properties. 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 F fly ash, normally produced from the combustion of bituminous or an anthracite coal contains CaO below 10% and possesses pozzolanic properties. Class F fly ash requires a cementing agent, such as Portland cement, quicklime or hydrated lime-mixed with water to react and produce cementitious compounds.

F. Experimentation

In all three samples S1, S2 & S3 collected at R.D 0.00km, 3.00km & 6.00km respectively as shown in fig. 1.2 for carrying out the various soil tests given below.

1) Sieve analysis test for particle size distribution
2) Liquid limit and plastic limit for the determination of soil index properties
3) Specific gravity of soil4. Proctor compaction test for the determination of maximum dry density (MDD) and optimum moisture content (OMC)
4) Determination of the bearing strength California Bearing Ratio (CBR) test.

The laboratory investigation was undertaken to attain the objectives of the study. Laboratory tests were performed over undisturbed soil and treated soil-fly ash admixture. Dispersive soil stabilized with varying percentages of fly ash, 15%, 20%, 25% and 30% were studied and investigated to determine their influence on engineering properties of the soil. The laboratory work carried out as per Indian standard and so on properties.

1) Proctor Compaction Test

Compaction is the method for densification of soil mass by tightening the air voids. The purpose of laboratory compaction test is so obtain that the proper amount of water at which the weight of the soil grains in a unit volume of the compacted is maximum. The amount of water is called the Optimum Moisture Content (OMC). The maximum dry density (MDD) is achieved at that time when the the soil is compacted at relatively high moisture content and almost all the air is driven out, this moisture content is called optimum moisture content. In the laboratory different values of moisture contents and the resulting dry densities are obtained after compaction and are plotted both to arithmetic scale. The points that observed are joined together as a curve. The maximum dry density and corresponding OMC are read from the curve.

The wet density of the compacted soil is calculated as below. It refers from the book Soil Mechanics and Foundation Engineering by Dr. K.R Arora.

$\square_c = \frac{W1 - W2}{V}$

Where,
w_1 = Weight of mould with moist compacted soil
w_2 = Weight of empty mould.
V = Volume of mould.

The dry density of the soil shall be calculated as follows. Refers from the book Soil Mechanics and Foundation Engineering by Dr. K.R Arora.

$$\gamma_c = \frac{W1 - W2}{V}$$

Where,
γ_t = wet density of the compacted soil
w = moisture content

Compaction of soil increases the density, shearing strength, bearing capacity, thus reducing the voids, settlement and permeability. The results of this are useful in stability of field problems like roads and airfield. The laboratory compaction test results are used to write the compaction specifications for field compaction of the soil.

2) California Bearing Ratio test

The California Bearing Ratio (C.B.R.) test conducted by California division of highway as a method of classifying and obtained the soil subgrade and base course materials for rigid pavements. The test is empirical and the results cannot be related to fundamental property of the material. The CBR is an evaluation of resistance of a material to penetration of standard plunger under restricted density and moisture conditions. The CBR test may be performed for undisturbed specimen in the laboratory. The test is simple and has been extensively calculated for the field correlations of rigid pavement subgrade thickness requirement. The test is performed by causing a cylindrical plunger of some diameter to penetrate a pavement component material at 1.25mm/minute. The loads for 2.5mm and 5mm are observed. This load is verbalized as a percentage of standard load value at a respective deformation level to obtain C.B.R. value. The values are given in the table 3.3. As per IRC recommendation the minimum value of C.B.R. required for a subgrade should be 8%. The process is standardized by Indian Standards Institution in two different categories. It is defined as the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/minute to that required for the corresponding penetration of a standard material.

$$\text{C.B.R.} = \frac{\text{TEST LOAD}}{\text{STANDARD LOAD X 100 \%}}$$

The following table gives the standard loads adopted for different penetrations for the standard material with a C.B.R. value of 100%.

Penetration of plunger (mm)	Standard load (kg)	Unit standard load, kg/cm^2
2.5	1370	70
5.0	2055	105
7.5	2630	134
10.0	3180	162
12.5	3600	183

Table 3.3: Standard Loads for Different Penetration Value

3) Specific Gravity of the soil

Specific gravity of soil is defined as the ratio of the weight of soil solids and weight of equal volume of water at room temperature. It is denoted by G. The Pycnometer method can be used for determination of the specific gravity of solid particles for both fine grained and coarse grained soils. The specific gravity of solids is determined by using the relation which is given by Dr.K.R Arora in Soil Mechanics and Foundation Engineering.

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

Where,
M_1= mass of empty Pycnometer
M_2= mass of the Pycnometer with dry soil
M_3= mass of the Pycnometer and soil and water
M_4 = mass of Pycnometer filled with water only
G= Specific gravity of solids

Fig. 4: Pycnometer Bottles

III. Observations, Analysis & Discussions

A. Particle Size Distribution

Before starting the testing of the samples of the soil, particle size distribution needs to be checked. The particle size distribution has been performed using the following IS sieve size pattern as mentioned below. The maximum size of sieve is 9.5 mm followed by the smallest sieve size 75 microns. In this chapter all tests performed for three different samples namely S1, S2, S3 at R.D 0.00km, 3.00km, 6.00km

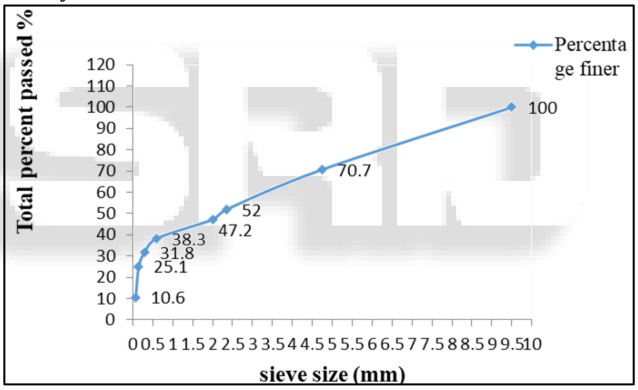

Fig. 5:

B. Proctor Compaction with 20% Fly Ash

- Volume of mould = 1000 cm^3
- Weight of mould with base plate = 4.8 kg
- Weight of procelain dish kg (w1) = 0.074 kg

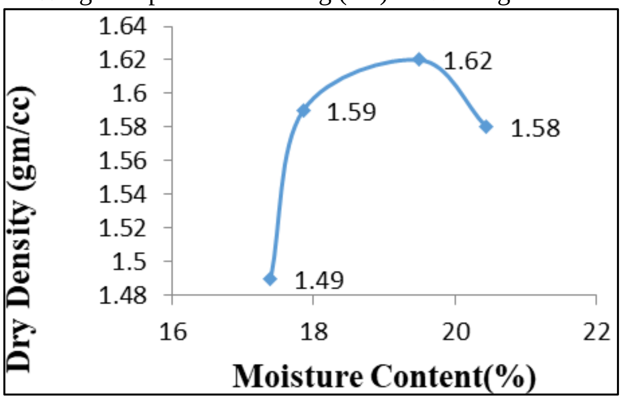

Fig. 6:

C. Liquid Limit

Liquid limit is one of the important parameters of soil which comes under Atterberg's limit. The test needs to be performed so as to predict the consistency state and properties of soil. The test is performed as per IS: 2720 (part 5). Prediction of water content is done against 25 blows.

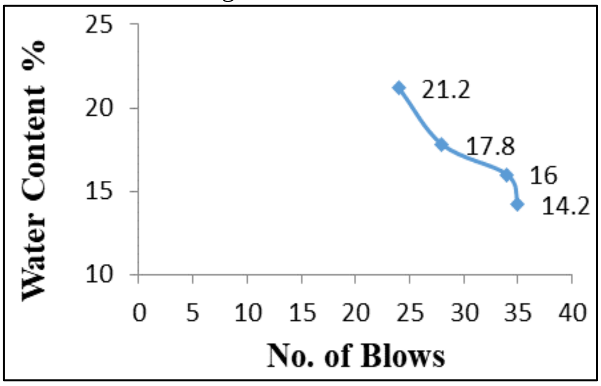

Fig. 7:

D. Specific Gravity

The next test performed is the specific gravity. It needs to be checked within the samples lies between the ranges which is from 2 to 3. Again the samples are taken for three running lengths as mention in the earlier test 0km, 3kms, 6 kms.

Average specific gravity = 2.73As in result, we got the value of average specific gravity as 2.73 which is within specified limit.

Note: specific gravity for soil ranges from 2.0 for organic soils and 3.0 for soil containing heavy minerals. But it is observed that in most cases it lies from 2.65 to 2.85.

IV. Conclusions & Future Scope

A. Conclusions

In the study, following are the conclusions:

From the standard proctor test it is observed that as fly ash percentage is increased from 15% to 30%, the Optimum Moisture Content increases but Dry Density on the other hand decreases.

The California Bearing Ratio test shows that the load sustained by the sample increases initially when fly ash is added up to 25% but if further fly ash is added the load sustained by sample decreases. Hence 25% fly ash addition is optimum, therefore the thickness of pavement resulting in reduction of built cost of the road structure.

Using fly as an additive in the soil helps us in improving the properties of weaker soil which is used in sub grade layer of the rigid pavement.

B. Future Scope

The other type of additives such as lime, kiln dust, moorum, rice husk, marble dust, cement etc. to the sub-grade soils can also be used for the purposes for which fly ash is used.

References

[1] Minnick, L. J., and Meyers, W. F., (1953) "Properties of lime fly ash and soil com- positions employed in road construction", Highway Research Board Bull, Vol. 69, pp. 1-28.

[2] Chopra, S. K., K.C. Narang, K. H. Babu, and R. B. Sharma, (1979) "Research and utilization of Indian fly ashes in cement manufacture—an overview," Proceedings of the 5th International Ash Utilization Symposium, Atlanta, GA, METC/SP-79/10, pp. 631-652.

[3] Terrel, R.L. Epps, J.A. Barenberg, E.J. Mitchell, J.K. & Thompson, M.R., (1979) "Soil stabilization in pavement structures: A user's manual", FHWA-IP-80-2, Vol. 2, Department of Transportation, Federal Highway Administration, USA.

[4] Leonards, G.A. and Bailey, (1982) "Pulverized coal ash as structural fill", ASCE soil mechanic and foundation engineering division, Vol. 108, pp. 517-531.

[5] Skarzynska, K. M. , Rainbow, A. K. M. and Zawisza, E. (1989) "Characteristic Coal Ash in Storage Ponds", Proceeding of XII ICSMFE, Vol. 3, A. A. Balkema, Netherlands, pp. 1915-1918.

[6] Martin, J. P., Collins, R. A. Browning, J. S. and Bhiel F. J. (1990) "Properties and Use of fly Ash for Embankments," ASCE journal of Energy Engineering, Vol. 116, pp. 71-86.

