© 2016 IJSRST | Volume 2 | Issue 2 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Soil Stabilization with Fly ash and Industrial Waste

B. Naga Niranjan Kumar[1], Dr. M. Ashok Kumar[2]

[1]Department of Civil Engineering, Dr. K. V. Subba Reddy Institute of Technology, Kurnool, Andhra Pradesh, India

[2]Department of Mechanical Engineering, Dr. K. V. Subba Reddy Institute of Technology, Kurnool, Andhra Pradesh, India

ABSTRACT

In this present work, it is aimed at developing a new building material from the lime scrap, an industrial The objective of this paper is to upgrade expansive soil as a construction material using industrial waste and fly ash, which are waste materials. Remolded expansive clay was blended with industrial waste and fly ash and strength tests were conducted. The potential of industrial waste -fly ash blend as a swell reduction layer between the footing of a foundation and sub grade was studied. In order to examine the importance of the study, a cost comparison was made for the preparation of the sub-base of a highway project with and without the admixture stabilizations. Stress strain behavior of unconfined compressive strength showed that failure stress and strains increased by 106% and 50% respectively when the fly ash content was increased from 0 to 25%. When the industrial waste content was increased from 0 to 12%, Unconfined Compressive Stress increased by 97% while CBR improved by 47%. Therefore, an industrial waste content of 12% and a fly ash content of 25% are recommended for strengthening the expansive sub grade soil. A fly ash content of 15% is recommended for blending into industrial waste for forming a swell reduction layer because of its satisfactory performance in the laboratory tests.

Keywords : Industrial waste, Fly ash.

I. INTRODUCTION

Soil stabilization is the process of improving the engineering properties of the soil and thus making it more stable. It is required when the soil available for construction is not suitable for the intend purpose. A land-based structure of any type is only as strong as its foundation. For that reason soil is element influencing the success of a construction project. Soil is either part of the foundation or one of the raw materials used in the construction process. Soil stabilization is required to increase the bearing capacity of foundation of soils. It is used to controlling the grading of soil and aggregates in the construction of bases and sub bases of the high ways & airfields. Geotechnical properties of problematic soils such as softfine-grained and expansive soils are improved by various methods. The problematic soil is removed and replaced by a good quality material or treated using mechanical and/or chemical stabilization. Different methods can be used to improve and treat the geotechnical properties of the problematic soils (such as strength and the stiffness) by treating it *in situ*. These methods include densifying treatments (such as compaction or preloading), pore water pressure reduction techniques (such as dewatering or electro-osmosis), the bonding of soil particles (by ground freezing, grouting, and chemical stabilization), and use of reinforcing elements (such as geotextiles and stone columns) (William Powrie, 1997). The chemical stabilization of the problematic soils (soft fine-grained and expansive soils) is very important for many of the geotechnical engineering applications such as pavement structures, roadways, building foundations, channel and reservoir linings, irrigation systems, water lines, and sewer lines to avoid the damage due to the settlement of the soft soil or to the swelling action (heave) of the expansive soils. Generally, the concept of stabilization can be dated to 5000 years ago. McDowell (1959) reported that stabilized earth roads were used in ancient Mesopotamia and Egypt, and that the Greek and the Romans used soil-lime mixtures. Kézdi (1979) mentioned that the first experiments on soil stabilization were achieved in the USA with sand/clay mixtures round 1906. In the 20th century, especially in the thirties, the soil stabilization relevant to road construction was applied in Europe. Aim of this research is to stabilize the locally available red soil around tirupur district. The stabilization is done for the following reasons. Soil stabilization is widely used in connection with road, pavement and foundation construction. It improves the engineering properties of the soil, e.g : Strength - to increase the strength and bearing capacity, Volume stability - to control the swell-shrink characteristics caused by moisture changes, Durability - to increase the resistance to erosion, weathering or traffic loading.

II. METHODS AND MATERIAL

A. Purpose

The purpose of manual is to provide general over view of soil stabilization used in the construction and maintenance of structure designed for supporting motor vehicle use. It is only qualified geo technical engineer can take recommendation on the techniques and material required for suitable sub-base design. It is used to reduce the permeability and compressibility of the soil mass in the earth structures and to increase its shear strength .It is also used to make an area trafficable within short period of time for military and other emergency purpose and used for city and sub urban streets to make them more noise-absorbing.

B. What is Soil Stabilization?

Soil is one of nature's most abundant construction materials. Almost all construction is built with or upon soil. When unstable construction conditions are encountered, a contractor has four options:

1) Find a new construction site
2) Redesign the structure so it can be constructed on the poor soil
3) Remove the poor soil and replace it with good soil
4) Improve the engineering properties of the soils

C. Test on Soils

Laboratory Tests:

Following laboratory tests have been carried out as per IS: 2720. The tests were carried out both on natural soil and stabilized soil with fly ash collected from Ennore Thermal Power Plant.

(i) Grain Size Analysis
(ii) Atterberg Limit Test
(iii) Proctor Compaction Test
(iv) Unconfined Compression Test
(v) Permeability Test Fly Ash India 2005, New Delhi Fly Ash Utilization Programme (FAUP), TIFAC, DST, New Delhi – 110016 VIII 5.3 After removing impurities like vegetation, stones etc. The soil was mixed with fly ash in varying proportion by volume. The Mixing was thoroughly carried out manually and the tests were conducted as per standard procedures. The liquid limit and plastic limit of the soil with varying percentage of fly ash is given in Table 1. The proctor tests carried out is summarized in Fig.1. The grain size analysis of the borrow soil and the fly ash is shown in Fig. 2. Unconfined compression strength tests have been carried out on cylindrical samples of 36 mm diameter and 72 mm high prepared using miniature compaction apparatus with 15% moisture content. The samples were allowed to cure by air drying for 15 days. The samples were tested with a constant strain rate of 0.625 mm/min. The permeability of natural soil and stabilized soil was measured using a falling head test in the laboratory.

Atterbergs Limits Tests

Atterberg limits are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit. As a dry, clayey soil takes on increasing amounts of water, it undergoes dramatic and distinct changes in behavior and consistency. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state, the consistency and behavior of a soil is different and consequently so are its engineering properties. Thus, the boundary between each state can be defined based on a change in the soil's behavior. The Atterberg limits can be used to distinguish between silt and clay, and it can distinguish between different types of silts and clays. These limits were created by Albert Atterberg, a Swedish chemist. They were later refined by Arthur Casagrande. These distinctions in soil are used in assessing the soils that are to have structures built on. Soils when wet retain water and some expand in volume. The amount of expansion is related to the ability of the soil to take in water and its structural make-up (the type of atoms present). These tests are mainly used on clayey or silty soils since these are the soils that expand and shrink due to moisture content. Clays and silts react with the water and thus change sizes and have varying shear strengths. Thus these tests are used widely in the preliminary stages of designing any structure to ensure that the soil will have the correct amount of shear strength and not too much change in volume as it expands and shrinks with different moisture contents. AS a hard, rigid solid in the dry state, soil becomes a crumbly (friable) semisolid when certain moisture content, termed the shrinkage limit, is reached. If it is an expansive soil, this soil will also begin to swell in volume as this moisture content is exceeded. Increasing the water content beyond the soil's plastic limit will transform it into a malleable, plastic mass, which causes additional swelling. The soil will remain in this plastic state until its liquid limit is exceeded, which causes it to transform into a viscous liquid that flows when jarred.

Liquid limit

Figure 1. Casagrande Cup in Action

The liquid limit (LL) is often conceptually defined as the water content at which the behavior of a clayey soil changes from plastic to liquid. Actually, clayey soil does have very small shear strength at the liquid limit and the strength decreases as water content increases; the transition from plastic to liquid behavior occurs over a range of water contents. The precise definition of the liquid limit is based on standard test procedures described below. The original liquid limit test of Atterberg's involved mixing a part of clay in a round-bottomed porcelain bowl of 10–12 cm diameter. A groove was cut through the pat of clay with a spatula, and the bowl was then struck many times against the palm of one hand. Casagrande subsequently standardized the apparatus and the procedures to make the measurement more repeatable. Soil is placed into the metal cup portion of the device and a groove is made down its center with a standardized tool of 13.5 millimeters (0.53 in) width. The cup is repeatedly dropped 10 mm onto a hard rubber base at a rate of 120 blows per minute, during which the groove closes up gradually as a result of the impact. The number of blows for the groove to close is recorded. The moisture content at which it takes 25 drops of the cup to cause the groove to close over a distance of 13.5 millimeters (0.53 in) is defined as the liquid limit. The test is normally run at several moisture contents, and the moisture content which requires 25 blows to close the groove is interpolated from the test results. The Liquid Limit test is defined by ASTM standard test method D 4318 The test method also allows running the test at one moisture content where 20 to 30 blows are required to close the groove; then a correction factor is applied to obtain the liquid limit from the moisture content.

The following is when one should record the N in number of blows needed to close this 1/2-inch gap : The materials needed to do a liquid limit test are as follows

- Casagrande cup (liquid limit device)
- Grooving tool
- Soil pat before test
- Soil pat after test

Another method for measuring the liquid limit is the fall cone test. It is based on the measurement of penetration into the soil of a standardized cone of specific mass. Although the Casagrande test is widely used across North America, the fall cone test is much more prevalent in Europe due to being less dependent on the operator in determining the Liquid Limit.

Importance of Liquid Limit Test:

The importance of the liquid limit test is to classify soils. Different soils have varying liquid limits. Also, one must use the plastic limit to determine its plasticity index.

Plastic Limit

The plastic limit (PL) is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. The procedure is defined in ASTM Standard D 4318..If the soil is plastic, this thread will retain its shape down to a very narrow diameter. The sample can then be remolded and the test repeated. As the moisture content falls due to evaporation, the thread will begin to break apart at larger diameters. The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 3.2 mm (about 1/8 inch).A soil is considered non-plastic if a thread cannot be rolled out down to 3.2 mm at any moisture. "Plastic limit is the lowest moisture content, expressed as a per-centage by weight of the oven-dry soil, at which the soil can be rolled into threacls $ inch in diameter without breaking into pieces' Soil which cannot be rolled into threads at any moisture content is considered non-plastic.

Plasticity Index:

The plasticity index (PI) is a measure of the plasticity of a soil. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties. The PI is the difference between the liquid limit and the plastic limit (PI = LL-PL). Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of 0 (non-plastic) tend to have little or no silt or clay. Plastic index is the difference between the liquid limit and the plastic Limit .It is the range of moisture content through which a soils plastic. When the plastic limit is equal to or greater than the liquid.

PI and their meanings

- (0-3)- Nonplastic
- (3-15) - Slightly plastic
- (15-30) - Medium plastic
- >30 - Highly plastic

Plasticity Index (IP) = WL-WP

= 64.5-41.9

= 22.6%

D. Properties of soil:

Physical properties of soil:

Natural black cotton soil was obtained from Gadag district in Karnataka State. The soil was excavated from a depth of 2.0 m from the natural ground level. The soil is dark grey to black in color with high clay content. The obtained soil was air dried, pulverized manually and soil passing through 425 μ IS sieved was used. This soil has a property of high moisture retentively and develops cracks in summer. This soil predominantly consists of expansive montmorillonite as the principal clay mineral. The physical properties of the soil used in this investigation are given in Table Sieve analysis**,** hydrometer analysis, and Atterberg’s limits were performed to classify the soil the index properties, Compaction characteristics and unconfined compressive strength test were carried out for both fine and coarse soil mixtures. The soils were classified in accordance with Indian Standard classification of soils for engineering purpose.

E. Specific Gravity of Soil

The specific gravity of soil is defined as the ratio of the mass of given volume of soil to the mass of an equal volume of water.

The specific gravity of solids for natural soils falls in the general range of 2.50 to 2.70.

Properties of Industrial Waste:

Physical Properties:

Composed of calcite or dolomite, or a combination of both, Marble is a metamorphic rock, which finds wide usage in buildings, monuments, and sculptures. Commercially however, all calcareous rocks produced by nature and capable being polished are called marbles. The heat and pressure in the earth's crust leads to re-crystallization of limestone over a period of time, which forces the limestone to change its texture and makeup. Fossilized materials in the limestone, along with its original carbonate minerals, re-crystallize and form large, coarse grains of calcite. Impurities present in the limestone during re-crystallization affect the mineral composition of the marble that forms. The minerals that result from impurities give marble wide variety of colors. The purest calcite marble is white in color. So in broader sense True Marble is metamorphosed limestone. Aesthetically more beautiful and available in wider range of colors, Marbles are valued more than limestone, though they share similar characteristics and applications to limestones. Extremely pure calcite marble is used for most statues. Large blocks of colored marble are, used for columns, floors, and other parts of buildings. Smaller pieces of such marble are crushed or finely ground and used as abrasives in soaps and other products. Crushed or ground marble is also used in paving roads and in manufacturing roofing materials and soil treatment products. Valued for its beauty and strength, this precious stone is resistant to fire and erosion.

PHYSICAL PROPERTIES	
Hardness	3 to 4 on Moh's Scale
Density	2.5 to 2.65 Kg/m3
Compressive Strength	1800 to 2100 Kg/cm2
Water Absorption	Less than 1%
Porosity	Quite low
Weather Impact	Resistant

- Physical properties of rock linked with texture and microstructure;
- Laboratory studies yield information's about rock texture and microstructure and therefore inferences about physical properties;
- Development of texture and microstructure related to geological history of rock;
- Field geology and laboratory studies allow estimating the microstructure and texture expected in an area.

Properties of Fly ash:

Physical properties of Fly ash:

Fly ash is a fine residue collected from the burning of pulverized coal in thermal power plants. The worldwide production of fly ash is growing every year. Fly ash is silt – size non-cohesive material having a relatively smaller specific gravity than the normal soils. The disposal of the fly ash is a serious hazard to the environment that consumes millions of rupees towards the cost of its disposal. Fly ash has been used in a variety of construction applications, such as compacted fills, concretes, bricks, liners, construction of embankments in many countries including India. Fly ash by itself has little cementations value but in the presence of moisture it reacts chemically and forms cementations compounds and attributes to the improvement of strength and compressibility characteristics of soils. In the present study, fly ash. The fly ash used was grey in color and the physical properties and chemical composition of fly ash are given below

Specific gravity of Fly ash:

The specific gravity of Fly Ash is defined as the ratio of the mass of given volume of Fly Ash to the mass of an equal volume of water. The specific gravity of solids for Fly Ash falls in the general range of 2.10to 3.The specific gravity of the soil with varying percentage of Fly Ash is given in tale 5 and fig5

Compaction Tests:

Compaction of soil:

Compaction is the process of increasing the Bulk Density of a soil or aggregate by driving out air. For any soil, at a given comp active effort, the density obtained depends on the moisture content. An "Optimum Moisture Content" exists at which it will achieve a maximum density. Compaction is the method of mechanically increasing the density of soil. The densification of soil is achieved by reducing air void space. During compaction, air voids reduces, but not water content It is not possible to compact saturated soil. It should be noted that higher the density of soil mass, stronger, stiffer, more durable will be the soil mass.

Hence, Compaction

1) Increases density
2) Increases strength characteristics
3) Increases load-bearing capacity
4) Decreases undesirable settlement
5) Increases stability of slopes and embankments
6) Decreases permeability
7) Reduces water seepage
8) Reduces Swelling & Shrinkage
9) Reduces frost damage

- In construction of highway embankments, earth dams and many other engineering structures, loose soils must be compacted to improve their strength by increasing their unit weight;
- Compaction -Densification of soil by removing air voids using mechanical equipment;
- The degree of compaction is measured in terms of its dry unit weight.

Three identical samples were prepared for their Maximum Dry Density and Optimum Moisture content based on the compaction curves obtained. The sample was subjected to various curing periods (1, 7, 14, 28 days) according to their trial combination chosen. Samples intended for long term testing were kept in desiccators to maintain 100% humidity and to prevent loss of moisture from samples. Water was sprinkled at regular intervals and was cured in the desiccators. All the samples intended for immediate testing were tested immediately. The unconfined compression test was carried out according to IS 2720(part 10) - 1973. The test was conducted using unconfined Compressive test apparatus at a strain rate of 1.25 mm/ minute. The specimen to be tested was placed centrally in between the lower and upper platform of testing machine. Proving ring reading was noted for 30 divisions on a deformation dial gauge. The loading was continued until three or more consecutive reading of the load dial showed a decreasing or a constant strain rate of 20% had been reached.

There are 4 control factors affecting the extent of compaction:
1. Compaction effort;
2. Soil type and gradation;
3. Moisture content; and
4. Dry unit weight (dry density).

Standard Proctor Compaction Test:

- The standard was originally developed to simulate field compaction in the lab
- Purpose: Find the optimum moisture content at which the maximum dry unit weight is attained

Equipments:

–Standard Proctor
1/30 ft3mold
5.5 lb hammer
3 layers of soil
25 blows / layer

Compaction Effort Compaction Effort is calculated with the following parameters

Mould volume = 2250
Compact in 3 layers
25 blows/layer
5.5 lb hammer

III. RESULT AND DISCUSSION

Soil-fly Ash-Industrial Waste:

Industrial waste-fly-ash-soil mixtures were prepared at several Industrial waste- fly-ash -soil ratios (i.e. 0, 5, 10, and15% Industrial waste and fly-ash content by weight), and then tested for their engineering properties relevant to embankment construction, including the compaction properties, compressive strength, and permeability. The mixing of the Industrial waste- fly-ash-soil as shown in fig .15.

Figure 2. Mixing of soil-fly ash- industrial waste

Compaction of Soil-Fly Ash-Industrial Waste:

The unit weight of Industrial waste- fly-ash-soil mixture is an important parameter since it controls the strength, compressibility, and permeability. Densification of ash improves the engineering properties. The unit weight of the compacted mixtures depends on the method of energy application, and moisture content at compaction. Gray and reported the engineering properties of compacted Industrial waste and fly-ash and found that properly compacted and stabilized fly ash has the requisite properties for use in load-bearing fills or highway sub-bases. Standard proctor compaction tests were performed on the Industrial waste- fly-ash-soil mixture at different Industrial waste- fly-ash-soil ratios. A premeasured amount of Industrial waste, fly-ash measured as percent of dry soil by weight, was mixed thoroughly to produce a homogeneous Industrial waste-fly-ash-soil mixture. Water was added (i.e. 6,9,11 and 14%) slowly mixing.

IV. ACKNOWLEDGMENTS

Authors would like to thank Department of Civil Engineering, Dr. K. V. Subba Reddy Inst. Of Technology, Kurnool-518218 (AP), India for providing all the facilities to carry out the experiments.

V. CONCLUSION

Based on the data accumulated from above research following conclusions have been made.

1. The borrowed clay soil has bearing capacity of 5 kg/mm2.
2. The stabilized clay soil with 5% ,10% ,and15% percentage of Fly Ash and industrial waste achieves bearing capacity of 35kg/mm2
3. The CBR value of borrowed clay soil is 3.1. From design curve in ‟ type traffic, pavement thickness for corresflying soil is 12 inches.
4. CBR value of stabilized soil is 4.82. Pavement thickness corresflying to this value is8.5inches.
5. Compaction of soil with adding fly ash and adding water content strength will be increase to compare compaction of soil only
6. Compaction of soil with adding flyash+industrial waste and adding water content strength will be increase to compare compaction of soil+flyash
7. Strength will be increase adding flyash+industrial waste with increasing water percentage at some level

VI. REFERENCES

[1] B. C. Punmia” Soil Mechanics and Foundations” , Year 2005

[2] Properties of soil” by Arora,

[3] Geotechnical Engineering, by C. V. Venkaramaiah”,

[4] Geotechnical Engineering by Ashok Kumar Jain and Arun Kumar Jain, Laxmi, Publications Pvt.Ltd.,New Delhi

[5] Das, B. M., Principle of Foundation Engineering, 6th (Indian Edition), Year (1999)

[6] Geotechnical Engineering by S. K. Gulhati & Mano Dutta-Tata Mc. Graw-Hill Publishing Company, New Delhi.2005.