

Stabilization of Black cotton soil using Fly ash

Prerna Priya, Ran Vijay Singh



Abstract: Expansive Black cotton clay soils are widely distributed worldwide, and are a significant damage to infrastructure and buildings. It is a common practice around the world to stabilize black cotton soil using fly ash to improve the strength of stabilized sub-base and sub grade soil. Soil stabilization is the improvement of strength or bearing capacity of soil by controlled compaction, proportioning or addition of suitable admixtures or stabilizers. The Black cotton soils are extremely hard when dry, but lose its strength fully when in wet condition. In monsoon they guzzle water and swell and in summer they shrink on evaporation of water from there. Because of its high Swelling and shrinkage characteristics the black cotton soils has been a challenge to the highway engineers. So in this research paper fly ash has been used to improve the various strength properties of natural black cotton soil. The objective of this research paper is to improve the engineering properties of black cotton soil by adding different percentage of fly ash by the weight of soil and make it suitable for construction. A series of standard Proctor tests (for calculation of MDD and OMC) and California Bearing Ratio (C.B.R) tests are conducted on both raw Black cotton soil and mixed soil with different percentages of fly ash (5%, 10%, 20%, 30%) by weight. A comparison between properties of raw black cotton soil, black cotton soil mixed with fly ash are performed. It is found that the properties of black cotton soil mixed with fly ash are suitably enhanced.

Keywords: Soil stabilization, Fly ash, Standard proctor test.

I. INTRODUCTION

Soil stabilization is the improvement of strength or bearing capacity of soil by controlled compaction, proportioning or addition of suitable admixtures or stabilizers. Stabilization can increase the shear strength of soil and control the shrink or swell properties of a soil, thus improving the load bearing capacity of a sub grade to support pavements and foundation. Stabilization can be utilized on roadways, parking areas, site development projects, airports and many other situations where sub grade material are not qualified for construction. Stabilization can be used to treat a wide range of sub-grade materials, varying from expansive clays to granular materials. This process is found using additives like fly ash, rice husk, lime, Portland cement etc.

ADVANTAGES OF SOIL STABILIZATION

- Improves soil strength.
- Reduce expansiveness.

- Improves soil workability.
- Improve the engineering properties of soil and make it suitable for construction.
- Avoid unseen settlement.
- Reduce dust in work environment.

APPLICATIONS:

- Foundations.
- Dam and Reservoir.
- Road constructions.

II. MATERIAL USED

Black cotton soil- Black cotton soils are inorganic clays of medium to high compressibility. They are characterized by high shrinkage and swelling properties. The black cotton soil is very hard when dry, but loses its strength completely in wet condition. 40-60% of the black cotton soil (BC Soil) has a size less than 0.001 mm.

Black cotton soil was collected from Patna, Bihar and then sent to soil laboratory.

Fly ash- Fly ash is a by-product of thermal power plants which use coal as fuel. It is finely divided residue that results from the combustion of pulverized coal and is transported from the combustion chamber by exhaust gases. Generally Fly ash can be classified as Class-c fly ash and Class-F fly ash. This classification is based on the percentage of calcium oxide available in fly ash. At present about 100 thermal power plants in India produce 1.3 million tones of fly ash.

Environmental benefits of fly ash:

- Increasing the life of concrete roads.
- Net reduction in energy use and greenhouse gas.
- Less material for disposal in landfill.
- Fly ash is costless and abundantly available all over the country.
- Utilization of fly ash solves the problem of air and water pollution.

Based on the chemical composition of fly ash, fly ash has been categorized into two categories, as given:

- ❖ Class-c fly ash
- ❖ Class-F fly ash

Properties of raw black cotton soil

The black cotton soil sample used in this project has been collected from Patna, Bihar. It was dug from depth of 1.5 m to 2m beneath the ground surface by open excavation. After that it was dried and shattered to perform the experiments.

Table 1: Properties of natural black cotton soil.

| SI.NO. | Parameters | values |
|--------|--------------------------|--------|
| 1. | Liquid limit | 41.00% |
| 2. | Plastic limit | 24% |
| 3. | Plasticity index | 17% |
| 4. | Optimum moisture content | 13.4% |

Manuscript received on December 25, 2020.
Revised Manuscript received on January 08, 2021.
Manuscript published on January 30, 2021.

* Correspondence Author

Prerna Priya*, Research Scholar, Department of Civil, BIT Sindri, Dhanbad, Jharkhand, India. E-mail: priya.perna97@gmail.com

Dr. Ran Vijay Singh, Department of Civil, BIT Sindri, Dhanbad, Jharkhand, India. E-mail: rvsingh.civil@bitsindri.ac.in

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

Stabilization of black cotton soil using fly ash

| | | |
|----|-------------------------------|-------------|
| 5. | Maximum dry density | 1.794 gm/cc |
| 6. | California bearing ratio(CBR) | 2.300% |
| 7. | Free swell index(FSI) | 42.6% |



Fig.1. Black cotton Soil



Fig.2. Fly ash

III. EXPERIMENTAL DETAIL

This is an experimental project to improve the different properties of black cotton soil by adding fly ash. Here different amount of fly ash have been used in the black cotton soil. Black cotton soil Sample with addition of different proportion of fly ash has been prepared. Using these black cotton soil sample test specimens were prepared and tested as per the experimental matrix. All the laboratory tests conducted to determine the index properties and engineering properties of present soil, and also determine the engineering properties of modified soil. In our study we conducted experiments on varying percentages of fly ash.

1. The basic laboratory test are (Atterberg's limit, compaction, CBR, UCS) were carried out on black cotton soil sample to determine the basic properties of soil.
2. The California bearing ratio and unconfined compressive strength tests were conducted to determine the strength behavior of black cotton soil with fly ash.

After removing impurities like stones, vegetation etc the soil was mixed with fly ash in varying proportion by volume. The mixing of fly ash in black cotton soil carried out four times. The mixing was thoroughly carried out manually and the tests were conducted as per standard procedures. The various results of laboratory tests are performed.

Laboratory test on natural soil

- 1) Atterberg's limits
 - a). Liquid limit
 - b). Plastic limit
- 2). Standard proctor Test
 - a). Maximum dry density (MDD)
 - b). Optimum moisture content (OMC)

- 3). Specific gravity
- 4). California bearing ratio
- 5). Free Swell index (FSI)

A. Fixing the percentage of fly ash.

For fixing the fly ash percentage in the soil, add the fly ash in raw black cotton soil with different percentages that is 5%, 10%, 20%, 30% of the dry weight of soil and find out the OMC-MDD for different percentages. At 20% amount of fly ash the MDD (maximum dry density) have been found maximum.

- a). In first test, black cotton soil was mixed with 5% fly ash.
- b). In Second test, black cotton soil was mixed with 10% fly ash.
- c). In third test, black cotton soil was mixed with 20% fly ash.
- d). In fourth test, black cotton soil was mixed with 30% fly ash.

Laboratory test on Natural soil+ Different percentage of fly ash

IV. DATA ANALYSIS

Table.2. Test result of natural soil

| Test No. | Test name | Fly ash proportion |
|----------|--------------------------|--------------------|
| 1. | Liquid limit | 0%,5%,10%,20%,30% |
| 2. | Plastic limit | 0%,5%,10%,20%,30% |
| 3. | Plasticity index | 0%,5%,10%,20%,30% |
| 4. | Optimum moisture content | 0%,5%,10%,20%,30% |
| 5. | Maximum dry density | 0%,5%,10%,20%,30% |
| 6. | California bearing ratio | 0%,5%,10%,20%,30% |
| 7. | Free swell index(FSI) | 0%,5%,10%,20%,30% |

Below results are the results of the test performed on the soil in natural conditions shown in table.2. These results will be the base of comparative study between the properties of soil in natural conditions and properties of soil after adding fly ash shown in Table.3.

Table.3. Test results of soil-fly ash mixtures

| Parameters | UOM | Fly ash percentage | | | | |
|--------------------------|-------|--------------------|------|------|-------------|------|
| | | 0% | 5% | 10% | 20% | 30% |
| Liquid limit | % | 41.0 | 39.0 | 37.5 | 34.3 | 31.5 |
| Plastic limit | % | 24.0 | 23.0 | 22.1 | 20.4 | 19.2 |
| Plasticity index | % | 17.0 | 16.0 | 15.4 | 13.9 | 12.3 |
| Optimum moisture content | % | 13.4 | 13.0 | 12.5 | 12.1 | 11.5 |
| Maximum dry density | gm/cc | 1.79 | 1.79 | 1.80 | 1.81 | 1.81 |
| | | 4 | 6 | 1 | 2 | 7 |



| | | | | | | |
|--------------------------|---|------|------|------|-----|-----|
| California bearing ratio | | 2.3 | 2.5 | 3.1 | 3.9 | 4.2 |
| Free swell index | % | 42.6 | 42.1 | 38.5 | 35 | 32 |

B. Liquid limit test of soil sample after mixing with different percentage of fly ash.

In this segment ,results for black cotton soil sample with different percentages of fly ash (5%,10%,20%,30%)are shown in details.A series of liquid limit tests are performed on black cotton soil with vary in percentages of fly ash and the corresponding test results are demonstrated below.

Table.3. Liquid limit of soil after mixing different . percentage of fly ash

| CONTENT | LIQUID LIMIT(%) |
|--------------------|-----------------|
| Black cotton soil | 41.0 |
| 5% fly ash | 39.0 |
| 10% fly ash | 37.5 |
| 20% fly ash | 34.3 |
| 30% fly ash | 31.5 |

Here results can be seen that with addition of fly ash upto 30% in soil sample,liquid limit value decreases from 41% to 31.5%.

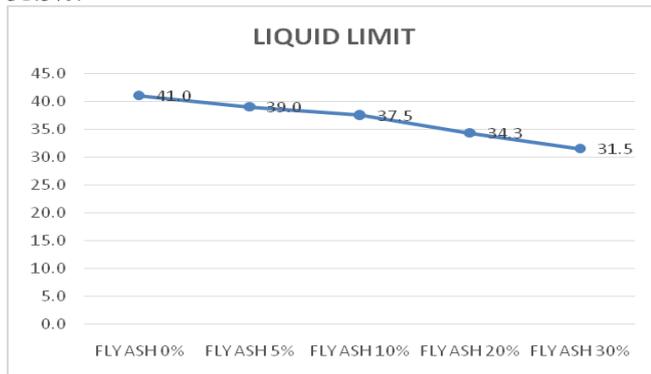


Fig.4. Fly ash (%) and liquid limit graph

C. Plastic limit test of soil sample after mixing with different percentage of fly ash.

In this segment ,results for black cotton soil sample with different percentages of fly ash (5%,10%,20%,30%)are shown in details.A series of Plastic limit tests are performed on black cotton soil with vary in percentages of fly ash and the corresponding test results are demonstrated below.

Table.4. Plastic limit of soil after mixing different . percentage of fly ash

| CONTENT | PLASTIC LIMIT(%) |
|--------------------|------------------|
| Black cotton soil | 24.0 |
| 5% fly ash | 23.0 |
| 10% fly ash | 22.1 |
| 20% fly ash | 20.4 |
| 30% fly ash | 19.2 |

Here results can be seen that with addition of fly ash upto 30% in soil sample,plastic limit value decreases from 24% to 19.2%.

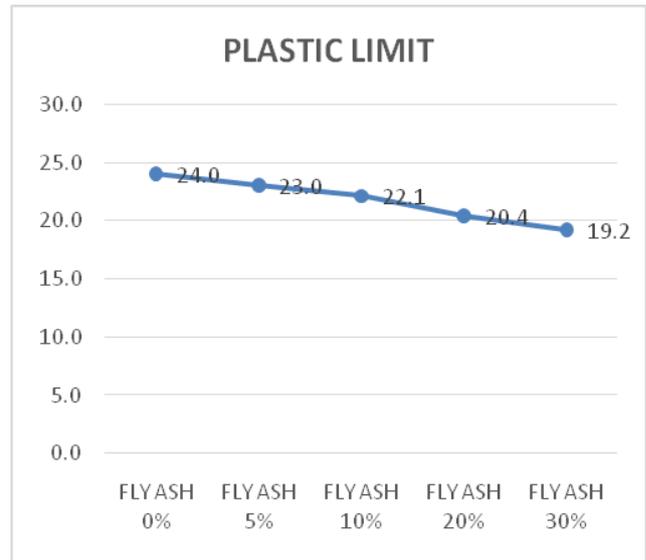


Fig.5. Fly ash (%) and plastic limit graph

D. Plasticity index test of soil sample after mixing with different percentage of fly ash.

In this segment ,results for black cotton soil sample with different percentages of fly ash (5%,10%,20%,30%)are shown in details.A series of Plasticity index tests are performed on black cotton soil with vary in percentages of fly ash and the corresponding test results are demonstrated below.

Table.5. Plastic limit of soil after mixing different . percentage of fly ash

| CONTENT | PLASTICITY INDEX(%) |
|--------------------|---------------------|
| Black cotton soil | 24.0 |
| 5% fly ash | 23.0 |
| 10% fly ash | 22.1 |
| 20% fly ash | 20.4 |
| 30% fly ash | 19.2 |

Here results can be seen that with addition of fly ash upto 30% in soil sample,plastic limit value decreases from 24% to 19.2%.

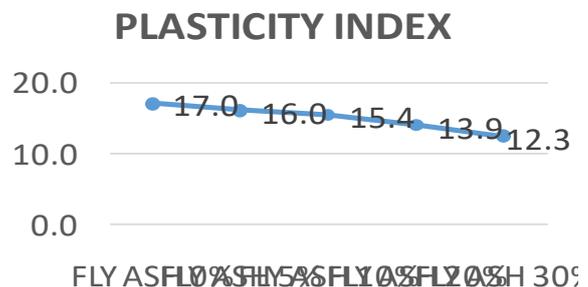


Fig.6. Fly ash (%) and plasticity index graph

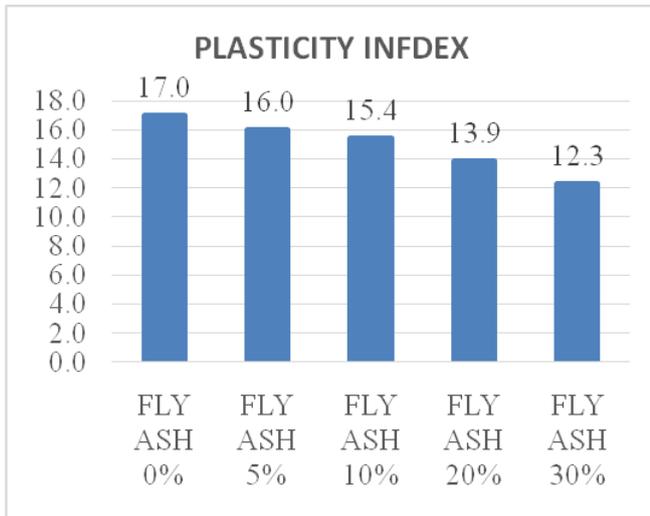


Fig.7. Bar chart variation of plasticity index for natural soil-fly ash mixture

E. Standard proctor compaction test of soil sample after mixing with different percentage of fly ash.

In this segment ,results for black cotton soil sample with different percentages of fly ash (5%,10%,20%,30%)are shown in details.A series of standard proctor compaction tests are performed on black cotton soil with vary in percentages of fly ash and the corresponding test results are demonstrated below.

Table.6. MDD and OMC of soil after mixing different . percentage of fly ash

| CONTENT | MDD (g/cc) | OMC(%) |
|--------------------|--------------|-------------|
| Black cotton soil | 1.794 | 13.4 |
| 5% fly ash | 1.796 | 13.0 |
| 10% fly ash | 1.801 | 12.5 |
| 20% fly ash | 1.812 | 12.1 |
| 30% fly ash | 1.807 | 11.5 |

Sample Here results can be seen that soil sample attains maximum dry density (1.812) after adding 20% fly ash and further addition of fly ash decreases the MDD.

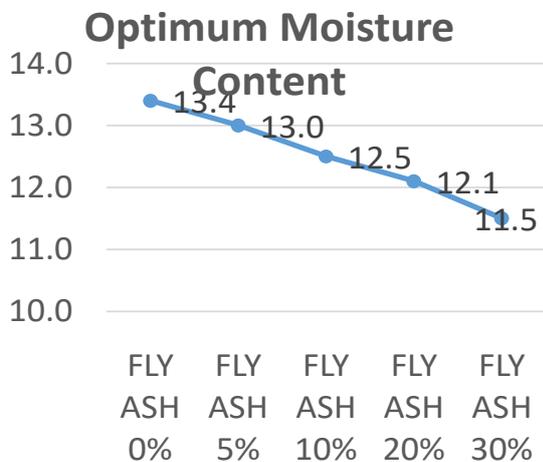


Fig.8. Fly ash (%) and OMC graph

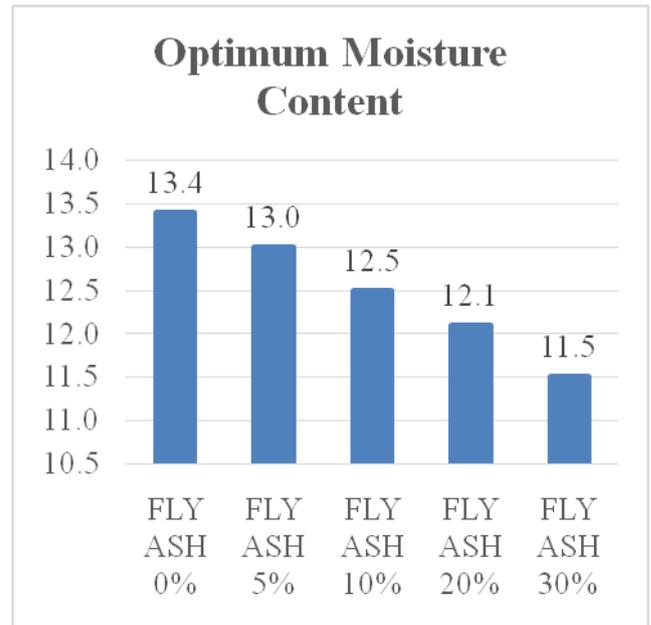


Fig. 9. Bar chart Variation of OMC sample with different % of fly ash

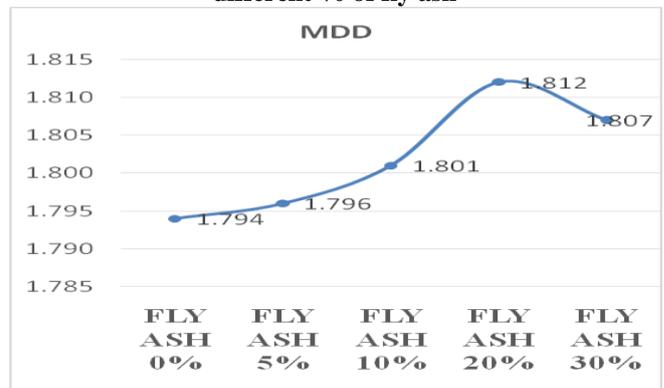


Fig.10. Fly ash (%) and MDD graph

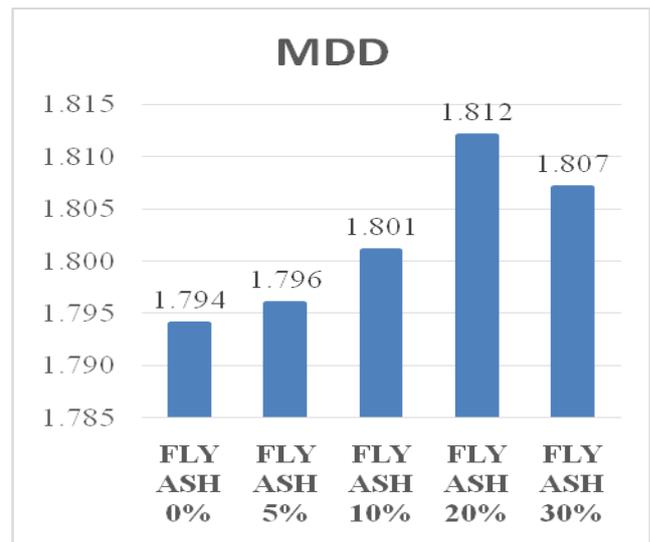


Fig.11. Bar chart variation of MDD sample with different (%) of fly ash



F. CBR

Generally the C.B.R. value at 2.5 mm will be greater than at 5 mm and in such a case/the former shall be taken as C.B.R. for design purpose. If C.B.R. for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the C.B.R.

TABLE.7.CALIFORNIA BEARING RATIO

| Penetration of plunger in mm | Dial reading in division | Load in Kgf |
|------------------------------|--------------------------|-------------|
| 0 | 0 | 0 |
| 0.5 | 4 | 7.6 |
| 1 | 8 | 15.2 |
| 1.5 | 11 | 20.9 |
| 2 | 14 | 26.6 |
| 2.5 | 17 | 32.3 |
| 3 | 19 | 36.1 |
| 4 | 22 | 41.8 |
| 5 | 25 | 47.5 |
| 7.5 | 30 | 57 |
| 10 | 34 | 64.6 |
| 12.5 | 38 | 72.2 |

California Bearing Ratio

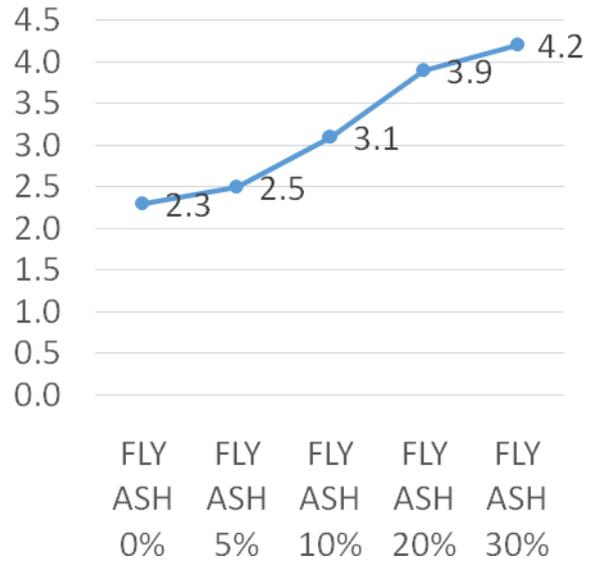
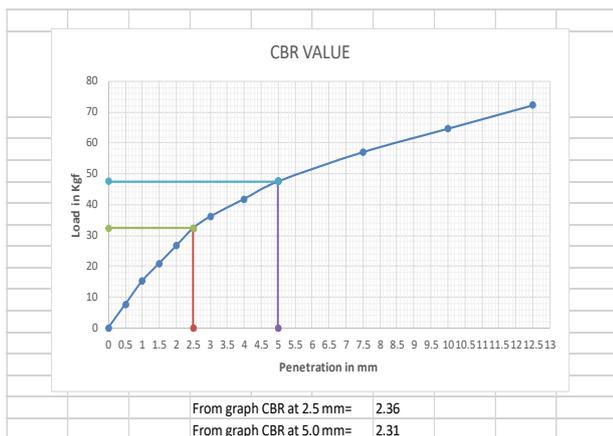


Fig.12. Fly ash (%) and CBR graph



From graph CBR at 2.5 mm = 2.36
From graph CBR at 5.0 mm = 2.31

CBR Value of soil sample with different percentage of fly ash

The following results are obtained from laboratory for CBR(California bearing ratio) value of sample soil with varying percentage of fly ash has been demonstrated below

TABLE.8.CBR Values at different percentage of fly ash

| Percentage of fly ash(%) | CBR at 2.5 mm |
|--------------------------|---------------|
| 0 | 2.3 |
| 5 | 2.5 |
| 10 | 3.1 |
| 20 | 3.9 |
| 30 | 4.2 |

Here results can be seen that with addition of fly ash upto 30% in soil sample, CBR value increases from 2.3 to 4.2.

California Bearing Ratio

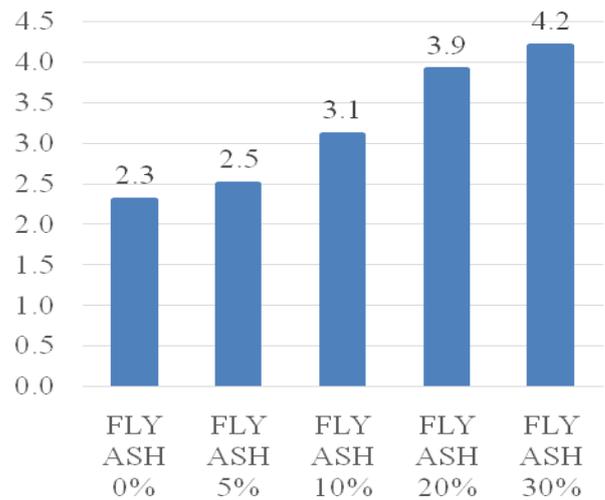


Fig.13. Bar chart variation of CBR sample with different % of fly ash

CONCLUSION

According to the data and results acquired from the experimental work on soil stability investigation with different percentages of fly ash i.e.(0%,5%,10%,20%,30%),the following conclusion can be drawn in the aspect of strength properties due to application of fly ash as a stabilizing agent for the natural black cotton soil.

➤ From the above data, the maximum dry densities are found to be 1.794 g/cc for 0%, 1.796 g/cc for 5%, 1.801 g/cc for 20%, 1.807 g/cc of 30% fly ash. Based on the results from the compaction test, it can be stated that with increase in percentage of fly ash the compaction parameter i.e.

MDD(maximum dry density) is increased upto 1.812g/cc at 20% fly ash content and then decreases. Other compaction parameter i.e. OMC(optimum moisture content) is found out to be 12.1% at 20% fly ash content. So it is concluded that for effective soil stabilization at 20% fly ash gives better result.

- Based on the results from the compaction test, it can be stated that at 20% fly ash content the compaction parameter i.e.MDD (maximum dry density) is found out to be maximum and is equals to 1.812gm/cc. Other compaction parameter i.e.OMC(optimum moisture content) is found out to be minimum(11.5 %) at 30% fly ash content.
- Based on CBR test results, it is observed that addition of fly ash as stabilizing agent for clayey soils produces significant increase in CBR value. It is concluded that ,with increase in fly ash the CBR values are also increased considerably and is found to be maximum 4.2 for 30 % fly ash.
- From the above discussion ,it is inferred that addition of fly ash to the black cotton soil there is appreciable impact on the compaction parameters and bearing capacity of soil. It is also inferred that ,expensive methods for stabilization of soils such as with cement, gypsum etc. can be supplanted together with fly ash as an alternative method to improve the weak black cotton soil properties.Fly ash can be used for stabilization of pavement sub grade ,embankment and other fields of civil engineering according to the requirements for black cotton soils.

REFERENCE

1. O. C. McDowell, "Stabilization with lime, lime-fly ash, and other lime reactive materials", High Res Board Vol 231, pp. 60-61, 1959.
2. T. S. Nagaraj, and N. Miura. "Soil Clay Behaviour, Analysis and Assessment", Brook Field, Rotterdam: AA. Belkema, 2001.
3. Chemical and Mechanical Stabilization of Subgrades and Flexible Pavement Sections", July 1998. TTN Tensar Technical Note BR 10, 1998.
4. A. Kezdi, "Stabilized Earth Roads". Amsterdam: Elsevier Scientific Publishing Company, 1979.
5. U. S. Army, U. S. Navy, and U. S. AirForce, "Soil Stabilization for Pavements", In University Press of the Pacific. Honolulu, Hawaii, 2005.
6. Mc Dowell, C. (1959). "Stabilization of Soils with Lime Lime-fly ash and other Lime reactive minerals", HRB,Bulletin No.231
7. Ramana Murthy, V. (1998). "Study on swell pressure and method of controlling swell of expansive soil", .PhD. Thesis, Kalkatiya university, REC, Warangal.
8. Ramana Sastry, M.V.B. (1989). "Strengthening Subgrades of Roads in Deltaic Areas of Andhra Pradesh", Proc of IGC-89, Visakhapatnam,India Vol.1,pp 181-184.
9. M. Jayakumar and Lau Chee Sing, "Experimental studies on treated sub base soil with fly ash and cement for sustainable design Recoendations", International Journal of engineering and applied Sciences.
10. Venkaramuthyalu, K. Ramu and G.V.R. Prasada Raju Expansive Soil" International Journal of Advances in Engineering& Technology, Jan 2012.
11. Chen,F.H.(1975) Foundations on Expansive Soils,Elsevier Scientific Pub.Co.Amsterdam.Adeniji,F.A. Conference on Arid zone Ideology Hydrology And water resources, Maduguri pp.331-348.
12. Brajesh Mishra,"A Study on Engineering Behaviour of Black cotton soil and its stabilization by use of ly ash.

AUTHORS PROFILE



Prerna Priya, M-Tech from BIT Sindri, Dhanbad, Jharkhand, INDIA, PIN-828123.

E-mail: priya.pruna97@gmail.com

Prerna priya is currently pursuing M-Tech in Soil and Foundation from Department of Civil from BIT Sindri, Dhanbad, Jharkhand, PIN-828123.

I had my B-Tech in Civil Engineering from M.I.T; Muzaffarpur.I had done training from B.S.R.D.C, Patna. I had done B-Tech project on "Design of

flexible pavement" in 2017.



Dr .Ran Vijay Singh, Department of Civil Engineering,B.I.T Sindri,Jharkhand,INDIA,PIN 828123.

Email:- rvsingh.civil@bitsindri.ac.in

Dr.Ran Vijay Singh is currently working as professor in the Department of CIVIL, BIT Sindri (under ministry of Higher, Technical Education, Skill Development, Government of Jharkhand), Dhanbad, PIN-828123.He is also Dean, Planning & Development For B.I.T, Sindri. He is prior to B.I.T Sindri worked as Specialist, Solid waste management, Environmental Specialist. He is also In-charge Sewer & Drains projects for Ministry of urban development and Housing, Government of Jharkhand.