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STABILIZATION OF PAVEMENT SUBGRADE BY USING FLY ASH REINFORCED WITH GEOTEXTILE IN FIELD OF GEOTECHNICAL ENGINEERING

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***Abstract*— Soil is an imperative aspect in civil construction. Due to poor engineering features, the local soils could lead to a lot of issues in construction and thus, it needs an improvement in their engineering properties. One of the methods of doing this is stabilization that enhances hordes of engineering characteristics including strength, bearing power, compressibility and several other soil properties.**

Soil Reinforcement is one of these techniques in which we enhance the engineering properties of the matter. This process involves the use of natural fibers to strengthen the soil, and this is an ancient concept. Due to this, the unduly distributed soils that are reinforced with fiber have lured the attention of geotechnical engineers for quite some time now.

The pavement performance is a critical aspect in terms of the features of soil upgrade that offers a surface for complete structure of the pavement. This is a matter of great importance, and the strength of pavements gets increased by proper construction & design practices. Tons of fly ash that emerges from hordes of thermal power plants has a low weight, is non-plastic and is extremely fine. This usually gets disposed as a slurry in ponds underlying the area. And if you would have noticed, the ash from these ponds leads to air pollution which is a very serious threat. Since the load-carrying capability of these materials is less, working on their civil engineering properties is quite difficult. However, these material's performance can be enhanced with the use of methods involving soil reinforcement.

For instance, you can employ it as sub-grade to the pavements by employing geotextile sheets for reinforcement. In this case study, certain parts of fly ask compressed to their max dry density with a very little moisture is affixed with the help of Geotextile layers and these even employ the CBR module. In accordance with plan dimension relating CBR module, Geotextile sheets are kept at different preparation of the first, second, third and fourth layers at distinct places. In each fixture of these Geotextile sheets, the value for California Bearing Ratio (CBR) is evaluated in labs and these outcomes are compared with CBR value outcomes that emerged beforehand.

***Index Terms*—Geo-Technical, Fly-Ash, Geo-Textile, EDX, FESEM.**

I. Introduction

One of the major sources of energy is Coal in India and is likely to be so in future as well. The fly as that comes out of the Indian thermal powerplants is estimated to be over 100 million tonnes. However, there are areas such as mine filling, structural filling land reclamation, road construction and several other such areas where this fly ash can be used. This can solve the disposal issue to a great extent. According to Toth et al., who learned using fly as for structural filling, devised that the structural nature of fly ash is quite equivalent to silt and if a structural fill is prepared using the fly ash, this would definitely do much better than the one made of natural materials.

Scholars like Balley and Leonard used non-treated coal as in a pulverized manner and it showed more cementing features when used as a product for filling the structure in order to use it as a foundation support for a brand-new precipitator at a power station located in Indianapolis, USA. Even Sridharan et al. studied the ash ponds in terms of their geotechnical features in India and found this flash ash having very less unit weight, but high properties relating friction, less compressibility and quite good for the structural fill uses. When you strengthen these materials with the use of soil improving methods, they can be used as a base of various physical structures, embankments and subgrades of roads. This process of reinforcing the soil with the help of tension resistance has been inculcated widely in engineering.

Both bound and unbound pavements get hammered by frequent loads that focus with strength on a point. They can lead to aging of precipitate and even rattle the construction of roads. This strengthening of the pavements and the roads and enhance its service life by lowering the fatigue and cracks due to settlement and thermal issues. The stress concentration on these Pavements and Roads gets lessened and distributes evenly. Subgrade is known as a layer that has been compacted, formed of naturally distributed soil, about 300mm thick, lying below the pavement of the crust and offering a suitable pavement base. The embankment subgrade can be compressed in a couple of layers, normally to a much better standard against the embankment's lower part. It is essential to compress the subgrade very well, in embankment or cutting, so as to use the complete ability and lessen the cost of the complete pavement size.

Geotextiles act like catalysts, and they are majorly employed in foundation components structures that support load. These structures include dams, railways and canals etc. and handover the load with the help of their own foundation within and below soil mass. The soil properties burdened by the load are critical or its stability and of any kind of structure. This can be used to increase the stability in the soil for which these textiles gained the limelight like a new geotechnical product.

Much later, geotextiles are used to increase the tensile properties and the mechanical features of materials used in civil engineering. These include road surfaces and below surface while constructing and renovating the previous highways. This nature of soil and the features offer geotextile functions and hence they earn the appreciation. With the help of detailed review, we can understand the importance of design and engineered jute textile that suits the needs of distinct geotechnical processes.

II. LITERATURE REVIEW

Kumar and Vikranth (in 2015) examined the enhancement in strong nature of black soil as they mixed different proportions of coconut fibre with fly ash such as 0 percent, 0.35 percent, 0.5 percent, 1 percent and fly ash percentage of 0 percent, 1 percent, 5 percent, 10 percent, 15 percent and 20 percent with unconfined compression strength test and CBR tests.

Islam and Asaduzzaman (in 2014) examined the enhancement in soil by using the reinforcements with 12-inch length and a diameter of 0.5-inch spread evenly in soil at distinct depths of about 0.75-inches, about 1.5-inches and 2.25 inches beneath footings. They used triple square footings (3 inch into 3 inch, 3.5 inch into 3.5 inch and 4 x 4 inches) to take the study. The first arrived settlement in a vertical format was governed by initial load of soil that was not reinforced in comparison to soil that had bamboo fibers. The value of failure for the model in any such case showed an increase in loading when you evaluated it with the soil that was not strengthened. There was a lot of enhancement in load bearing capacity against the soil that was not reinforced. A single system of layers, the load bearing power was max and what was less was settlement when they placed the reinforcing layer at around 0.3B. If there are lots of layers, BCR value gets enhanced with the increase in reinforcement layers.

Wen the fly ash mix with soil was studied for the reinforcement of about 0.5 percent and 1 percent, the polyester fibers about 20mm long were used and this study was carried forward in India by Havanagi and Kaniraj. It showed that the mixed result of fiber and fly ash on the turf (Jadhao et al in 2008 and Kaniraj et al in 2001).

According to Kumar et al, if the expansive soil had polyester fiber of about 12mm long and this is layered in clayey soil that is quite compressible from 0 to 1 percent. The outcomes showed that reinforcing clayey soil that was compressible as well with fibers arranged randomly can lead to an enhance in ultimate load carrying capability and lessen the ultimate load settlement.

They devised that the bearing power of soil and the bearing pressure that is safe (SBP) will enhance with the enhance in content of fiber leading to 0.5 percent and it reduces then when further fibers are included (Maheshwari et al. in 2011). Scientists from Japan discovered that low length PET fibers about 64 mm in size when added to the soil showed a lot of piping forbearance and this layer o soil with reinforcement also enhanced soil stability against seepint to prevent flooding (Furumoto et al in 2010).

III. SAMPLING

A. Fly Ash

For this research, MPL or Maithon Power Limited was appointed as a station for sampling and this is situated in Dhanbad district in Jharkhand state with latitudes of the area being 230 49' 38" N and longitudes being 860 45' 41" E. MPL is one of the joint ventures of Damodar Valley Corporation and Tata power that brought 1050MW (about 2 x 525 MW units) in Dhanabad city, Jharkhand, India.

This is the first ever 525MW Project from India with the plants employing subcritical power and these thermal plants were based on coal and were credited to be the first ever PPP project or Public Private Power plants in India.

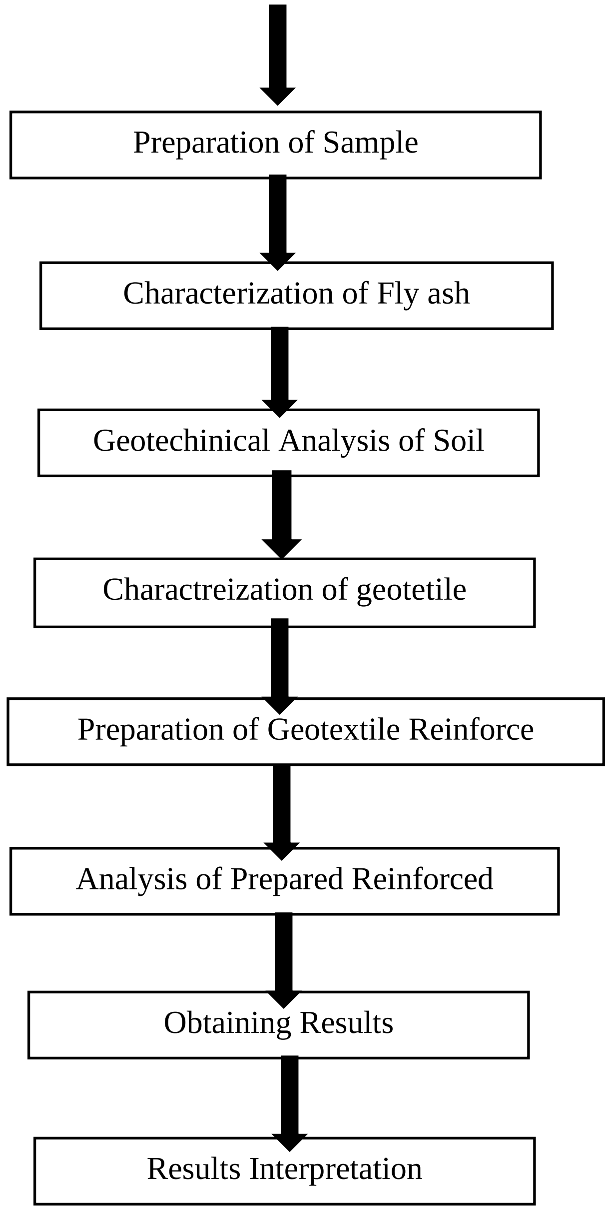
B. Soil

The sample of soil was obtained from Azad Institute of Engineering and Technology, Lucknow. This is done with the use of core cutter method with depth taken as 1 meter below the ground. The soil is left to dry for a couple of days and this soil is them crushed firmly. This crushed soil passes through an IS sieve of 4.75mm and this soil is then used for study purpose. This soil should pass 425micron sieve.

C. Geo Textile

Geotextile is known as a fibrous material that is used with soil environment and contains non-woven and woven materials with polymers, natural products like jute, fabricated with the use of textile process. Polypropylene: When you polymerize the monomers of propylene with specific catalysts, it gives birth to thermoplastic polypropylene in a crystalline environment. This can be subjected to oxidation and needs additives to guard to keep them safe from maturing. Some other additives may be employed to enhance thermal stability, resistance to UV and resistance underwater. This study used polypropylene Geotextile in a non-woven form that was brought from Ayyappa geo synthetics installers in Lankelapalem that is near Vishakhapatnam.

IV. METHODOLOGY



VI. ANALYSIS

A. GEOECHNICAL PARAMETER

Sampling analysis is performed inside Geotech, lab for Geotechnical constraints (as mentioned in IS 2720:1983) with the preparation of sample as per the IS code 2720 (first part) in 1983 and the blow-given tests were conducted:

1) Specific Gravity:

In order to know specific gravity of fly-ash-mixed soil of fine grains, this test takes place with the help of density bottle procedure according to IS2720 (3rd Part/first section). Specific Gravity is defined as the proportion of weight of a certain amount of material at designated temperature to the similar amount of water in a distilled form at similar temperature.

Fig 5.1: Density bottle

Calculation:

$$specific\ gravity = \frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_2)}$$

2) Bulk Density:

This is defined as the per unit bulk volume weight of dry soil with the presence of air spaces. Bulk density for the soils can fluctuate a great bit when different kinds of soils are taken and can be influenced due to organization applications. Including a lot of carbon-based elements in the soil could lessen its bulk density and process that compress the soil may enhance the bulk density. The process followed is taken from IS2720 (second part in 1973).

Apparatus Required :
1. Graduated cylinders.
2. Balance.

Fig 5.2: Moisture content can

Calculations :

Calculate the moisture content of the fly ash as a percentage of the dry fly ash weight.

$$Moisture\ content = \frac{w_2 - w_3}{w_3 - w_1} X\ 100$$

W_1= Weight of can (g)
W_2= Weight of moist fly ash + can (g)
W_3= Weight of dried fly ash + can (g)

3) Compaction

Laboratory determination of Proctor Compaction Test needs to be carried out. The tests can help to obtain max dry density for fly ash, and this can be used as a benchmark for testing on the field. This can also help to test the consequence of moisture laid on density of the taken soil. If soils that have high density, it needs a modified version of Proctor Compaction testing that employs higher value. No doubt, this could be carried out using IS2720 (8th Part – 1983).

Fig 5.3: Compaction Mould

Calculation:

Calculate the moisture content of each layer of the fly ash as a percentage of the dry sample weight.

$$Moisture\ content = \frac{w_2 - w_3}{w_3 - w_1} X\ 100$$

W_1= Weight of tin (g)
W_2= Weight of moist fly ash + tin (g)
W_3= Weight of dried fly ash + tin (g)

4) Permeability

This test is performed when water is made to flow over a comparatively low sample of soil adjoined against a standpipe that offers water head while allowing the measure of water volume that passes along in the sample. Soil permeability can also be called as permeameter for falling head. This permeameter for falling head is employed to assess the permeable nature of low pervious soil. This permeability test is achieved with the help of falling head method according to the IS2720 (17th part -1986).

Fig 5.4: Permeability Mould

Calculation:

The coefficient of permeability is given by

$$k = \frac{2.3aL}{At} log_{10}\left(\frac{h_1}{h_2}\right)$$

Where,

h_1 = initial head,
h_2 = final head,
t = time interval,
a = cross-sectional area of the liquid stand pipe,
A =cross-sectional area of the specimen,
L = length of specimen.

5) Plastic Limit

For a particular kind of soil this is defined as the content of water in it beneath which it is no more plastic. As soon as it gets turned over to threads of about 3mm in dia., it starts crumbling. Test for plastic limit is achieve according to the IS standards 2720 (5th part – 1958).

Calculation:

$$Plastic\ limit = \frac{w_2 - w_3}{w_3 - w_1} X\ 100$$

W_1= Weight of tin (g)
W_2= Weight of moist fly ash + tin (g)
W_3= Weight of dried fly ash + tin (g)

6) Shrinkage Limit

This is defined as the amount of water in soil when this content of water is just enough to completely fill the soil pores and the soil just reaches its saturation limit. But do not consider the soil volume to be decreased less than shrinkage limit. This test for shrinkage limit is performed according to IS2727 (5th part – 1958).

Calculation:

Shrinkage limit can be determined from the relation

$$shrinkage\ limit = \frac{(M_1 - M_s) - (V_1 - V_2)\rho_w}{M_s}$$

Where,
M_1= initial wet mass,
V_1= initial volume
V_2= final volume
M_S = dry mass

7) Grain Size Analysis

The purpose of this test is to know the percentage of distinct sizes of grains in a particular type or soil. Using sieve or mechanical analysis, you can govern the dispersal of particles that are coarse and large in size. Against this, you can determine the concentration of fine particles using hydrometer method. This distribution of distinct sixes of grains can affect the soil's engineering features. And with analysis of the sizes of grains, you can get their distribution value which is essential to classify the kind of soil. This test is done with the help pf sieve according to IS2720 (4th part – 1985).

B. CHEMICAL AND MORPHOLOGICAL PARAMETER ANALYSIS

You need to perform sample analysis with the help of this simple experiment

1) X-ray florescence (XRF) Test

XRF or X-Ray fluorescence spectrometer is a kind of xray instrument that is employed in normal, fairly non-damaging rock chemical analysis fluids, minerals and sediments. Normally the principle for wavelength-diffusing spectroscope that share similarity with EPMA or electron microprobe. Although, XRF is not capable of making studies for very little spot sizes for EPMA (ranging from 2 to 5 microns) and therefore it is normally employed in large-scale examination of chief and trace rock elements, sediments or minerals.

If you talk about XRF studies, they rely on basic principles that could be similar for some other methods involving instruments and correlation among beans of electros with x-rays for the samples, taking x-ray spectroscopy with spectroscopy for dispersive wavelength (microprobe WDS). This examination of trace and chief elements in the earthly materials with the help of x-ray fluorescence is imaginable due to the atomic behavior while they share an interaction with the radiations. In an excited state due to high energy, the materials can turn ionized. The radiations that emit out have less energy as compared to the x-rays with primary incident and this is known as fluorescent radiation. Since the emitted photon energy is a trademark of the evolution in between orbitals of specific electrons in a specific element, the outcome of these fluorescent x-rays can be employed to perceive the availability of elements already there in these samples.

2) Scanning Electron Microscope for field emission or EFE-SEM test

You can image s specimen surface by using this test and this is done by raster scanning with the help of beams of high energy electrons. These electrons stay in touch with atoms that contain samples to give rise to signals that devise information related to surface landscape, arrangement and other features like electrical conductivity. Electron gun is used to offer a huge amount of an extremely stable current but in a diminutive beam. Emission sources exist in 2 different classes: Field Emitter and Thermionic Emitter. The type of Emitter is the major distinction between a Scanning Electron Microscope Field-Emission type and a normal Scanning Electron Microscope or SEM.

3) EDX test of Energy Dispersive X-Ray Test

In a method where multiple techniques could be employed, EDX holds a strong value and normally when you carry out contamination analysis and investigations pertaining to the industrialized forensics. The technique can exist in a number of forms and it can be quantitative, qualitative or semi-quantitative and with the help of mapping, you can also get the elements' spatial dissemination. This EDX technology is considered non-destructive and samples that hold value can be analysed wherever they are found without or with the preparation of the sample. In conditions when coupled EDX Data and Microscopy data are not adequate to detect a sample, balancing procedures could be employed, and these include Raman Microscopy, Surface Analysis and Infra Red Microscopy etc.

4) AAS test or Atomic Absorption Spectroscopy:

This method used to gauge the quantity of energy (existing as light photons) being absorbed in the sample. More clearly, there is a detector that is used as a gauge the light wavelengths that are derived from the specimen and puts them against the wavelengths that priorly penetrated through specimen. There is also a signal processor that joins in wavelength change and this gets portrayed as a readout with apex energy absorbing capability at different wavelength. All the atoms have distinctive array of wavelength where the energy gets absorbed and this is due to the distinctive electron configuration in the ultimate shell. This lets the qualitative analysis take place for the pure sample. If you need to disclose the amount of identified element in a specimen, you first need to establish a platform for evaluation with the help of evaluation quantities. You can do it with the use of calibration curve.

C. LOAD BEARING ANALYSIS

California Bearing Ratio Test

The CBR test or California Bearing Ratio is done on materials used for construction so that we can know the strength of the soil in terms of its subgrade and even the materials in base course. People who design structures such as airport runways, highways, parking lots and taxiways etc. trust these values obtained from CBR test when they take into account the thickness of the base and the pavement.

CBR test is actually the amount of resistance in some material that opposes the incursion of normal plunger in a controlled environment for moisture and density. Since developed by California Highway division, this process is used to classify and evaluate subgrades for the soils and the materials in the base pertaining to flexible pavements. This test takes place in an untouched or reshaped specimen. In this, we use a cylinder plunger that measures about 50mm in dia., and this permeates into the material of the pavement at a speed of 1.25mm every minute. The load reading for distance of 2.5mm and distance of 5mm are noted. To express this load, we portray it in proportion with normal value of load at a particular level of deformation to get the final CBR value.

VII. RESULTS

A. RESULT FOR ANALYSIS OF FLYASH

1) GEOTECHINICAL ANALYSIS

Table 6.1: Geo-technical Analysis of Fly ash

Properties		Value
Specific Gravity		1.28
Bulk Density		1.10
Moisture Content		1.16
Compaction		19.824
Permeability		~5.23× 10^{-4} cm^2
Plastic Limit		16.823
Shrinkage Limit		14.23
Grain Size analysis	D_{10}	0.32
	D_{30}	0.412
	D_{60}	0.57
	Cu	2.33
	Cc	1.009

2) CHEMICAL AND MORPHOLOGICAL ANALYSIS

- X-Ray Florescence (XRF)

Table 6.2: XRF Analysis

Compound	Percentage (by weight)
SiO_2	50.23
Al_2O_3	24.30
Fe_2O_3	6.31
MgO	0.63
TiO_2	1.86
CaO	0.81
MnO	0.039
Na_2O	0.08
K_2O	1.49
P_2O_5	0.356
Total	86.023

- FESEM

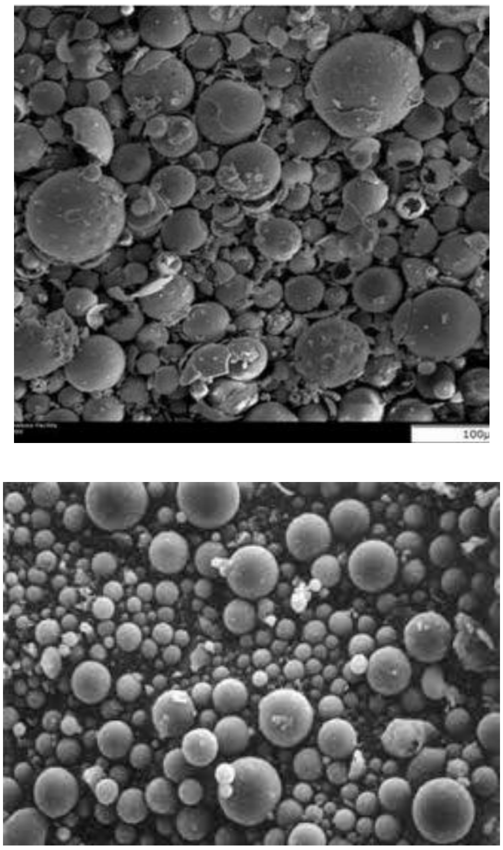
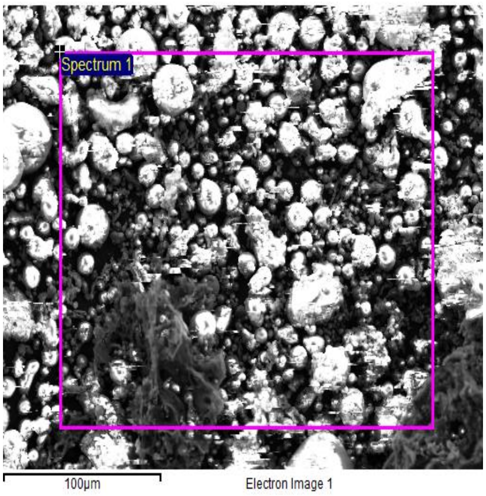


Fig 6.1: FESEM image of fly ash

- EDX



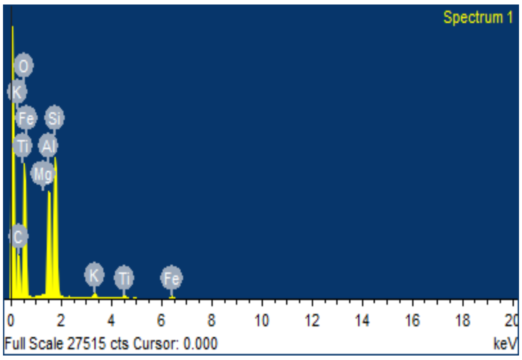


Fig 6.2: EDX Spectrum

Table 6.3: EDX Analysis

Element	**Weight**	**Atomic**
C	28.86	39.03
O	44.56	44.92
Mg	0.19	0.16
Al	9.02	5.32
Si	14.10	7.98
K	0.84	0.40
Ti	0.89	0.39
Fe	1.67	0.42
Total	100	

- Atomic Absorption Spectroscopy

Table 6.4: AAS Analysis

Elements	**Concentration (ppb)**
Copper	0.62
Cadmium	0.09
Cobalt	0.02
Iron	5.2
Manganese	0.9
Lead	0.04
Nickel	0.4
Zinc	0.7

B. RESULT FOR ANALYSIS OF SOIL

1) GEOTECHINICAL ANALYSIS

Table 6.5: Geotechnical Analysis of Soil

S. No.	Property	Value
1	Specific Gravity	2.53
2	Bulk Density	1.93
3	Fineness	64.2
4	Moisture Content	15.32
5	Liquid Limit	37.09
6	Plastic Limit	21.85
7	Plastic Index	15.23
8	Gravel	1.7
9	Sand	35.18
10	IS classification	Sandy Silt

C. CHARACTERISATION OF GEOTEXTILE

Table 6.6: Characterization of Geotextile

S. No.	Property	Value
1	Tensile Strength	6 KN/m
2	Grab Tensile Strength	600 N
3	Roll Width	4 m
4	A.O.S	< 75 m
5	Trapezoidal Tear Strength	175 n
6	CBR Strength	600 N

D. RESULT FOR REINFORCEMENT ANALYSIS

Table 6.7: Result for CBR Analysis (Test Series 1)

Embedment Ratio	CBR value (%)	Strength Ratio = $\frac{CBR\ (Reinforced)}{CBR\ (Unreinforced)}$
Unreinforced	0.792	-----
0.25	0.868	1.137
0.50	0.956	1.213
0.75	1.051	1.371
1.00	1.159	1.526
1.25	1.127	1.476
1.50	1.079	1.422
1.75	1.046	1.403
2.00	1.38	1.391

Table 6.8: Result for CBR Analysis (Test Series 2)

No of Geotextile Layer	Embedment Ratio	CBR value	Strength Ratio
0	0	0.78	-
1	0.25	0.87	1.19
2	0.25, 0.50	1.40	3.08
3	0.25, 0.50, 0.75	2.65	3.31
4	0.25, 0.50, 0.75, 1	4.07	5.10
5	0.25, 0.50, 0.75, 1, 1.25	3.72	4.98

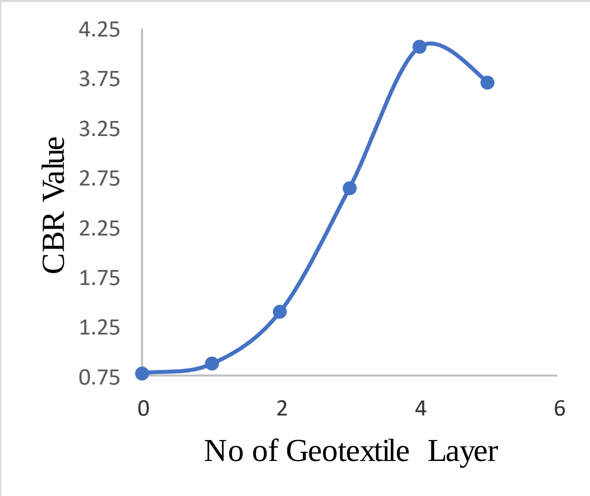


Fig 6.3 Variation of CBR value with the no of Geotextile layer

VIII. CONCLUSION

Based on the testing done and results obtained the followings conclusions were made

- On addition of fly ash in the soil sample increase in the strength were observed.
- On adding the fly ash the difference in the strength were notice by 30% in CBR test.
- In first series of testing done by placing geotextile in single unit the maximum strength ratio that was obtained is 1.76. This was obtained when geotextile was placed just below the middle line of the sample.
- In second series of testing done by placing multiple of geotextile membrane and the maximum strength ratio that was obtained is 5.10 when four layers of geotextile was used in the sample and the strength obtained was far better than the strength obtained in the first series of testing.
- The value of CBR test for double layer of geotextile was found to be 1.40 which is 44% higher.
- The CBR value for triple layer of geotextile is 2.65 which is 47% higher when compared with single- and double-layer geotextile.
- The CBR value for four layer of geotextile is 4.07 which is 80% higher when compared with single and double and triple layer geotextile.

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