International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2014): 5.611

A Study on Improvement and Cost Effectiveness of Pavement Subgrade by Use of Fly Ash Reinforced with Geotextile

Brajesh Mishra

M. Tech. Assistant Engineer, U.P. Cane Development Department, Lucknow, India

Abstract: ***The performance of a pavement is directly related to the characteristics of the soil subgrade, which provides base for the whole pavement structure. Therefore it is essential that the performance of pavements to be enhanced by adopting suitable design and proper construction methods. Now-a-days huge amount of fly ash produced from various thermal power plants is low unit weight, non-plastic, very fine and disposed in slurry form into ponds covering large area. The ash acquired from ponds gets directly air-borne and thus constitutes a serious pollution threat to the society. These materials have a low load carrying capacity, degraded settlement distinctiveness and their utilization in civil engineering works is a tough assignment. On the other hand the performance of these materials can be improved by using soil reinforcement procedure. It can be used as a pavement sub grade with the help of Geotextile sheets as reinforcement. In this study, samples of fly ash compacted to its maximum dry density at the finest moisture content is organized without and with Geotextile layers in the CBR mould. Geotextile sheets equal to the plan dimensions of CBR mould is placed in four distinct layers of different locations in the CBR mould. The CBR (California Bearing Ratio) values of each arrangement of Geotextile, are evaluated in the laboratory and compared with the results of CBR values without and with Geotextile layers.***

Keywords: Soil, fly ash, Geotextile, Stabilization, CBR (California Bearing Ratio), Maximum dry density.

1. Introduction

Now-a-days as a result of rapid growth of urbanization pavements either paved or unpaved are exposed to repeated high traffic loads. These can cause precipitate aging and failure of the road construction. Roads & Pavement reinforcement increases the life of service of the roads and highways by decreasing fatigue, reflective, thermal and settlement cracking. Roads & Pavement reinforcement relieves and redistributes stress concentrations in the pavement. Subgrade can be defined as a compacted layer, generally of naturally happening local soil, assumed to be 300 mm in thickness, just below the pavement crust, providing appropriate foundation for the pavement. The subgrade in embankment is compacted in two layers, generally to a higher standard than the lower part of the embankment. The subgrade, whether in cutting or in embankment, should be well compacted to utilize its full strength and to economize on the overall pavement thickness.

Ayyappan et. al (2010) [9] have been investigated separately either on fly ash / lime stabilization of soil or fiber reinforced soil. Sharma (2012) [10] investigated on the behavior of expansive soil modified with blend of soil, fly ash and Recron 3S fibre of 12mm length. Raji et. al (2011) [1] investigated on the application of fly ash and/or coir geotextile by accomplished various laboratory tests, including compaction and California Bearing Ratio (CBR) tests. A field simulation was carried out on selected subgrade systems using a Wheel Tracking, Karthik et. al (2014) [7] observed the effect of Fly ash derived from burning of sub-bituminous coal at electric power plants in stabilization of soft fine-grained red soils. H. P. Singh et. Al (2013) [6] studied that soil can be reinforced with Jute fiber and CBR tests were carried out with and without reinforcement. The current MORTH Specifications require that the subgrade should be compacted to 100% MDD attained by the Modified Proctor Test (IS 2720-Part 7). For both major roads and rural roads the material used for subgrade construction should have a dry unit weight of not less than 16.5kN/m³.

2. Materials Used

2.1 Soil

The soil sample used for this study was collected at a depth of 1.0m beneath the ground surface. The soil is primarily allowed to dry for 2 days and the dried soil is thoroughly grinded. The grinded soil is allowed to pass through 4.75mm IS sieve and the passed soil is used for the current study. Soil passing through 425 microns sieve is used for influential liquid limit and plastic limit. The soil contains 65% of fines. The Index and engineering properties of the soil were present in table:1

Table: 1 Geotechnical properties of the unmodified soil

Sl. No.	Property	Value
1	Gravel	1.3%
2	Sand	34%
3	Fines (silt + clay)	65%
4	Bulk density	2.15 g/cc
5	Specific gravity	2.65
6	Liquid limit	36.80%
7	Plastic limit	22.20
8	Plasticity Index	14.60%
9	Optimum moisture content	17.5%
10	Maximum Dry Density	1.78 g/cc

2.2 Fly Ash

Fly ash is an essential industrial by-product that comes from the burning of coal, used for the production of electrical energy. In our country, only a small percentage of this is used for the construction of technical projects, while the rest is dumped (stockpiled), which causes serious problems to the accessible environment. It has been found that stabilization with fly ash, improves the engineering and mechanical characteristics of soil, so it is a viable option to use fly ash as a modifier. Stabilization of soils and pavement bases with coal fly ash is gaining rising popularity among pavement engineers in the recent past. The grade of fly ash used in the experimental work is "F" grade. The chemical composition of fly ash shown in table: 2

Table: 2 Chemical composition of fly ash

Sl. No.	*Chemical Component*	*Chemical content by % weight*
1	SiO2	59
2	Al2O3	17
3	Fe2O3	6.5
4	CaO	6
5	MgO	2.30
6	SO3	1
7	LOI(Loss on Ignition)	4.60

2.2.1 Favorable properties of Fly ash

- Light weight, lesser pressure on sub-soil
- High shear strength
- Coarser ashes have high CBR value
- Pozzolanic nature, additional strength due to self-hardening
- Amenable to stabilization
- Ease of compaction
- High permeability
- Non plastic
- Faster rate of consolidation and low compressibility
- Can be compacted using vibratory or static roller

2.2.2. Engineering properties of Fly ash

Parameter	*Range*
Specific Gravity	1.90-2.55
Plasticity	Non-plastic
Maximum Dry density(gm/cc)	0.9-1.60
Optimum moisture content(%)	38-18
Cohesion(KN/m^2)	Negligible
Angle of internal friction	30° - 40°
Coefficient of consolidation Cv (cm^2/sec)	1.75 x 10^{-5} – 2.01 x 10^{-3}
Compression Index	0.05-0.4
Coefficient of uniformity Cu	3.1-10.7

2.3 Geo Textile

Geotextile can be simply defined as "a textile material used in a soil (geo) environment" and consist of woven and non-woven polymeric materials and natural materials, such as jute, constructed using textile processes. Polypropylene: The polymerization of propylene monomers in the presence of specific catalyst produces the crystalline thermoplastic polypropylene. It is very liable to oxidation and additives are necessary to protect against ageing. Other additives are also used to improve thermal stabilization, UV resistance and underwater resistance. The Geotextile used in this study is poly propylene non woven Geotextile. The different properties of geotextile are show in table: 3

Table: 3 Properties of Geotextile

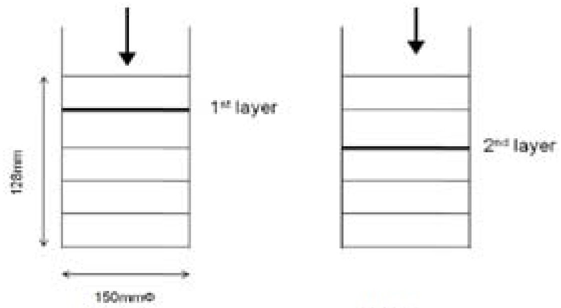
Properties	Units	FPEG-2
Mass (ASTM –D 5311)	Gms/M2	200
Tensile strength (ASTM –D 4595)	KN/m	6
Grab Tensile strength (ASTM –D 4595)	N	600
CBR Puncture strength(ASTM –D 4833) Plunger dia 7 ENISO 12236- Plunger dia 50mm	 N N	 600 1200
Trapezoidal tear strength(ASTM –D 4632)	N	175
A.O.S.	m	< 75
Roll Width	Meter	4

3. Methodology

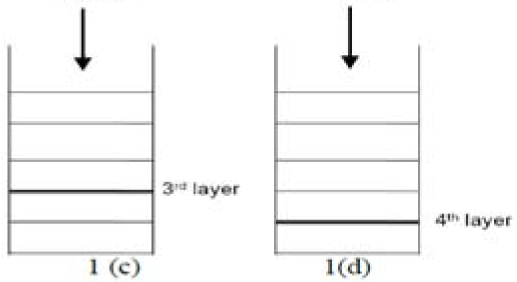
Compaction tests were carried out for different fly ash contents to determine the maximum dry density (MDD) and optimum moisture content (OMC). This fly ash content is used for the further CBR tests. CBR tests were conducted by following the procedure given in IS code. The Geotextile was applied in different layers in the specimen as mentioned below.

1) 1^{st} , 2^{nd} , 3^{rd} and 4^{th} layers in each
2) 1^{st} and 3^{rd} layers, 2^{nd} and 4^{th} layers and at all the layers.

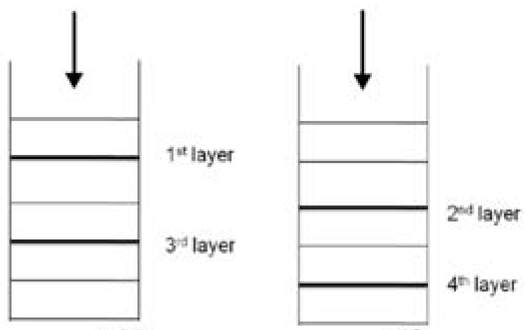
The positions of Geotextile placed is illustrated in figure: 1



1 (a) 1 (b)



1 (c) 1(d)



1 (e) 1 (f)

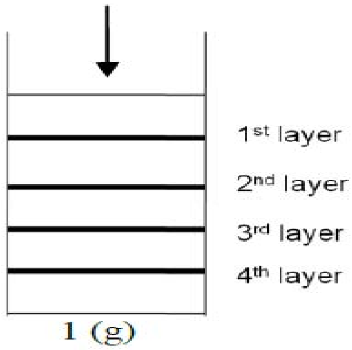


Figure 1: Geotextile layers

Summary of test results of soil modified with fly ash reinforced geotextiles are given below. Compaction test results are presented in table: 4 and CBR results are presented in table: 5

Table 4: Compaction test results by varying the fly ash Content

Type	*OMC(%)*	*MDD(g/cc)*
Unmodified soil	17.42	1.78
Soil+ 5% fly ash	20.25	1.62
Soil+ 7% fly ash	18.10	1.72
Soil+ 9% fly ash	17.60	1.70

Table 5: Test results for Unsoaked and Soaked CBR

Type	CBR Value	
	Unsoaked	Soaked
Unmodified soil	2.90	1.50
Modified	3.00	1.82
1st layer	3.80	2.36
2nd layer	3.78	2.20
3rd layer	3.40	2.10
4th layer	3.20	2.00
1st and 3rd layer	3.90	2.98
2nd and 4th layer	5.20	3.60
1st , 2nd , 3rd and 4th layer	5.50	4.10

4. Analysis and Discussions on Test Results

Test data signified through figures to analyze the influence of fly ash on soil with respect to **OMC, MDD** and the effect of geotextile on the **CBR** values.

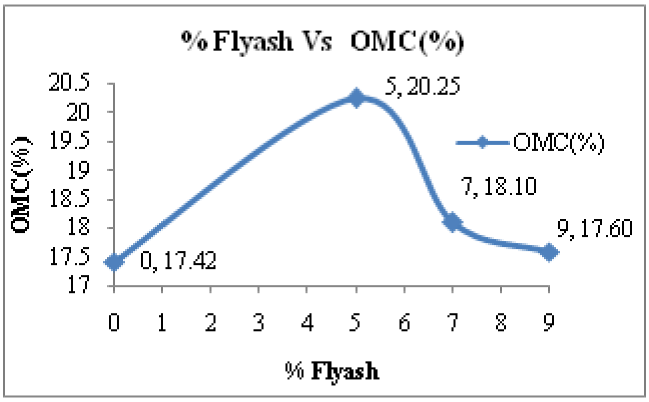


Figure 2: Compaction curve for OMC and Percentage fly ash

The OMC value for natural soil is 17.42%. By increasing the Fly ash content, the OMC value increases to 20.25% at 5% fly ash and decreased by further increasing the fly ash content. This may be due to the mixture requires more water to coat the particles each other.

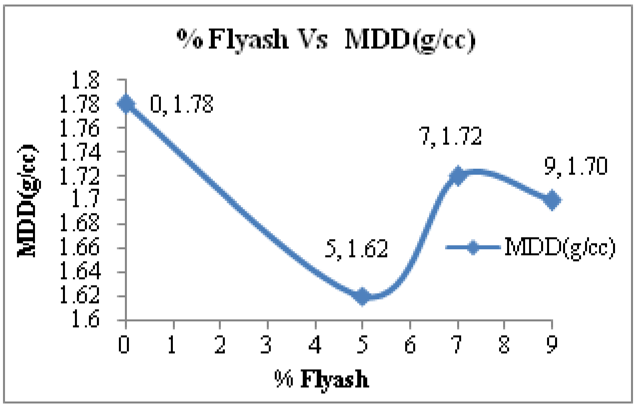


Figure 3: Compaction curve for MDD and Percentage of fly ash

The MDD value for natural soil is 1.78 g/cc. By increasing the fly ash from 5% to 9%, the dry density value is reduced compared to the natural soil. This may be due to low specific gravity of the fly ash compared to the soil. Whereas with-in these three values the maximum dry density achieved is 1.72 g/cc at 7% replacement. This fly ash content is used for the further CBR tests.

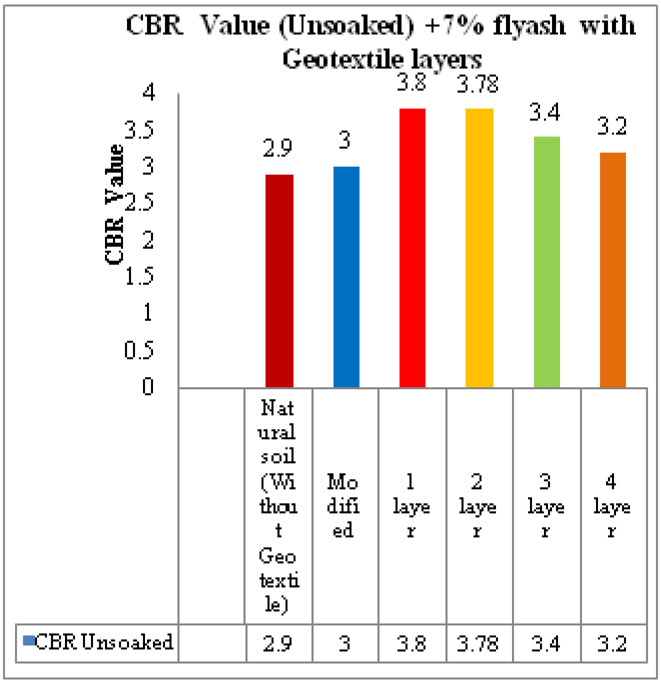


Figure 4: Variation of Unsoaked CBR values with and without Geotextile in each layer

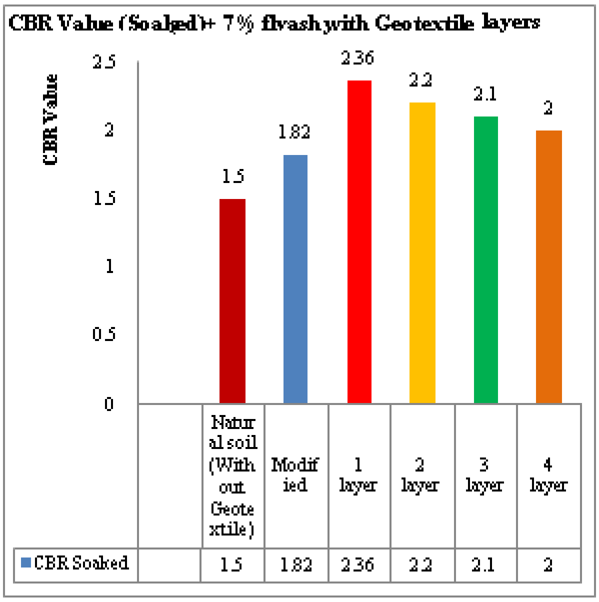


Figure 5: Variation of Soaked CBR without and with Geotextile in each layer

The CBR value for natural soil is 1.50%. By the addition of fly ash, the CBR value increased to 1.82% which is an increment of 21.33%. The CBR value obtained is 2.36% when the geotextile is placed at 1st layer is maximum when compared to other three individual layers. The percentage increase in CBR is 57.33% compared to that of natural soil.

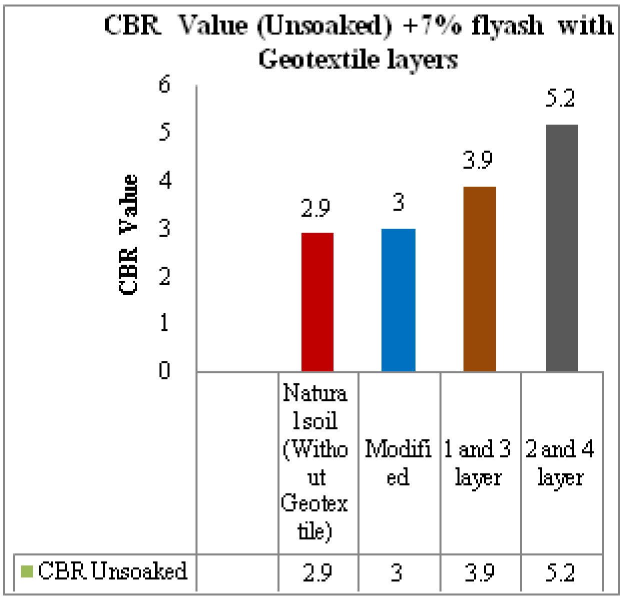


Figure 6: Variation of Unsoaked CBR without and with combinations of Geotextile layer

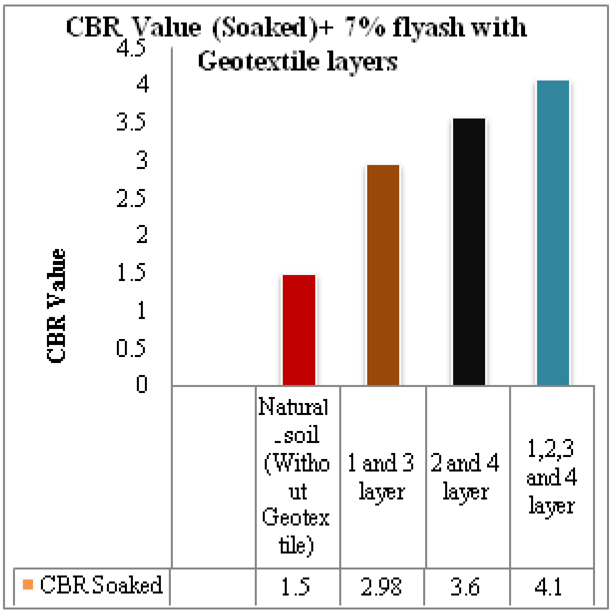


Figure 7: Variation of Soaked CBR without and with combinations of Geotextile layer

The CBR value of 2.98 % is obtained when the geotextile is placed at 1st and 3rd layers. Here the percentage increase in CBR value is 98.67% compared to that of natural soil. The CBR value of 3.60% is obtained when the geotextile is placed at 2nd and 4th layers. Here the percentage increase in CBR value is 106.67% compared to that of natural soil which is more than the results obtained when the geotextile is placed at 1st and 3rd layers.

The CBR value of 4.1% is obtained when the geotextile is placed at all four layers which is an increment of 173.33% compared to the unmodified soil and hence the thickness of the pavement section will be reduced, resulting in cost-effective pavement.

5. Conclusions

Based on the study and tests conducted following conclusions can be drawn-

- By addition of fly ash, the CBR value is increased by 21.33% when compared to unmodified soil.
- The CBR value was increased by 16.67% where the geotextile is placed at 1st layer when compared to other three layers.
- The CBR value was increased by 41.33% where the geotextile is placed at 2nd and 4th layers when compared to 1st and 3rd layers.
- The CBR value was increased by 173.33% by placing the geotextile at all four layers compared to the unmodified soil.

By placing the geotextile in between the subgrade layers, the properties of the soil can be increased and ultimately reduces the subgrade layer thickness, showing cost- effective pavement.

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Author Profile

Brajesh Mishra received the B.E. and M.Tech. degrees in Civil Engineering from Madan Mohan Malviya Engineering College, Gorakhpur, India (Now-MMMUT) in 1988 and KNIT, Sultanpur, India in 2014 respectively. At present working with U.P. Cane Development Department, Lucknow, responsible for construction of road projects.