

Comparative Study on Soft Soil Stabilisation of Pavement Subgrade by using Flyash, Lime and Geogrid

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ABSTRACT : *The subgrade of any pavement plays an important role in load bearing and support of traffic in the form of foundation. The present study describes the use of Flyash (an industrial by product), hydrated lime, lime/flyash and geogrid was used to stabilize a soft soil of highway subgrade so that a firm working platform could be provided for pavement construction. The first objective of the study was, evaluated the soil properties like particle size, liquid limit, plastic limit, plasticity index and identified as a soft soil. Second objective of the study was, improving of the bearing capacity of soft soil by using flyash, lime, lime/flyash as a admixture and geogrids as a reinforcement. California Baring Ratio (CBR) and Unconfined Compression (UCC) tests were conducted in the laboratory on the soil alone; soil-flyash mixture, soil-flyash-lime mixture and placement of geogrids at different layers of soil. From our study, the inclusion of geogrids at various layers of soil improved the bearing capacity when compared to the other mixtures (soil-flyash mixture, soil-flyash-lime mixture)*

Keywords – *Bearing capacity, california bearing ratio, flyash, geogrid, subgrade, unconfined compression.*

1. Introduction

Geotechnical properties of problematic soils such as soft fine-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 geo-technical properties of the problematic soils (such as strength and stiffness) by treating it in-situ. These methods include densifying treatments (such as compaction or pre-loading), Pore water pressure reduction techniques (such as dewatering or electro osmosis), the bonding of soils particles (by ground freezing, grouting, and chemical stabilisation) and use of reinforcing elements (such as geo-textiles and columns).The chemical stabilisation of problematic soils (soft fine-grained and expansive soils) is very important for many of the geo-technical 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. The engineers are often faced with the problem of constructing road beds on or with soils (especially soft clayey and expansive soils). These problematic soils do not possess enough strength to the wheel loads upon them either in construction or during the service life of the pavement. These soils must be, therefore, treated to provide a stable sub-grade or a working platform for the construction of the pavement. One of the strategies to achieve this is “soil stabilisation”. The quality of the sub-grade soil used in pavement application is classified into five types (very poor, poor to fair, fair, good and excellent) depending on the California Bearing Ratio (CBR) values. The quality of the sub-grade soil used in pavement applications is classified into five types (soft, medium, stiff, very stiff and hard sub-grade) depending on unconfined compressive strength values. The sub-grades having CBR values of (0-3%) are very poor and poor to fair (3-7%). Sub-grades having Unconfined Compressive Strength (UCS) values (25 – 100 KN/m²) are soft and medium. These types are considered as unstable sub-grades and need to be stabilised especially in terms of pavement applications.

In the present study, an attempt has been made to study the influence of adding an admixture of flyash and lime for the soft soil modification and also reinforcement by geogrids at various positions through series of laboratory tests.

2. Materials

2.1. Flyash

Fly ash is composed of fine spherical silt size particles in the range of 0.074 to 0.005 mm. Fly ash is one of the most useful and versatile industrial by-products used for physical modification of stabilisation .When geotechnical Engineers are faced with problematic soils (such as clayey or expansive soils), the engineering

properties of those soils may need to be improved to make them suitable for construction. Waste materials such as fly ash or pozzolanic materials are a source of silica and alumina with high surface area has been used for soil improvement. Recent investigations reported that fly ash is a potential material to be utilized for soil improvement.

Around 110 million tonnes of flyash get accumulated every year at the thermal power stations in India. Properties of flyash from different power plants vary and therefore it is recommended that characterization of ash proposed to be used should be conducted to establish the design parameters. The properties of ash depend primarily on type of coal and its pulverization, burning rate and temperature, method of collection, etc. The significant properties of flyash that must be considered when it is used for construction of road embankments are gradation, compaction characteristics, shear strength, compressibility and permeability properties. Individual flyash particles are spherical in shape, generally solid though sometimes hollow. Flyash possesses a silty texture and its specific gravity would be in the range of 2.2 to 2.4, which is less than natural soils. Flyash is a non-plastic material. As a result of soil stabilization with flyash, compression strength and plasticity were improved, while it was proven that ash can be used successfully as an additive for the base and sub-base layer construction of pavement, as well as for the construction of embankments in compressed soils.

2.2. Lime

Lime can be used either to modify some of the physical properties and thereby improve the quality of soil or to transform the soil into a stabilized mass, which increases its strength and durability. The amount of lime additive will depend upon either the soil to be modified or stabilized. Generally, lime is suitable for clay soils with $PI \geq 20\%$ and $> 35\%$ passing the No.200 sieve (0.074 mm). Lime stabilization is applied in road construction to improve subbase and sub-grades, for railroads and airports construction, for embankments, for soil exchange in unstable slopes, for backfill, for bridge abutments and retaining walls, for canal linings, for improvement of soil beneath foundation slabs, and for lime piles. Lime stabilization includes the use of burned lime products, quicklime and hydrated lime (oxides and hydroxides, respectively), or lime by-products. The improvement of the geotechnical properties of the soil and the chemical stabilization process using lime take place through two basic chemical reactions as follow: I) *Short-term reactions* including cation exchange and flocculation, where lime is a strong alkaline base which reacts chemically with clays causing a base exchange. Calcium ions (divalent) displace sodium, potassium, and hydrogen (monovalent) cations and change the electrical charge density around the clay particles. This results in an increase in the interparticle attraction causing flocculation and aggregation with a subsequent decrease in the plasticity of the soils. II) *Long-term reaction* including pozzolanic reaction, where calcium from the lime reacts with the soluble alumina and silica from the clay in the presence of water to produce stable calcium silicate hydrates (CSH), calcium aluminate hydrates (CAH), and calcium alumina silicate hydrates (CASH) which generate long-term strength gain and improve the geotechnical properties of the soil. The use of lime for soil stabilization is either in the form of quicklime (CaO) or hydrated lime Ca(OH)₂. Agricultural lime or other forms of calcium carbonate, or carbonated lime, will not provide the necessary reactions to improve sub-grade soils mixed with lime. In the present study, hydrated lime was used. It is produced by reacting quicklime (CaO) with sufficient water to form a white powder. This process is referred to as *slaking*.

2.3. Geogrids

Geogrids are single or multi-layer materials usually made from extruding and stretching high-density polyethylene or polypropylene or by weaving or knitting and coating high tenacity polyester yarns. The resulting grid structure possesses large openings (called apertures) that enhance interaction with the soil or aggregate. The high tensile strength and stiffness of geogrids make them especially effective as soil and aggregate reinforcement.

3. Methodology

- a. Determination of effective percentage of fly ash and lime for stabilizing the soft soil.
- b. Determination of improvement in California Bearing Ratio (CBR) of subgrade soil using fly ash, flyash+lime.
- c. Determination of the effect of Geogrids on soil subgrade and its performance on strength properties.
- d. To find the improvement in California Bearing Ratio (CBR) of subgrade soil using Geogrids at various depths in soil sample.

- e. To make a comparative study of results obtained before and after placement of fly ash, lime and Geogrids.

4. Test Results

Table1. Flyash Properties (Vijayawada Thermal Power Station, Andhra Pradesh)

S.No	Description	Observed values
1	Specific gravity	1.90 -2.5
2	Max.dry density	0.95 -1.60g/cc
3	Optimum moisture content	19 -38%
4	Permeability	$8 \times 10^{-6} - 7 \times 10^{-4}$ cm/s
5	Uniformity coefficient	3-10.5
6	Compression index	0.05 -0.40
7	Cohesion	Negligible
8	Angle of shearing resistance	$30^{\circ} - 40^{\circ}$
9	Silica	46.5%
10	Alumina	24.2%
11	Iron	10%
12	Calcium	13%
13	Magnesium	4%
14	Carbon	1.10%

Table2. Properties of soil and optimum percentage of fly ash

S.No	Properties	Values	Soil+ 20% Fly ash
Grain size distribution			
1	Sand	13%	27
2	Silt	15%	11
3	Clay	72%	62
Atterberg Limits			
4	Liquid limit	63%	47%
5	Plastic limit	28%	25%
6	Shrinkage limit	15.5%	20.4%
7	Plasticity index	35	22
Compaction properties			
8	OMC	16%	16.65
9	MDD g/cc	1.71	1.6
10	Unsoaked CBR	6.598	10.4
11	Soaked CBR	2.5	4.4
12	Differential free swell	160	80

Table3. Properties of soil with optimum % of fly ash + optimum % of lime

S.No	Property	Type of mix		
		Soil	Soil+20% flyash	Soil+20% flyash + 6% lime
1	Soaked CBR (%)	2.5	4.4	10.56
2	UCC (kPa)	92.5	131.21	796.1

Table4. Properties of Geogrid (Tencate Mirafi Pvt.Ltd)

Properties	Unit	TS 80
Mechanical Properties		
Tensile strength	kN/m	28
Elongation at max.load	%	100
Static puncture resistance	N	4250
Cone drop test	mm	14
Hydraulic Properties		
Permeability vertical	mm/s	55
Opening size O ₉₀	µm	90
Identification properties		
Thickness	mm	3.2
Mass per unit area	g/m ²	385
Width	m	2/4
Length	m	90

Table5. CBR Test results (Unsoaked)

PENETRATION(mm)	DIAL READING	LOAD (kg)	CBR VALUE (%)
0.5	4.0	27.81	
1.0	7.0	42.67	
1.5	10.0	69.53	
2.0	12.0	83.44	
2.5	14.0	97.34	7.1
5.0	19.0	132.11	6.43
7.5	21.5	149.49	
10	22.0	152.97	
12.5	23.0	159.92	

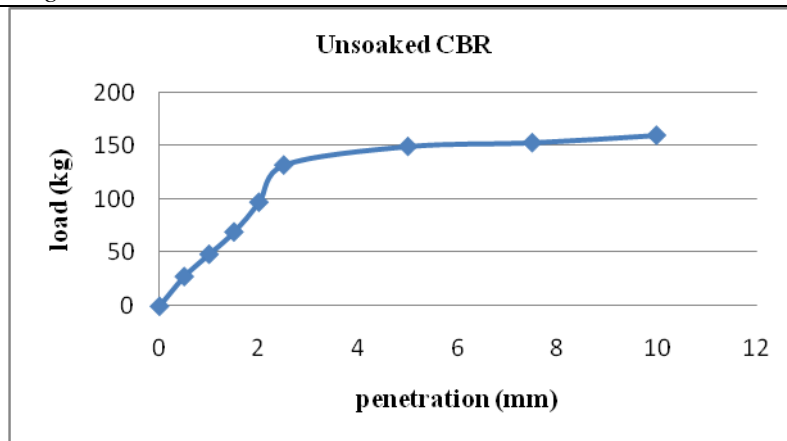


Fig.1 CBR graph for unsoaked condition of soil

Table6. CBR Test results (Soaked)

PENETRATION(mm)	DIAL READING	LOAD (kg)	CBR VALUE (%)
0.5	3.0	20.86	
1.0	6.0	41.72	
1.5	9.5	66.06	
2.0	11.5	79.76	
2.5	13.5	93.87	6.85
5.0	14.5	100.82	4.91
7.5	16.0	111.25	
10	16.5	114.73	
12.5	20.0	139.06	

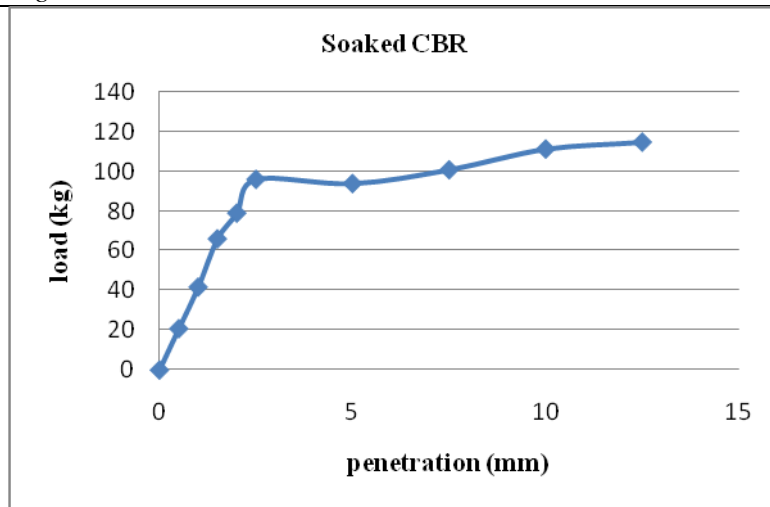
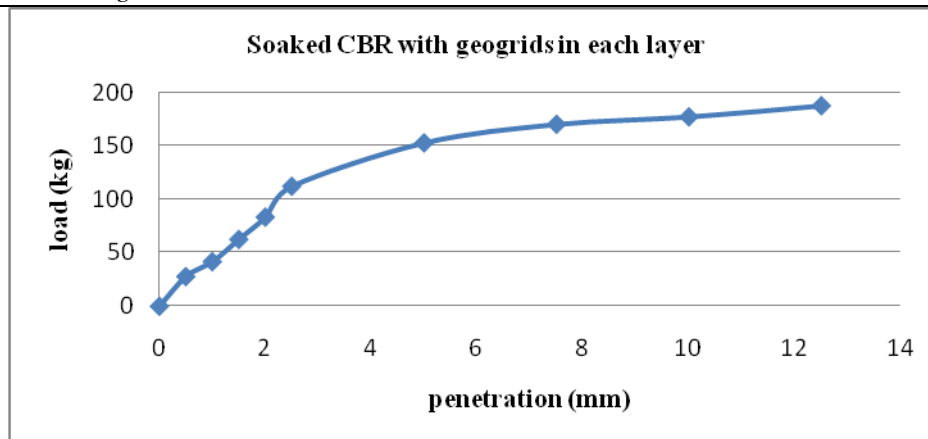


Fig.2 CBR graph for soaked condition of soil

Table7. CBR Test results (Soaked)

PENETRATION(mm)	DIAL READING	LOAD(kg)	CBR VALUE (%)
0.5	4.0	27.81	
1.0	6.0	41.72	
1.5	9.0	62.58	
2.0	12.0	83.44	
2.5	16.2	112.29	12.20
5.0	22.0	152.97	8.40
7.5	24.5	170.35	
10	25.5	177.31	
12.5	27.0	187.74	



5. Conclusions

In the case of flyash stabilisation process, the optimum flyash content was fixed to 20% (according to pH method). The values of UCC and CBR are increased with increasing flyash content (from 8 to 20%) and decreased with a continual increase in flyash content (20%). In the flyash/lime stabilisation process, the optimum flyash/lime content of soil was fixed to (20%FA + 6%L) and carried out the laboratory tests of UCC and CBR, when the addition of flyash and lime together increased the UCC values from 131.21 to 796.1 kPa and CBR values from 4.4 to 10.56. In the present study, reported that, but this increase has upper limit at the optimum flyash/lime ratio, and this was fixed to 1:3 (Lime: Flyash), less or more than this ratio the values of UCC and CBR are decreasing trend.

From the Geogrid study the CBR value for unsoaked soil is 7.1% and with reinforcing of geogrid at H/5 distance is increased to 7.61%. Second study conducted for CBR, the geogrid was placed at H/5 and H/10 is 7.87%, geogrid at H/5, H/10 and H/15 is 8.37% and geogrid in each layer is 9.1% (unsoaked condition). The CBR value for soaked soil is 6.85% and with inclusion of geogrid in each layer is 12.20%. Comparing the methods of stabilisation by using flyash, lime, lime/flyash and geogrids, enhancement of CBR value is more in the case of inclusion of geogrids in various positions in the soil bed.

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