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Experimental Analysis of Lime Stabilized Clayey Subgrade Soil Reinforced With Polypropylene Fiber

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ABSTRACT: In this article, the effectiveness of optimized lime & polypropylene fiber reinforced subgrade soil is studied from the point of view of strength. Black cotton soil was collected along chainage 532 of Samruddhi highway near Kopargaon in Maharashtra state. Varying percentage of hydrated lime was added during modified proctor test & optimized percentage of 8% of lime by weight of soil sample was obtained. The soil with optimized percentage of lime & varying percentage of polypropylene fiber (i.e. 0.2%,0.4%,0.6%,0.8%) were tested for UCS & CBR test. Also CBR test was conducted for worst condition i.e. soaked condition. The results obtained from UCS test & CBR test were analysed to get the optimum % fiber and variation in strength with % of fiber. The further study aims to find effect of Direct Shear Test & Field performance of test pit by using dynamic cone penetration test (DCPT) to check on field CBR.

KEYWORDS: Optimized lime, Polypropylene fiber, Hydrated lime.

I. INTRODUCTION

Now Days the reduction of available land resources, more and more construction of civil engineering structures is carried out over weak or soft soil, which leads to the establishment and development of various ground improvement techniques such as soil stabilization and reinforcement. Lime stabilization has been extensively applied in practice of civil engineering such as foundations, roadbeds, embankments and piles. When lime is added to soils, it reacts with soil particles, which leads to the improvement in many engineering properties of soils.

Pradhan et al.[1] have presented the effect of random inclusion of polypropylene fibers on strength characteristics of soil.Senol[2] has concluded in the article that the fibre inclusions increased the strength of the fly ash specimens and changed their brittle behavior into ductile behavior.Dang et al.[4]have investigated the behaviour of expansive soils stabilized with hydrated lime and bagasse fibres.Starcher and Chunyang [5] have analysed the mechanical behavior of a cement-soft soil mixture, a series of consolidation tests and unconfined compressive strength (UCS) tests were conducted with special attention being paid to the effects of curing time and vertical curing stress.

II. METHODOLOGY

Some investigators found that the strength behavior of soils was greatly improved after lime treatment. Some researchers found that lime treatment contributed to the brittle failure characteristics of soils that led to a rapid and great loss in strength when failure occurs. In recent years, discrete fibres have been added and mixed into soils to improve the strength behavior of soils.

It was reported that there were notable increases in shear strength, toughness and plasticity of a cohesive soil after reinforcement with discrete polypropylene fibre. However, the reports on the use of discrete fibre for improving the toughness and strength of lime-stabilized soils have not been seen yet. Thus, an attempt to admix polypropylene fibre and lime to soils for ground improvement was made in this project. Specimens were subjected to compaction characteristics test, unconfined compressive tests and CBR test. Moreover, other important index properties and failure characteristics were studied. The primary objective of this paper described herein is to assess the usefulness of admixture of polypropylene fibre and lime as soil treatment material for improving the pertinent engineering properties of a clayey soil, e.g. strength, swelling–shrinkage potential and failure characteristics.

In this present study the optimized lime & polypropylene fiber used to reinforced subgrade soil. Details of these materials as follows

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Hydrated lime-Lime is the high-temperature product of the calcination of limestone. To be classified as limestone, the rock must contain at least 50 percent calcium carbonate. When the rock contains 30 to 45 percent magnesium carbonate, it is referred to as dolomite, or dolomitic limestone. Lime is manufactured in various kinds of kilns by one of the following reactions:

$CaCO_3$ + heat =O_2 + CaO (high calcium lime)

$CaCO_3$ + heat = 2CO + CaO (dolomitic lime)

By above reaction, resulting lime is reacted (slaked) with water to form hydrated lime[$Ca(OH)^2$]. The basic processes in the production of lime are: (1) quarrying raw limestone; (2) preparing limestone for the kilns by crushing and sizing; (3) calcining limestone; (4) processing the lime further by hydrating; and (5) miscellaneous transfer, storage, and handling operations. The major uses of lime are metallurgical i.e.aluminum, steel, copper, silver, and gold industries, environmental i.e.flue gas desulfurization, water softening, pH control, sewage-sludge destabilization, and hazardous waste treatment, and construction i.e. Soil stabilization, asphalt additive, and masonry lime).

Polypropylene Fibres- The raw material of polypropylene is derived from monomeric C3H6 which is purely hydrocarbon. Its mode of polymerization, its high molecular weight and the way it is processed into fibres combine to give polypropylene fibres very useful properties as explained below

- There is a sterically regular atomic arrangement in the polymer molecule and high crystallinity. Due to regular structure, it is known as isotactic polypropylene.
- Chemical inertness makes the fibres resistant to most chemicals
- The hydrophobic surface not being wet by water content helps to prevent chopped fibres from balling effect during mixing like other fibres.
- The water demand is nil for polypropylene fibres.

The fibres are manufactured either by the pulling wire procedure with circular cross section or by extruding the plastic film with rectangular cross-section. They appear either as fibrillated bundles, mono filament or microfilaments the properties of these types of PP fibres are given in the fibrillated polypropylene fibres are formed by expansion of a plastic film, which is separated into strips and then slit. The fibre bundles are cut into specified lengths and fibrillated. In monofilament fibres, the addition of buttons at the ends of the fibre increases the pull out load. Further, the maximum load and stress transfer could also be achieved by twisting fibres.

III. EXPERIMENTATIONAND RESULTS

The experimental work carried out in the laboratory and details of collection of sample of Soil, Hydrated lime, & Polypropylene fibers are studied.The properties of the collected soil samples, fibers and lime are as follows

Table 1 Basic Properties of Soil

Test conducted	Results
Specific gravity	2.653
Liquid limit and Plastic Limit	71.1% & 40.80%
MDD and OMC	1.298 gm/cm3 and 35.2%
California Bearing Ratio	5.26%
Class of Soil	MH
UCS Value	3.73kg/cm2

Table 2 Properties of Fibre

Properties	Fibrillated Fibre
Length	24 mm
Tenacity	5.5 GPD
Breaking Elongation	20%
Density	0.91gm/cm^3
Melting Point	165°C
Aspect Ratio	100

Table 3 Properties of Lime

Properties	Content in %
Sand Silica	0.5%
Ca(OH)2	95%
Moisture	1.12%
Melting Point	165 ° C

Further in order to investigate the effect of inclusion of Polypropylene Fibre on Lime treats soil properties. Important geotechnical properties of subgrade soil were determined by mixing Polypropylene fibre with 0%, 0.2%, 0.4%, 0.6% and 0.8% percentage by weight.

Table 4 Testing for this investigation

Sr. No.	**Name of Test**	**Percentage of Lime added**						**No. of Test**
		0	**2**	**4**	**6**	**8**	**10**	
1	Modified Proctor Test	1	1	1	1	1	1	6

After obtaining lime optimized sample on the compaction criteria, further investigation is carried out on lime optimized soil by adding different % of fibre, to know the effect of fibres as below.

Table 5 Testing for this investigation

Sr. No.	**Name of Test**	**Percentage of Fiber added**					**No. of Test**
		0	**0.2**	**0.4**	**0.6**	**0.8**	
1	Modified Proctor Test	1	1	1	1	1	5
2	Unconfined compression Test(UCS)	1	1	1	1	1	5
3	California Bearing Ratio(CBR)	1	1	1	1	1	5
Total number of Tests							21

For the futher work sample prepared as follows

1. Collected sample kept in oven dry to make it air dry.
2. In the preparation of samples, if Hydrated Lime were not used then, the air-dried soil mixed with an amount of water that depends on the OMC of the soil.
3. If Hydrated Lime was used, the adopted content of Hydrated Lime Slurry is prepared by adding water as per OMC and first mixed into the air-dried soil in small increments by hand, making sure that all the Hydrated Lime were mixed.
4. If Fibre was used then the above process should be repeated. , the adopted content of Fibre and first mixed into optimized hydrated lime optimized mix in small increments by hand, making sure that all the Fibre were mixed thoroughly, so that a fairly homogenous mixture obtained, and then the required water added.

IV. RESULT AND DISCUSSION

After all the experimental setup and thevarious tests the following results and graphs were obtained.

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a. Unconfined Compression Test

Table 6 Results of UCS Test

Combinations	q_u (MPa)
Soil	0.3629
Soil +8% Lime	0.820
Soil +8% Lime+ 0.2% Fibre	0.908
Soil +8% Lime+ 0.4% Fibre	2.494
Soil +8% Lime+ 0.6% Fibre	1.468
Soil +8% Lime+ 0.8% Fibre	0.648

From above table shows, it is found to be maximum stress for 0.4% fibre contain with large strain%,.Fibre inclusion enhances the peak stress & exhibit more ductile behavior upto optimum content due to its anchoring phenomenon & absence of planes of weakness.From fig. 1 shows typical stress-strain curves for different combination. It is found that addition of 8% lime in soil leads to UCS value 8.42 kg/cm^2 for the 8.55% strain. When 0.4% fibre is added 8% lime optimized sample, UCS value is found to be 25.42 kg/cm^2 for strain value is 9.87%. This indicates that fibre inclusion leads to increment in UCS value of lime optimized sample. This improvement is due to anchoring phenomenon & skin friction between particles and fibres.

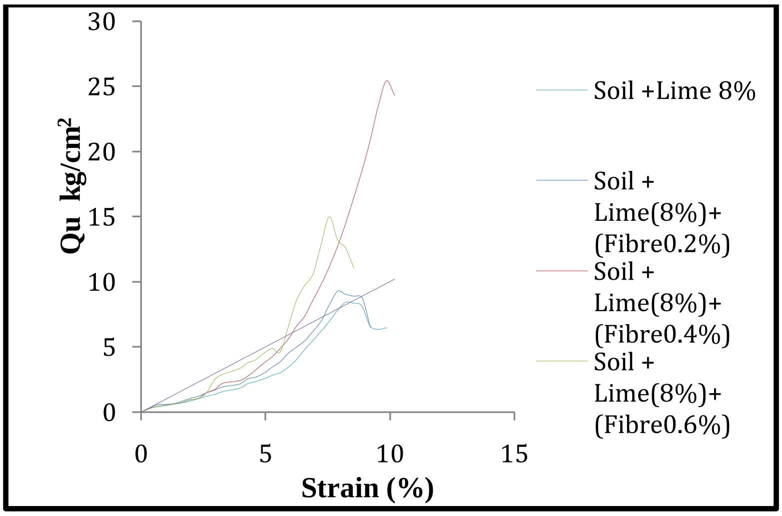

Fig 1 UCS Test results for different combination.

b. California Bearing Ratio Test-

The Purpose of this test is to know effect of Polypropylene fibre on its Strength Properties, How these fibres helps to improving its bearing strength, initially soil having very low CBR value which is 5.26% then Lime treated soil sample but for road construction we requires good CBR and also to check its CBR at worst condition we conducted soaked CBR test on Fibre following table showing effect of fibres on its CBR value.

After treating with lime, unsoaked CBR value is found to be 3.84% which is decreasing. This decrement is due to more absorption of water by soil particle but when soaked test is carried out, CBR value going to be increased & found to 15.99%. This is due to pozzolanic reaction which is accompanied by cation exchange phenomenon. After addition of fibre unsoaked CBR value is going to be increased upto optimize contain, The substantial improvement in CBR value could be attributed to cation exchange between calcium ions in lime and metal ions on surfaces of clay particles. Then, such physical and chemical reactions form agglomeration and flocculation of clay particles further addition leads to decrement in it. Further investigation is carried out with addition of fibre, Fiber inclusion in soil leads to increment in CBR value both in soaked and unsoaked, This increment in CBR value is due to anchoring phenomenon of fibre with agglomerated soil particle which is agglomerated due to lime reaction. Increasing fibre content beyond 0.4% leads decrease the stiffness and loss of post peak strength. It is found that addition of 0.4% fibre gives maximum percentage

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of CBR for soaked & unsoaked test.
The soaked values are more than that of unsoaked value, Therefore it can be concluded that it can be useful in worst condition also. That's all concluded below in Table 6.

Table 6 Results CBR Test

Soil+ 8% Lime +Different %age of Fibre	**Unsoaked**	**% Increased**	**Soaked**	**% Increased**
0	3.84	--	15.99	--
0.2	4.28	111	17.08	106.81
0.4	11.97	301.7	26.56	249.84
0.6	9.81	255.46	24.08	225.14
0.8	5.48	142.7	16.81	105.12

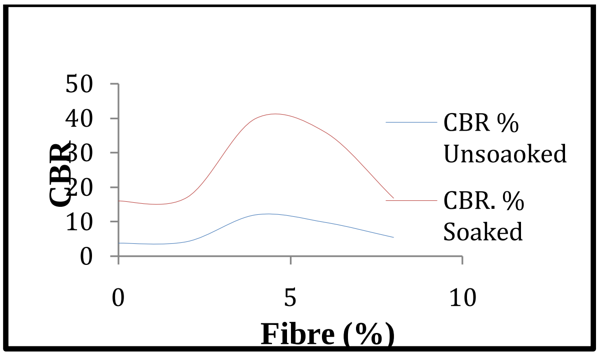

Fig 2 Graph for Unsoaked & Soaked CBR value

c. Direct Shear test-

Small box shear test conducted on Lime optimized sample reinforced with fibres in order to see effect of fibre inclusion on its Cohesion C (kN/cm^2) and angle of friction **ϕ^o**

Table 7 Results of Direct Shear Test (Small Box) for Fibrillated Fibre

Fibre %	**C kN/m2**	**ϕ^o**
0	47.69	25.76^{O}
0.2	51.50	28.43^{O}
0.4	47.5	32.16^{O}
0.6	38.74	34.61^{O}
0.8	40.98	37.7^{O}

In order to know effect of Polypropylene fibres on Lime treated soil, Direct shear test was done. Results of DST shown in above table for unreinforced lime optimized sample, value of Cohesion C and Angle of Internal Friction ϕ^0 obtained was 47.69kN/m^2 and 25.76^0 respectively, In case of Fibrillated Fibre as fibre content goes on increasing, C value continuously decreasing. the fibre content beyond 0.6% fibre some gain in C value &ϕ^0 value continuously increasing as fibre content increases up to 0.8%. Further investigation was not carried out due to MDD decreasing. main reason for this is skin friction between Lime and fibre which helps in increase angle of internal friction ϕ^0,as Percentage of fibre goes on increasing cohesion between soil lime optimized mix goes on decreasing, except at Fibrillated fibre content 0.2% and 0.8%, C value increased.

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V. CONCLUSION

Based on the experimental work carried out in the present study, the following conclusions are drawn:

1. For the Soil and Lime mixture, it has been seen that the optimum mix for the Soil-Lime mixture has been obtained for the soil+8% Lime content based on the compaction curve.

Table 8 Test results for Soil +8% Lime

MIX	COMPACTION		CBR %		UCS q_u Mpa
	MDD (kN/m^3)	OMC (%)	Unsoaked	Soaked	-
Soil +8% Lime	12.48	33.19	3.84	15.09	0.820

2. When the soil optimum mix has been mixed with different percentage of the Fibre it has been observed that 0.4% Fibre content shows good results for Compaction, unconfined compression test & CBR test.

Table 9 Test results for Soil , 8% lime & various % age of fibre

MIX	COMPACTION		CBR %		UCS qu Mpa
	MDD (kN/ m3)	OMC (%)	Unsoaked	Soaked	
Soil+8% Lime + 0.2% Fibre	**13.45**	31.964	4.28	17.08	0.908
Soil+8% Lime + 0.4% Fibre	**13.63**	30.87	11.97	26.56	2.494
Soil+8% Lime + 0.6% Fibre	**12.80**	30.95	9.81	24.08	1.468
Soil+8% Lime + 0.8% Fibre	**12.49**	34.50	5.48	16.81	0.648

a) It can be concluded that Soil treated with fibre addition has the better influence on strength of the mix. This can be attribute to anchoring phenomenon and absence of weak planes only upto 0.4% content further increase leads non homogeneous structure due replacement of soil particle by fibre.

b) It is found that CBR value of soil increasing on stabilizing with Lime and Fibre, Also increased CBR value is found for soaked samples. It is because of Pozzolanic reaction which is accompanied by cation exchange reaction of lime which resulting in cementaceous gel.

c) Inclusion of fibre leads to increment in CBR value upto optimized mix. Further addition of fibre leads to CBR decreasing due to absoption of water by fibre. So it can be used in road embankment and below foundation. For fibre inclusion in lime treated soil, CBR value increase to 26.56% , Also CBR value for lime treated soil 15.99%

d) Fibre inclusion gives strain hardening ductile failure of Lime treated clayey soil.

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