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Study of Engineering Properties of Clayey Soil Due To Addition of Polypropylene Fibre and Lime Admixture

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Abstract

To decrease the fragility of soil balanced out by lime just, a new investigation of a recently proposed combination of polypropylene fiber and lime for ground improvement is depicted and announced in the paper. To examine and comprehend the impact of the combination of polypropylene fiber and lime on the designing properties of a clayey soil, nine gatherings of treated soil examples were ready and tried at three distinct rates of fiber content (for example 0.05%, 0.15%, 0.25% by weight of the parent soil) and three distinct rates of lime (for example 2%, 5%, 8% by weight of the parent soil). These treated examples were exposed to unconfined pressure, direct shear, swelling and shrinkage tests. Through examining electron microscopy (SEM) examination of the examples subsequent to shearing, the further developing components of polypropylene fiber and lime in the dirt were talked about and the noticed test outcomes were clarified. It was discovered that fiber content, lime content and relieving length had critical effect on the designing properties of the fiber–lime treated soil. An expansion in lime content brought about an underlying increment followed by a slight abatement in unconfined compressive strength, union and point of interior contact of the clayey soil. Then again, an increment in lime content prompted a decrease of enlarging and shrinkage potential. Be that as it may, an increment in fiber content caused an increment in strength and shrinkage potential however welcomed on the decrease of expanding potential. An expansion in restoring term worked on the unconfined compressive strength and shear strength boundaries of the settled soil essentially. In light of the SEM investigation, it was tracked down that the presence of fiber added to actual connection among fiber and soil though the utilization of lime delivered synthetic response among lime and soil and changed soil texture altogether.

Keywords: Soil; Polypropylene fibre; Lime; Ground improvement; SEM analysis

1. Introduction

With 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 (Ye and Ye, 1999; Jiang, 2002). When lime is added to soils, it reacts with soil particles, which leads to the improvement in many engineering properties of soils. Some investigators

Table 1
Engineering properties of the clayey soil used

Serial number	Engineering properties	Values
1	Specific gravity	2.73
2	Grain size analysis	
	Gravel	0.0%
	Sand	13.2%
	Silt	61.8%
	Clay	25.0%
3	Consistency limit	
	Liquid limit	34.5%
	Plastic Limit	16.9%
	Plasticity index	17.6
4	IS Classification	CL
5	Compaction study	
	Optimum moisture content	15.8%
	Maximum dry density	1.70 g/cm^3
6	Shear strength parameters	
	Cohesion	90.0 kPa
	Angle of internal friction	19.1°

found that the strength behavior of soils was greatly improved after lime treatment (Balasubramaniam et al., 1989; Locat et al., 1990, 1996; Narasimha Rao and Rajasekaran, 1996). The work of Bell (1996) indicated that soils treated with lime experienced notable increases in optimum moisture content while undergoing a decrease in maximum dry density. Rajasekaran and Narasimha Rao (1996, 2002) reported that the strong cementation bonds between soil particles, brought by lime–soil reactions, could resist the forces applied effectively, which resulted in the reduction of compressibility of marine soils. Du et al. (1999) and Al-Rawas et al. (2005) carried out tests on the expansive soils and found that both swell percentage and swell pressure reduced to zero with a given amount of lime admixed to expansive soils. While the use of lime improves the above engineering properties, it brings unfavorable changes of other properties. The test results of Clare and Cruchley (1957) indicated that there was a decrease in plasticity of soils after lime stabilization. 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 (Sabry et al., 1996; Cai et al., 2005).

In recent years, discrete fibres have been added and mixed into soils to improve the strength behavior of soils (Mandal and Murti, 1989; Prabakar and Sridhar, 2002). Li et al. (1995) reported that there were notable increases in shear strength, toughness and plasticity of a cohesive soil after reinforcement with discrete polypropylene fibre. The results of Cai et al. (2005) indicated that fibre-reinforced soils took on the strain-hardening ductile failure characteristics. In addition, some investigators

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(Péra and Ambrois, 1998; Savastano et al., 2003; Kaufmann et al., 2004) found that the use of discrete fibre increased significantly the toughness and led to further improvement of the strength behavior of cement. 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 im- provement was presented in this paper.

In order to understand the effect of polypropylene fibre content, lime content and curing time on the strength behavior of a clayey soil investigated, a great number of untreated and treated soil specimens were subjected to unconfined compressive tests and direct shear tests. Moreover, other important engineering properties such as swell percent, shrinkage parameters and failure characteristics were studied. Besides these tests, some specimens after shearing were taken for scanning electronic microscopy (SEM) analysis. On the basis of SEM analysis, the improving mechanisms of polypropylene fibre and lime were discussed and the observations from tests were explained. 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.

2. Materials and experimental programme

Materials

The soil used herein was Xiashu soil, a typical clayey soil extensively distributed in Nanjing region, China. Owing to high initial moisture content, the soil was air- dried at first and then broken into pieces in the lab- oratory. Engineering properties of the collected soil are presented in Table 1. Polypropylene fibre used in this investigation was provided by Nanjing Fibre Company.

Table 2
Physical and chemical properties of fibre used

Serial number	Physical and chemical properties	Values
1	Fibre type	Single fibre
2	Unit weight	0.91 g/cm^3
3	Average diameter	0.034 mm
4	Average length	12 mm
5	Breaking tensile strength	350 MPa
6	Modulus of elasticity	3500 MPa
7	Fusion point	165 °C
8	Burning point	590 °C
9	Acid and alkali resistance	Very good
10	Dispersibility	Excellent

Table 3
Preparation of specimens for different tests

Test	Size		Moisture content (%)	Dry density (g/cm^3)
	Diameter (mm)	Height (mm)		
Unconfined compression[a]	39.1	80	16.5	1.6
Direct shear	61.8	20	16.5	1.6
Swelling	61.8	20	16.5	1.6
Shrinkage	61.8	20	30	1.5

[a] Four-layered compaction was adopted to keep the uniformity of specimens.

The behavior parameters of the fibre are given in the Table 2. In addition, the content percentages of CaO and MgO in lime are, respectively, 71.27% and 3.64%, which ensures the effectiveness of lime stabilization.

3. Conclusions

The effects of both polypropylene fibre and lime on the unconfined compressive strength, shear strength parameters, swelling–shrinkage potential and failure characteristic of the clayey soil have been studied. It is shown from the test results that the addition of the mixture of polypropylene fibre and lime causes the beneficial changes in the above engineering properties of clayey soil used in this investigation.

It is observed from testing that these engineering properties of fibre–lime soil vary and depend on many factors such as fibre content, lime content and length of curing. The unconfined compressive strength, cohesion and friction angles increase while increasing the length of curing. An increase in lime content contributes to an initial increase followed by a slight decrease in unconfined compressive strength and shear strength parameters of the clayey soil. The optimum gain in strength appears to be with about 5% lime. On the other hand, the swelling– shrinkage potential and toughness of clayey soil reduce with an increase in lime content. An increase in fibre content leads to increases in strength, shrinkage potential

tests in China. Owing to different test requirements, there are differences in preparation of specimens for different tests. Table 3 shows the preparation of specimens for each test carried out in this investigation. After completion of compaction, all specimens, except for the untreated specimens and pure fibre ones (made only by fibre), were wrapped with thin plastic film and stored in the curing box (20 ± 1 °C, 96 ± 2% RH) until tested at 7, 14 and 28 days.

and toughness of soil while results in the reduction of swelling potential. In brief, with the combination of lime stabilization and fibre reinforcement techniques, the fibre–lime soil exhibits more gains in strength, cohesion and internal friction angle than lime stabilized soil does. However, the swelling–shrinkage potential and failure characteristic of fibre–lime soil stand between pure fibre soil and pure lime soil.

SEM images of four soils including the untreated soil, fibre-reinforced soil, lime-stabilized soil and fibre–lime soil indicate that fibre reinforcement is a physical interaction between fibre and soil which has few influence on the soil fabric, while lime stabilization is a chemical reaction between lime and soil which greatly changes soil fabric and thereby results in the variation of some engineering properties of soil.

Trough this investigation, it is clearly indicated that the technique of fibre reinforced lime soil is a very effective method of ground improvement, which improves the strength, swelling–shrinkage potential and toughness of soil and consequently, enhance the stability and durability of infrastructures such as foundation and roadbed. However, the construction technology of the method has not been well developed yet. Some key problems probably met in future engineering practice, e.g. the mixture of discrete fibre and lime soil, are now under consideration. With the development of the construction technology, this improvement technique will have an extensive application prospect and could be employed in many fields of geotechnical engineering, such as foundation, roadbed and slope engineering.

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