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Stabilization of Soft Clay Using Nylon Fiber and Fly Ash

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Abstract. Soil stabilization is done to improve its engineering performance such as shear strength, compressibility and permeability. Soil stabilization may physical, chemical, biological or combined methods to meet an engineering purpose. Soft clay is problematic soils from civil engineering construction point of view. To make them more feasible to construction purposes, numerous materials have been used. In this paper stabilization of soft clay using nylon fiber and fly ash were evaluated. Experiments were conducted on soil treated with fly ash only and soil treated with both fly ash and nylon fiber. The methodology used was first to find out the optimum fly ash that can be utilized in untreated soil. Further various percentage of nylon fiber (0.25 and 0.5) was added at various fly ash percentages (10, 20, 30 and 40) and found out the optimum. Optimum percentage was obtained from standard proctor test and strength was obtained from unconfined compressive strength test. Optimum percentage of nylon fiber and fly ash was obtained as 0.25% and 20% by weight of soil respectively. Result of optimum percentage on unconfined compressive strength and plasticity characteristics of treated soil were determined over a curing period of 1day, 7 days and 28 days. The strength of soil stabilized with nylon fiber and fly ash were found to be improved and the strength of treated soil was more in the case of combination of fly ash and nylon fiber.

Keywords: Soil Stabilization, Soft Clay, Nylon Fiber, Fly Ash.

1 Introduction

Soil has been used as a construction material. Almost all foundations are sited on soil. In places where soil is poor in mechanical property, civil engineers face challenges to improve its properties. The properties of soil vary from site to site. Among soil clays generally have low shear strength, high compressibility and high volumetric changes. Soft clay is soils with large fractions of fine particles such as silty and clayey soils, which have high moisture content and it is located near or under the water table. The strength of soft clay is very less and it can be molded by light finger pressure. Soft clay is problematic soil from civil engineering construction point of view. To make them more feasible to construction purposes, stabilization has to be done. Soil stabilization is the alteration of any property of soil to improve its engineering performance. Soil stabilization may physical, chemical, biological or combined methods to meet an engineering purpose. In situations where large area of the soil is covered under construction, the soil stabilization methods become difficult and costly task. In such situations reliable methods needs to be devised. In recent technology more number of traditional additives is used for stabilization purpose. Present study has been undertaken to investigate the strength improvement of soft clay stabilized with fly ash and nylon fiber. Ryan D. Starcher and Chunyang Liu (2013) studied the improvement in cement and cement-fibre treated soft soil. UCS tests were carried out on cement-improved soils and cement-fibre improved soils and found out strength gain based on curing time alone and strength gain based on curing time and vertical curing stress. Unconfined compressive strength was found to be improved. Cement-improved soil behaved as brittle material and introduction of fibre increased the ductility. Shenbaga R. Kaniraj and Vasant G. Havanagi (2001) conducted a study on soil mixed with fly ash stabilized with cement and reinforced with fiber. The soil – fly ash mixture was stabilized using cement and polypropylene fiber. UCS test was carried out in specimen stabilized with cement and also in specimen stabilized with cement and reinforced with fiber. UCS of a fly ash-soil mixture increases due to addition of cement and fibers. The increase in UCS caused by the combined action of cement and fibers is either more than or nearly equal to the sum of the increase caused by them individually based on the period of curing and the material added. Innocent Kafodya and F. Okonta (2018) has shown the result of pre-compression and addition of natural fiber on the mechanical properties of soil stabilized with lime and fly ash. The sisal fibers used were 25mm length and they were applied at different percentages such as 0.25%, 0.5%, 0.75% and 1%. Strength of stabilized specimens were determined. Results showed that fiber inclusion improved the strength. Stabilization of soft clay by using fly ash and nylon fiber was studied in this paper.

2 Materials

The soil used in this study was soft clay. The soil was collected from four locations in the paddy field. The paddy field was located near Mavoor – Chathamangalam road. Liquid limit test was carried out on these soils collected from various locations. For each soil the value of liquid limit was different and the soil for which got maximum liquid limit of about 97% was selected for the project. The clay was one type of most problematic soil. Table 1 shows the properties of soil. Fly ash was the stabilizer used in this study. Class F fly ash of specific gravity 2.37 was used. Fly ash was collected from Sanjana Traders, Mangalore. The synthetic fiber used in this project was Nylon fiber. Nylon fiber was procured from Go Green Products Company. Nylon fiber of 0.3mm diameter and 12mm length was used in this study.

Table 1. Table captions should be placed above the tables.

Properties		Values
Natural moisture content, %		129
Specific Gravity		2.44
Grain Size Distribution	Clay, %	38
	Silt, %	40
	Sand, %	22
IS Classification		CH
Liquid Limit, %		97
Plastic Limit, %		39
Plasticity Index, %		58
Shrinkage Limit, %		25
Maximum Dry Density, g/cc		1.26
Optimum Moisture Content, %		35.52
Unconfined Compressive Strength, KPa		75

3 Experimental Work

Experimental work included characterization of soil and the investigation of improvement in strength of soil mixed with nylon fiber and fly ash. Standard proctor test, liquid limit test, plastic limit test and UCC test were carried out in the soil - fly ash mix. Added fly ash percentages were 10%, 20%, 30% and 40% by weight of soil. Test samples for UCC test was prepared by mixing the soil and fly ash at maximum dry density and optimum moisture content obtained from standard proctor test. Both cured and uncured strength were determined. Cured strength was determined for 1 day, 7 days and 28 days. Liquid limit and plastic limit also determined for cured and uncured samples. Standard proctor test was carried out on soil mixed with various combinations of fly ash and nylon fiber. First the soil was mixed with 0.25% of fiber and four varied percentages of fly ash. Then soil was mixed with 0.5% of fiber and four varied percentages of fly ash. From standard proctor test, optimum percentage of fly ash and nylon fiber was obtained and UCC test was carried out for soil mixed with optimum percentage of fly ash and nylon fiber. Both cured and uncured strength of soil-fly ash-fiber mix was determined.

4 Result and Discussion

4.1 Soil treated with fly ash

Compaction characteristics. Optimum percentage required in the soft clay was determined by conducting light compaction test. Light compaction test was conducted by mixing the soil with 10%, 20%, 30% and 40% of fly ash by dry weight of soil. From figure 1, it is clear that the gradual addition of fly ash in soil increasing the dry density up to 30% addition of fly ash and after that it starts reducing. The optimum fly ash percentage was obtained as 30% by dry weight of soil.

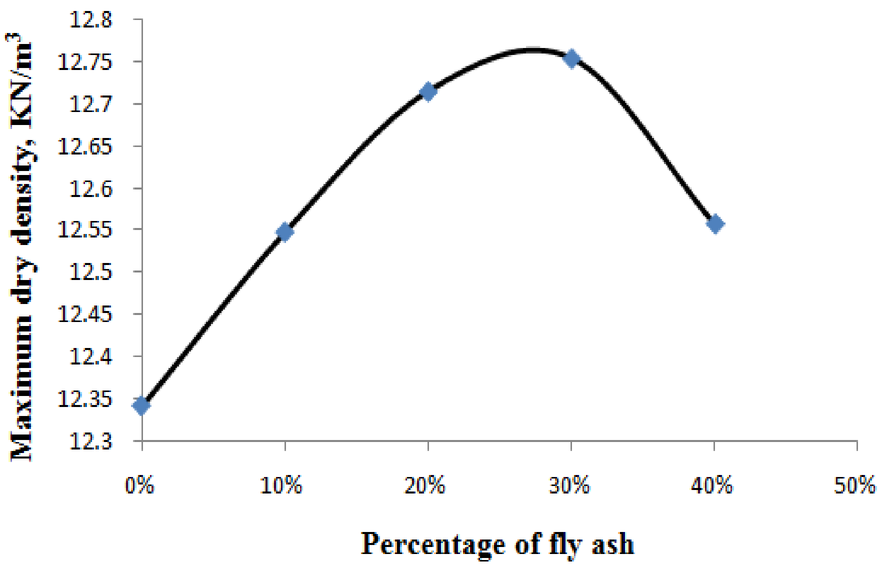

Fig. 1. Variation of maximum dry density with different percentage of fly ash.

Unconfined compressive strength of soil mixed with fly ash

Stress strain behavior of soil treated with fly ash was determined by conducting unconfined compressive strength test. Test specimens for the unconfined compressive strength test were made with the maximum dry density and optimum moisture content obtained from the respective standard proctor test. For each fly ash percentages such as 10%, 20%, 30% and 40%, samples were casted and kept for curing. Both uncured and cured samples were tested to get their unconfined compressive strength. Among the casted samples three were tested after 5 hour of casting and remaining samples were kept for curing for 1day, 7days and 28days.

Figure 2 gives the trend of variation of strength of soil mixed with different fly ash percentages. The unconfined compressive strength of soil treated with fly ash was increased with curing period for each percentage of fly ash. The peak strength of specimen increased with increase in fly ash content up to 30% and after that it started reducing. For every percentage the peak strength was increased with curing time.

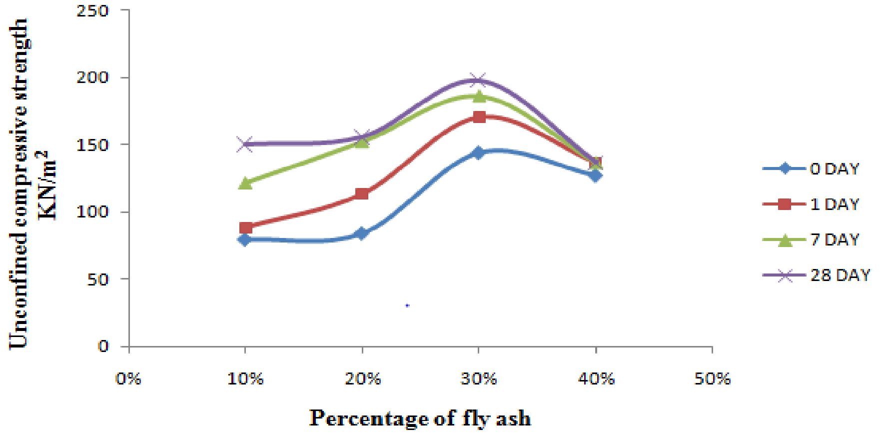

Fig. 2. Unconfined compressive strength of soil mixed with different percentage of fly ash for various curing period.

Plasticity characteristics. The treatment of soil with admixtures influences the plasticity characteristics of soil. Changes in plasticity characteristics cause changes in strength of the soil. Fly ash was used as the admixture with the soil. Liquid limit and plastic limit tests were carried out as per standard specifications to study the effect of fly ash on plasticity characteristics of soil. The plasticity characteristics of clay got improved on treating with fly ash. Variation of liquid limit of soil treated with fly ash is shown in figure 3. The liquid limit was decreased with more addition of fly ash content. Liquid limit was also decreased with the increase in curing period.

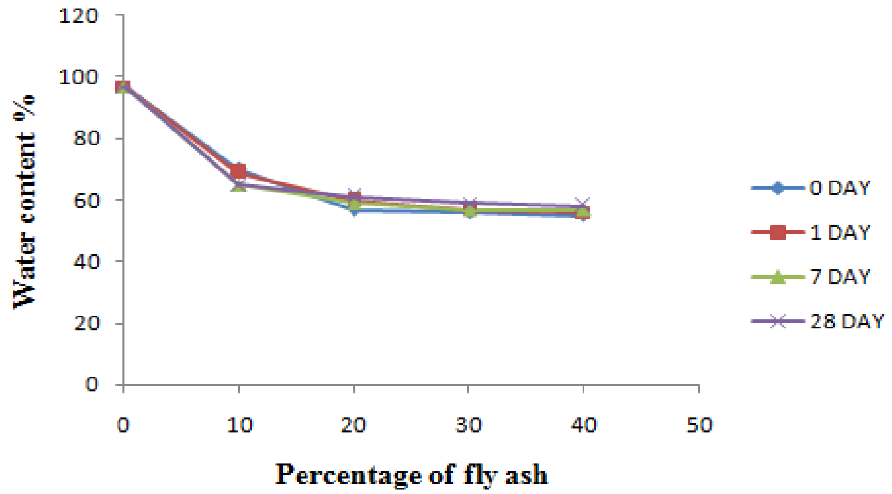

Fig. 3. Liquid limit of soil mixed with different percentage of fly ash for various curing period.

Plastic limit was also decreased with increase in fly ash content.

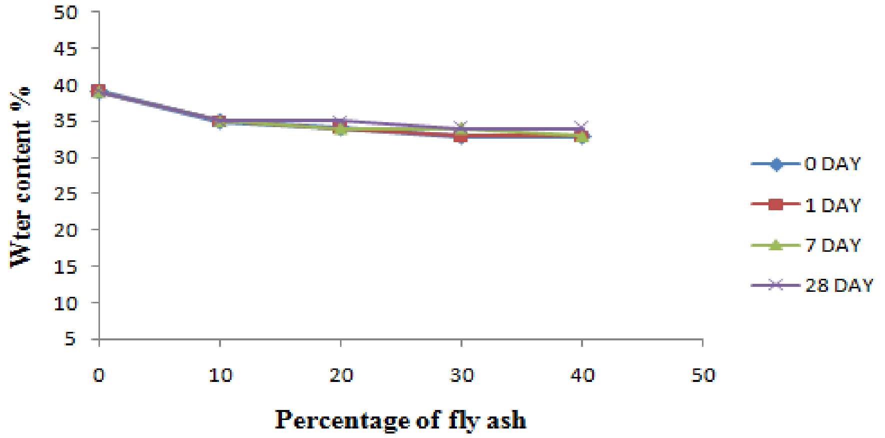

Fig. 4. Plastic limit of soil mixed with different percentage of fly ash for various curing period

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Compaction characteristics. Optimum percentage of fly ash and nylon fiber required to achieve highest strength of soil was determined by conducting light compaction test. The test was conducted by mixing the soil with various combinations of fly ash and nylon fiber. Standard proctor test was carried out in the soil mixed with different combination of fly ash and nylon fiber. Percentages of fly ash were 10, 20, 30 and 40 by dry weight of soil and percentages of fiber were 0.25% and 0.5% by dry weight of soil.

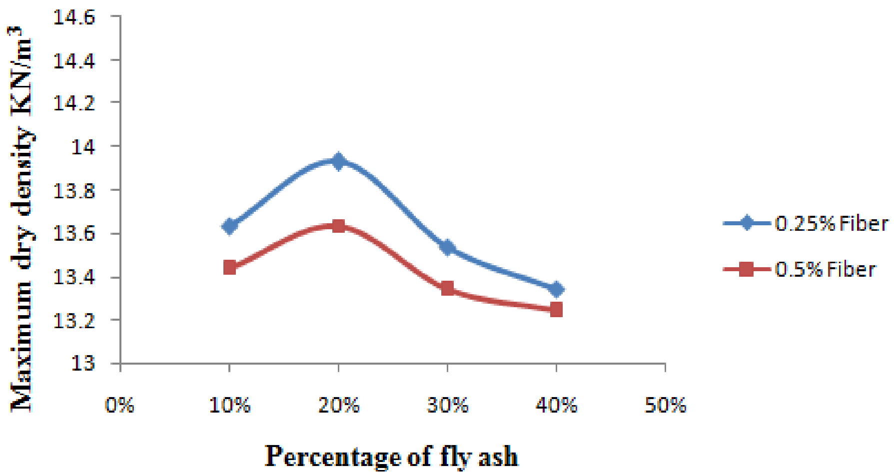

Fig. 5. Maximum dry density of soil treated with various percentage of fly ash and nylon fiber.

Compaction test was first done by mixing 0.25% of fiber by weight of soil with four different percentages of fly ash. For 0.25% of fly ash, maximum dry density is increased till 20% addition of fly ash. After that maximum dry density started decreasing. Then 0.5% of fiber by dry weight of soil was mixed with four different percentages of fly ash. The trend of difference in maximum dry density for 0.5% fiber was also the same. While comparing the two percentages of fiber, higher value of maximum dry density was obtained for 0.25% of fiber in the soil. From standard proctor test, optimum fly ash percentage was obtained as 20% by dry weight of soil and optimum percentage of nylon fiber as 0.25%.

Unconfined compressive strength of soil mixed with fly ash and nylon fiber. Unconfined compressive strength of soil treated with fly ash and nylon fiber was determined by testing samples in unconfined compression testing machine which were prepared by mixing soil with 20% fly ash, 0.25% nylon fiber and water at a density of 13.93KN/m^3 and moisture content of 22% which were obtained from light compaction test.

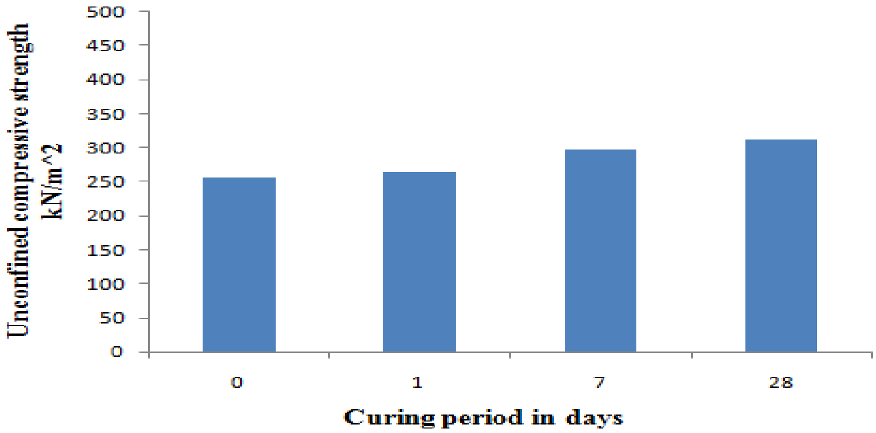

Fig. 6. Variation of Unconfined compressive strength of soil mixed with 20% fly ash and 0.25% nylon fiber for various curing period.

4.2 Comparison of test results

1. From standard proctor test maximum dry density and optimum moisture content of raw soil was obtained as 12.36KN/m^3 and 35.52% respectively. For soil mixed with various percentage of fly ash, optimum percentage was obtained as 30% and maximum dry density and optimum moisture content were changed to 12.75KN/m^3 and 32.4% respectively for soil stabilized with optimum percentage of fly ash. In the case of combination of fly ash and nylon fiber, optimum percentage of fly ash was obtained as 20% and that of nylon fiber was obtained as 0.25%. For soil treated with optimum fly ash and

nylon fiber, maximum dry density and optimum moisture content were changed to 13.93KN/m^3 and 22% respectively.

2. For untreated soil unconfined compressive strength was 75KPa. Strength was increased to 145Kpa for optimum percentage of fly ash without curing. Strength is increased about 93 % for soil mixed with optimum percentage of fly ash without curing. For soil stabilized with optimum percentage of fly ash and nylon fiber, UCS was increased to 256KPa without curing and the increase was about 77% compared to soil stabilized with fly ash alone.
3. After a curing period of 28 days, UCS was increased to 198KPa for soil treated with fly ash and strength was increased to 311KPa for soil treated with both fly ash and nylon fiber. The increase in strength after a curing period of 28 days for soil treated with fly ash alone and soil treated with both fly ash and nylon fiber were 37 % and 21% respectively.

5 Conclusions

The effect of fly ash alone and combined inclusion of nylon fiber and fly ash in soft clay was evaluated in this paper. The major conclusions obtained from laboratory tests and analysis of test results are summarized as follows:

1. The optimum percentage of fly ash was obtained as 30% for soil mixed with fly ash alone and optimum percentage of fly ash and nylon fiber were 20% and 0.25% respectively for soil mixed with both fly ash and nylon fiber. There is formation of lumps when percentage of nylon fiber is increased after optimum percentage. A
2. Addition of fly ash improved the strength of untreated soil. For soil mixed with optimum percentage of fly ash, unconfined compressive strength was increased about 93% without curing and the strength was increased about 37% after a curing period of 28 days.
3. Unconfined compressive strength was more in the case of soil mixed with fly ash compared to untreated soil. Strength was maximum for soil put together with optimum fly ash and the strength was increased with increase in period of curing.
4. Plasticity characteristics such as liquid limit and plastic limit were decreased with increase in percentage of fly ash and also with the curing period.
5. For soil stabilized with optimum percentage of fly ash and nylon fiber, UCS was increased about 77% without curing compared to soil stabilized with fly ash alone and the strength was increased about 21% after a curing period of 28 days.
6. Strength is more in the case of soil mixed with both fly ash and nylon fiber compared to strength of soil mixed with fly ash alone and untreated soil. Hence combined inclusion gives more strength and inclusion of fiber improved ductility also.

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