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Swell-Consolidation Characteristics of Fibre-Reinforced Expansive Soils

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Abstract. Many innovative foundation techniques have been devised to counter act the swell-shrink problems posed by expansive soils. Some of these techniques include physical alteration, sand cushioning, cohesive non-swelling soil (CNS) layers, belled piers, under-reamed piers, granular pile anchors and chemical stabilization. Reinforcing expansive soils with randomly oriented geo-fibers is also an effective technique for controlling the volumetric changes in expansive soils. This paper presents the swell-consolidation characteristics of fiber-reinforced expansive soils. Polypropylene fiber was used to reinforce expansive soil specimens. One-dimensional swell-consolidation tests were conducted to study the swell consolidation characteristics of fiber-reinforced clay specimens. The fiber content (fc) was varied at 0%, 0.25%, 0.5%, 0.75%, 1%, and 1.25% by the dry weight of the soil.

Keywords: expansive soil, polypropylene fiber, swells–consolidation characteristics.

1 Introduction

Expansive soils swell when they absorb water and shrink when water evaporates from them. Due to this alternating swelling and shrinkage, lightly loaded civil engineering structures founded in these soils are severely distressed. Many innovative techniques have been devised in order to counteract the problems posed by expansive soils. Physical alteration, belled piers, and granular pile-anchors are some of the innovative foundation techniques adopted for expansive soils. The chemical stabilization of expansive soils, using lime and fly ash, has also been found quite effective in controlling the volumetric changes in expansive soils. Fly ash columns are a recently developed foundation technique, which has yielded promising results. Apart from the above techniques, geosynthetic inclusions as a technique of random reinforcement have also been found quite effective in controlling swell and shrinkage. Nowadays, natural fibers such as kenaf, coir, banana, jute, flax, sisal, palm, reed, bamboo and wood fibres are used for soil reinforcement. The reasons for using natural materials are because of its environmental and economic advantages. The consolidation tests were performed to understand the compressibility and swell characteristics with different percentage of polypropylene fiber in the laboratory. To examine the possible improvements in the compressibility and swell characteristics, local soil samples was reinforced with random distribution of polypropylene (synthetic) fibers as percentage (0%, 0.25%, 0.5%, 0.75%, 1%, 1.25%).

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2 Experimental Program

One dimensional consolidation tests were conducted to evaluate the effect of Polypropylene fiber on the swell-consolidation characteristics of the soil. Materials used for the study is illustrated below.

2.1 Materials used

Soil. The expansive soil was collected from Kozhinjampara village, Chittur thaluk in Palakkad district. The geotechnical properties of soil are given in Table 1. The soil is classified as high plastic clay (CH) according to IS Plasticity chart.

Table 1. Geotechnical properties of soils.

Properties	Values
Specific gravity	2.56
Sand fraction (%)	27
Fraction passing 0.075 mm sieve (%)	73
Liquid Limit,(%)	79
Plastic limit (%)	28
Shrinkage limit (%)	13
Plasticity index (%)	51
Soil classification system	CH
Optimum moisture content (%)	26
Maximum dry density (kN/m^3)	15.2
Free Swell index (%)	73

Polypropylene (PP) fibers. Polypropylene fiber is the most common synthetic fiber used as a reinforcement material for the soil improvement and concrete. This fiber has properties of hydrophobic, non-corrosive resistance over chemicals, alkalis and chlorides. Reinforcing soil with polypropylene fiber can increase UCS and shear strength. The Polypropylene (PP) fibers used for the study were collected from Reliance Industries Limited Mumbai.

Physical properties of PP fiber from the manufactures manual are shown in the Table.2

Table 2. Physical Properties of Polypropylene Fibers

Properties	Values
Density	0.91g/$cm3$
Modulus of elasticity	3500MPa
Average diameter	0.034mm
Average length	12mm
Aspect ratio	353
Breaking tensile strength	350MPa
Fusion point	165^{o}c
Burning point	590^{o}c
Acid and alkali resistance	Very good
Dispersibility	Excellent

3 Sample Preparation

The collected black cotton soil in the form of wet condition was placed in an oven for 24 hours and then crushed into dry powder form. Then soil sample is sieved through 425 micron IS sieve. Sample was prepared at maximum dry density and optimum moisture content. Soil specimen is having 6cm diameter and 2cm height. By using density and volume the weight of soil is calculated. The PP fiber of a constant 12mm length were added to this soil at different percentages of fiber content such as 0%, 0.25%, 0.5%, 0.75%, 1%, 1.25% (% of dry weight of soil) and it is mixed with the soil .The fibers are randomly oriented. Then optimum water was added gradually and mixed until the water spread all over the soil. The soil, fiber and water were mixed manually spending sufficient time with proper care to get homogeneous mix.

4 Testing Program

The specimen and mould assembly is placed in the apparatus and connected to the water reservoir to allow the water in to the sample for saturated condition. After applying the seating load of 10kpa, the first load increment of 25kpa was applied and the stop watch was started at the same instant and the initial reading was noted. The dial gauge readings were noted at certain time intervals. The Coefficient of consolidation (Cv) was found from the dial gauge reading v_s. graph. The Compression index (Cc) and Swell index (Cs) values are obtained from the e-logp curve.

Fig. 1. Experimental set up of consolidation test

5 Results and Discussions

The void ratio- pressure relationship curves for both unreinforced and reinforced soil is given in the figure.3.The values of compression index (c_c) and swell index (c_s) are-calculated from e- log P curves. The slope of straight portion of e-log P curve gives the compression index values and the slope of rebound curve of e- log P curve gives the swell index values. The variation of compression index and swell index with varying percentage of fiber is shown in figure.4 and figure.5 respectively. The variation of coefficient of consolidation with varying percentage of fiber is illustrated in the figure.6 below.

Coefficient of consolidation was found from dial gauge reading vs √t graph .The value of coefficient of consolidation (c_v) initialy decreases and then increases on adding different percentage of PP fibers. This is mainly due to the fact that the fibers provides a drainage path to drain out the water from the soil.So that more water will dissipate through the pores and reduces the time required to achieve primary consolidation.The void ratio v_s pressure curve is given below. The void ratio decreases with the percentage inclusion of polypropylene fibers since the void spaces are occupied by fibers.

The compression index v_s percentage of fiber graph and swell index v_s percentage of fiber graph are shown below .The value of compression index (c_c) and swell index (c_s) decreases on adding polypropylene fibers up to 0.75% and thereafter with the addition of polypropylene fiber value shows an increase. The decrease in the compression index value is due to the fact that the tensile strength of polypropylene fiber induces cohesion in clay particles. The reason for decrease in swell index is the interlocking effect and friction effect induced by the fiber.

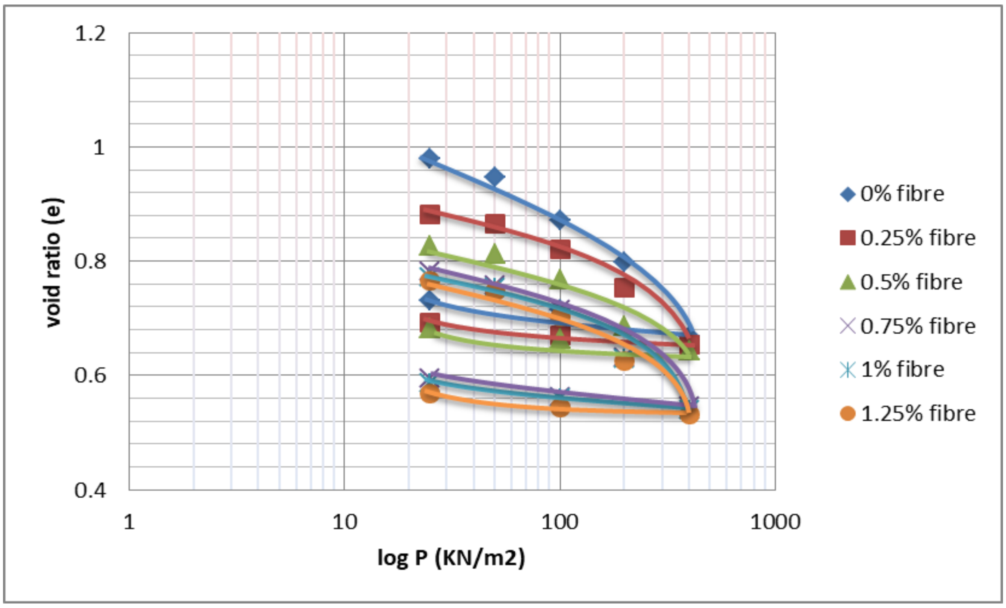

Fig.2. Variation of void ratio

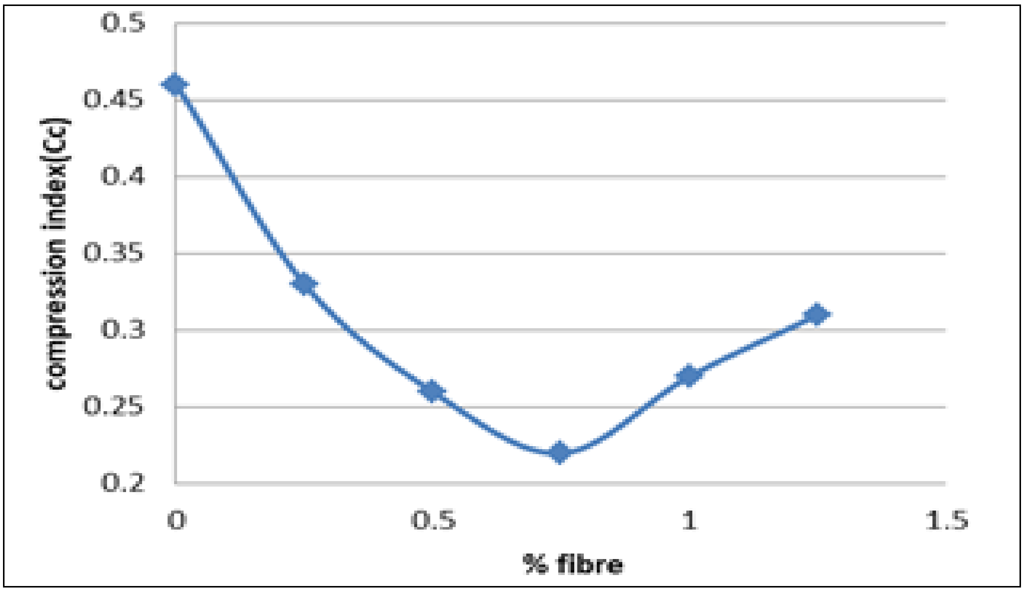

Fig.3. Variation of compression index with different percentage of PP fiber

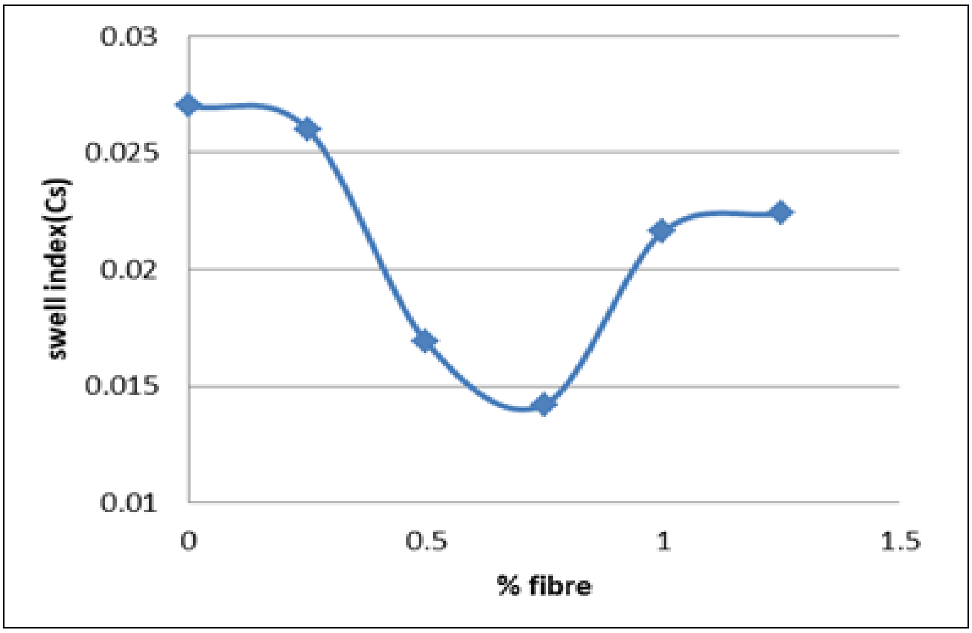

Fig.4. Variation of swell index with different percentage of PP fiber

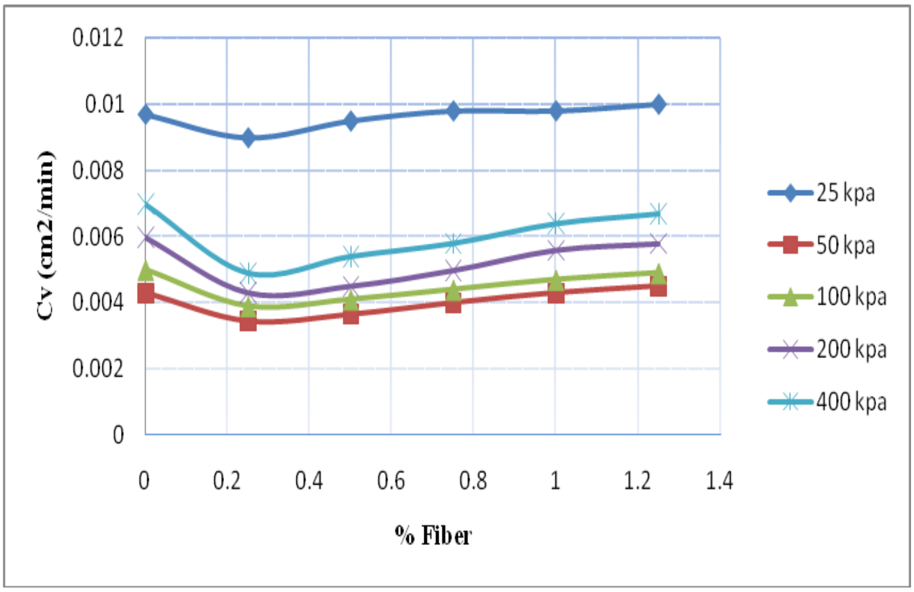

Fig.5. Variation of coefficient of consolidation

6 Conclusions

Soil was classified as CH soil. Polypropylene fiber was used to improve the compressibility behavior of soil. The addition of polypropylene fiber produces the following changes:

1. The compressibility characteristics and swell behavior of soil is improved.
2. The consolidation parameter namely, compression index (C_c) decreases with inclusion of PP fibers in the soil up to 0.75% fiber content and thereafter on adding PP fiber C_c increases.
3. Minimum C_c value is observed at fiber contents of 0.75% for soil reinforced with PP fibers.
4. Compression index decreased by 53 % at 0.75% of fiber.
5. The swell index (C_s) decreases with inclusion of PP fiber in the soil up to 0.75% fiber content and thereafter on adding PP fiber C_s increases.
6. Minimum C_s value is observed at fiber contents of 0.75% for soil reinforced with PP fibers
7. Swelling index decreased by 48 % at 0.75% of fiber.
8. The increase in the coefficient of consolidation (C_v) on adding fiber content is due to the drainage path provided by the short PP fiber.

Based on the results obtained, it is recommended that polypropylene fiber can be used as a reinforcing material for improving the consolidation and swell characteristics of the soil.

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