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BEARING CAPACITY OF A STRIP FOOTING RESTING ON TREATED AND UNTREATED SOILS

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ABSTRACT: Expansive soils are highly susceptible to volumetric changes leading to rapid loss in the bearing capacity of footings resting on them. Among several techniques available to treat expansive soils, lime or fly ash stabilization gained prominence during the past few decades due to its abundance and adaptability. Chemical stabilization is widely used to treat expansive soils as it develops base exchange and cementation processes between clay particles.When expansive soils are treated with chemicals, it is essential to obtain the load-settlement response of footing resting on stabilized ground. In this study, Finite Element Analysis is performed using the commercial software, PLAXIS 2D, to obtain the load-settlement response of a strip footing resting on untreated and treated expansive soil. The bearing capacity of strip footing resting on treated soil is found to be about 150% higher than that of footing resting on untreated soil.

INTRODUCTION

Untreated expansive soils are highly susceptible to volumetric changes with changes in moisture content leading to a rapid loss in the bearing capacityof footings resting on them. To overcome this, expansive soils have to be stabilised inorder to improve their properties. Although different methods like soil replacement, prewetting and moisture control, etc., are available to treat expansive soils, these methods have certain limitations like high hauling cost, non-availability of competent replacement material, and difficulty in adaptability and construction, etc.

Chemical stabilization is an effective and economical method to treat expansive soils. In this study, lime and fly ash are used to improve the strength and compressibility properties of expansive soil.

This paper compares the load-settlement response of a strip footing resting on untreated and treated ground. The numerical modelling is performed using a commercially available Finite Element Software – PLAXIS 2D (2013).The improvement in the limit bearing capacity of the footing is also proposed.

REVIEW OF LITERATURE

Selected Studies on Chemical Stabilization Using Lime and Fly ash

Among several techniques adopted to overcome the problems posed by expansive soils, lime stabilization gained prominence due to its abundance and adaptability [Snethan (1979)] [1]. Petry and Armstrong (1989) proposed that chemical stabilization of expansive clays involves changing the physical and chemical environment within and surrounding the clay particles in such a way that the clay particles require less water to satisfy the static imbalance. This makes it difficult for water to move into and out of the system [2]. Cokca (2001) found that plasticity index and swell potential decrease with addition of fly ash. The fly ash addition greater than 20% is comparable to lime addition equal to 8% in terms of reducing the plasticity and the swell potential in the soil [3]. Kumar and Sharma (2004) observed that the free-swell index reduced to 50% with the addition of 20% of fly ash. In addition, the plasticity characteristics were also reduced [4]. White et al. (2005) reported that the strength gain in soil-fly ash mixtures is dependent on curing time, temperature, compaction energy, and compaction delay [5]. Ramu and Babu (2010) reported that fiber reinforced fly ash with cement as an additive resulted in reduction of heave by about 84% compared to that of uncushioned soil [6]. According to Geliga et al. (2010), the shear strength of sample mixtures cured for 7 days decreased when the amount of fly ash was equal to 80% of the total weight of the mixture. Besides, 60% of fly ash and clay mixture (by weight) resulted in the highest value of axial stress of the sample [7]. According to Harichane et al. (2010), a significant increase in cohesion was observed with time for samples stabilized with 8% lime content. However, the addition of natural pozzolana resulted in only a marginal increase on cohesion and friction angle with time. The combination of 20% natural pozzolana+8% lime resulted in high increase in cohesion for 28 days curing period [8]. Ramdas et al. (2011) reported 10%-13% increase in the unconfined compressive strength with the addition of 25% fly ash, whereas addition of lime up to 4% resulted in 40%-60% increase in the unconfined compressive strength [9]. Pankaj et al. (2012) reported a significant improvement in the CBR value of expansive soil stabilized with lime and fly ash, leading to a decrease in the thickness of pavement by about 66% [10]. Hasan (2012) observed that fly ash equal to 15% was the optimum value leading to maximum increase in the cohesion of soil- fly ash mixtures. This value of cohesion increased with curing time up to 14 days. However, the addition of fly ash had an insignificant effect on the angle of shearing resistance of the mixture [11]. Bose (2012) observed that the maximum unconfined compressive strength was obtained at 20% fly ash when mixed clay sample, and further addition of fly ash was found to reduce the compressive strength [12].

Recent Studies on BearingCapacity of Footing

Smith and Griffiths (1998) reported that the bearing capacity analyses are carried out using finite element method by a viscoplastic algorithm and the elastic- perfectly plastic Tresca yield criterion. The soil medium is discretized using iso-parametric plane-strain elements [13]. Esmaili and Hataf (2008) observed that the results from the finite element analysis show a reasonably good agreement with laboratory experimental results with a discrepancy of within 0 to 14% [14]. Loukidis et al. (2008) used the finite-element method to determine the collapse load of a rigid strip footing resting on a uniform layer of frictional soil subjected to inclined and eccentric loading. The soil was assumed to be elastic-perfectly plastic and follows the Mohr-Coulomb failure criterion [15]. Musso and Ferlisi (2009) analysed the behaviour of a model strip footing resting on a saturated soil and subjected to centric or eccentric vertical loading. Experimental tests carried out on a small-scale physical model were able to reproduce the effective stress levels equivalent to those existing in the prototype problems [16]. Keskin and Laman (2012) performed both finite element analysis and experimental studies on the bearing capacity of footings. They concluded thatthe ultimate bearing capacity values obtained from FEAwas only slightly greater than that obtained from the model tests [17]. Balunaini et al. (2012) proposed the settlement influence factors due to uniform circular load acting on finite two layer system and found thatthe factors are in good agreement with the factors proposed by Ueshita and Meyerhof based on theory of elasticity [18]. Kaya and Ornek (2013) reported that the numerical analyses using an elastoplastic hyperbolic model gave results that are close to physical model tests. However, the numerical models from their analyses were found to underestimate the test results [19].

PROBLEM DEFINITION

A strip footing of width equal to 2m is resting on a treated ground. It is proposed to obtain the load-settlement response of the treated ground and compare the response with that of untreated ground. It is also proposed to obtain the improvement in the limit bearing capacity of the footing resting on treated and untreated.

METHODOLOGY

Experimental Analysis

The strength parameters of the untreated expansive soil were determined using unconsolidated, undrained (UU) triaxial tests. The undrained shear strength was found to be equal to 54 kPa.

The experimental results obtained after treating the soil with lime (contents ranging from 0% to 12%) and fly ash (ranging from 0% to 25%) by weight were analysed. Based on the experimental study, expansive soil was found to have the maximum undrained shear strength when treated with lime and fly ash contents equal to 9% and 20%. The undrained shear strength of treated soil was found to be equal to 407kPa.

The limit bearing capacity values of the strip footing resting on untreated and treated soil were calculated from the bearing capacity equation, and were found to be equal to 555 kN/m^2 and 1373 kN/m^2, respectively.

RESULTS AND DISCUSSIONS

Finite Element Analysis

Finite element analysis (FEM) was performed using the commercial software Plaxis 2D-(2013). Plane-strain conditions were assumed and the soil model was developed. The boundary distances were suitably chosen in order to simulate the semi-infinite extent of soil medium.25m x 25m sized model was found to have minimum influence of boundaries on the load-settlement response of the footing (Fig. 1).

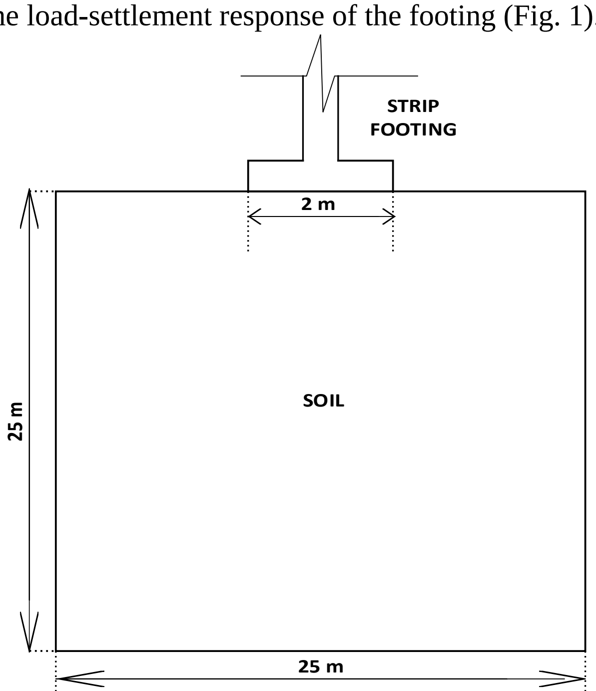

Fig. 1 Schematic representation of soil and footing

A strip footing of width equal to 2m was placed on the soil surface exactly at the center of the soil model as shown in Fig.1.

The FE model has been configured with 15-noded triangular elements. Mohr-Coulombmaterial model was assumed to represent untreated and treated soil. The boundaries are laterally fixed on both sides, and fixed horizontally and vertically at the bottom boundary.

Table 1 gives the soil properties of untreated expansive soil used to determine the bearing capacity of the strip footing resting on the untreated ground.

Table 1 Untreated expansivesoil properties

S.No	Property	Value
1.	Poisson's Ratio (μ)	0.2
2.	Modulus (E)	15000kPa
3.	Unsatured unit weight of soil	16 kN/m^3
4.	Saturated unit weight of soil	18 kN/m^3

The geometry consisted of 12593 number of nodes and 1544 number of soil elements with an average element size of 0.6362 m.

Fig. 2 shows the settlement profile of untreated ground. The Figure indicates that the maximum settlement was found just below the footing and the settlement decreases with depth. The limit bearing capacity of footing (per meter length) resting on untreated expansive soil was found to be 563kN/m^2 which is in close agreement with the limit bearing capacity of footing calculated from bearing capacity equation.

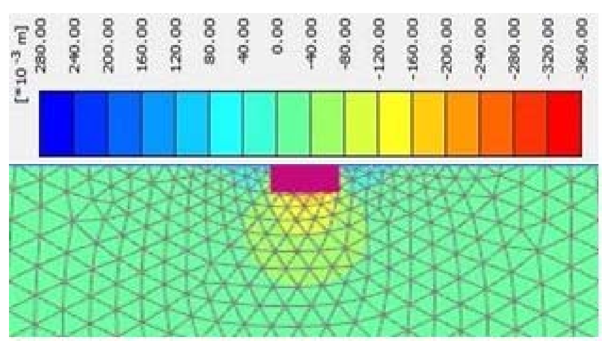

Fig. 2 Settlement profile of untreated expansive soil for a prescribed rigid footing displacement equal to 200mm

Similar method was followed while simulating the model for treated Soil. The settlement profile and the corresponding load-settlement curve are shown in the figures below.

Table 2 Treated soil properties

S.No	Property	Value
1.	Poisson's Ratio (μ)	0.2
2.	Modulus (E)	15000kPa
3.	Unsatured Unit wt. of Soil	16 kN/m^3
4.	Saturated Unit wt. of Soil	18 kN/m^3

It was clear from Fig. 3 that the settlements are maximum just below the footing and reduced with increment in the depth. It was inferred that the bearing capacity (per meter length) for the untreated expansive soil was found to be 1408kN/m^2 which was near to the bearing capacity value that was calculated from the experimental results. All the simulations were carried out in a very fine mesh for undrained condition and obtained results are compared with each other.

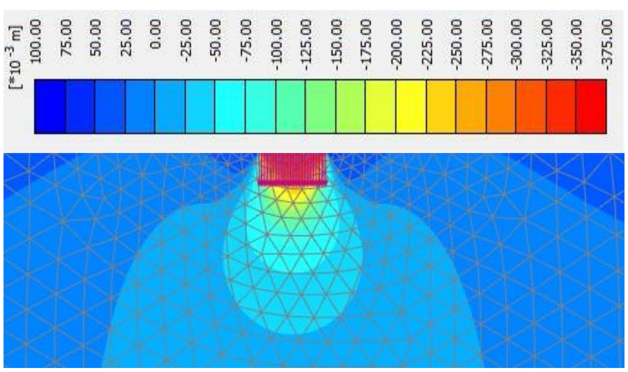

Fig. 3 Settlement profile of treated soil for a prescribed rigid footing displacement equal 200mm

Fig. 4 shows the load versus settlement of footing. As the settlement increases, the load on the footing increases and the load reach a constant value beyond a certain footing settlement. The bearing capacity of footing was found to increase to a greater extent when the expansive soil was treated with optimum percentages of lime and fly ash. In both the cases, the limit bearing capacity value obtained from the Finite Element analysis was found to be in a close agreement with values obtained from the theoretical bearing capacity equation.

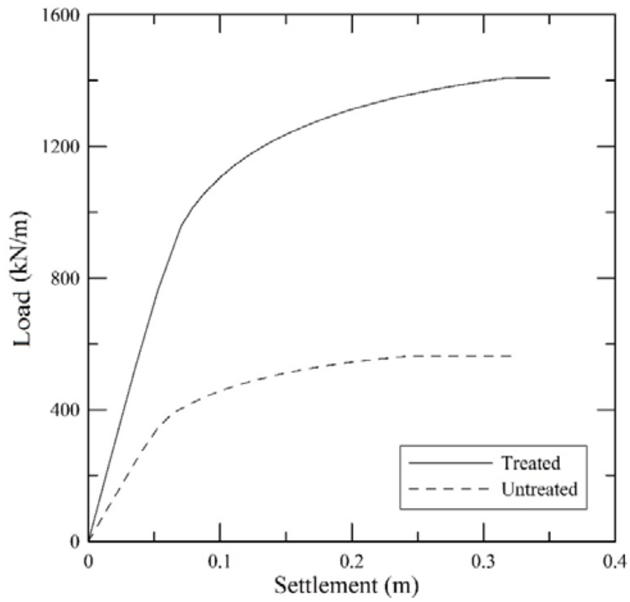

Fig.4 Variation of load on the footing with settlement in the case of footing resting on untreated and treated soils

Table 3 Comparison of untreated and treated soil properties

S.No	Property	Untreated	Treated
1.	Saturated unit weight (kN/m^3)	18	18
2.	Unsaturated unit weight (kN/m^3)	16	16
3.	Modulus (kPa)	15000	15000
4.	Poison's Ratio	0.2	0.49
5.	Cohesion (kPa)	54	342
6.	Friction Angle	0^o	10^o
7.	UCS (kPa)	108	815
8.	Shear Strength (kPa)	54	407
9.	Limit load (per 'm') (kN/m^2) {from bearing capacity equation}	555	1373
10.	Limit load (per 'm') (kN/m^2) {from FEM}	563	1408
12.	Improvement in the bearing capacity of footing {based on FE analysis}	150 %	

Table 3 gives all the soil properties including the limit bearing capacity values calculated from both FE analysis and from theoretical bearing capacity equation.

CONCLUSIONS

- It was observed that the limit bearing capacity of footing on treated soil was about 2.5 times than that of footing on untreated soil.

- The bearing capacity of footing calculated from FE analysis are found to be in close agreement with that obtained using the theoretical bearing capacity equation.

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