Experimental Study on Load Settlement Behaviour of Granular Stone Column in Expansive Soil

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Abstract. In today's construction industry as land reclamation is increasing rapidly so ground improvement has become necessity. Ground improvement is carried out by increasing vibration, structural fill or reinforcement, vegetation, admixtures, etc. out of all the methods the stone column technique is a very effective method of improving the strength parameters of soil like bearing capacity and reducing settlement, particularly for the construction of flexible structures such as road embankments, oil storage tanks, etc. on soft soils. It offers a very economical and sustainable alternative to piling and deep foundation. The Model test was performed on untreated soil and treated soil with 40 mm, 60 mm, 80 mm diameter stone column. The investigation focused on the influence of diameter of granular stone column. The tests were conducted on granular stone column having l/d ratio equal to 10. From the studies performance of smaller diameter stone column is superior to that of bigger diameter stone column. Due to its higher modulus of elasticity than that of soil, it absorbs more load than soil and reduces overall settlement

Keywords: Stone column, Expansive soil, Ground improvement

1 Introduction

In India about 5.46 lakh sq.km area (i.e. 16.6 percent of the total geographical area of the country) is covered by black cotton soil and this soil is mainly found in Maharashtra, Madhya Pradesh, Karnataka, Andhra Pradesh, Gujarat and Tamil Nadu. In the recent past, a large number of ports and industries are being built. In addition, the land available for the development of Residential, Institutional, commercial, industrial and infrastructure etc. are scarce particularly in urban areas [1]. This requires the utilization of sections having weak strata with varied engineering characteristics. Several of these areas are lined with thick, soft clay deposits, with very low shear strength and high compressibility [12]. Piles are normally being used in this land to carry the load of a super structure. For a low rise construction, the cost of piles may be very high and people often use some ground improvement technique [5].

Out of several techniques offered for improvement of the weak strata, the stone columns used in a large extent due to the wide savings in cost and in program schedules over the conventional piling solutions. Stone columns are used in weak deposits to increase the load-carrying capacity and reduce settlement of foundations [2].

Expansive soil loses its strength on wetting and drying. Although the phenomenon of swelling and shrinkage is common with most of the soils (except sand and gravel), it is exhibited considerably in clayey soil. A large number of methods that are commonly suggested to improve the behaviour of such soils includes the soil replacement, mechanical and chemical stabilization, and thermal treatment [1]. A brief review of the common methods and their shortcomings has been discussed by Kumar and Jain (2016). The literature presented that granular piles are extensively being used to improve the load carrying capacity and to reduce settlements of soft expansive soil [7]. Further, load carrying capacity can be increased by mixing nylon fibres or encasing the pile by geogrid [3,7].

The present study aims at the load-settlement behaviour of untreated and treated soil with varying diameter stone column. The influence of diameter of granular stone column was accessed having column's l/d ratio equal to 10 [4].

2 Experimental work

The experimental work consists of two parts

1. Determination of physical and mechanical properties of soft soil and stone column materials.
2. Testing of model embankments resting on soft soil strengthened by stone columns.

2.1 Experimental Setup

An experimental setup with an approximate scale of 1/10 to 1/20 of the prototype was designed. A plastic tank was used to host the bed of soil and all its accessories. The tank has internal diameter 1000 mm and depth 800 mm. The tank was sufficiently rigid and exhibited no lateral deformation during the preparation of soil bed and during the test. The loading frame consists of two steel rods welded together with steel plates at bottom and top steel plate was movable for arrangement of fixing the jack. Load was applied using hydraulic jack and measured using proving ring and displacement was measured using dial gauge.

2.2 Properties of soil and stone column material

The soft soil used for experiment was collected at depth of 5 m from Bapu track, Nashik. The soil and stone column material were characterised using routine laboratory tests such as Atterberg limits [10], specific gravity [8] grain size distribution [9] and standard proctor test [11]. Table 1 present the properties of soil and stone column material used in present study.

Table 1. Properties of soil and stone column materials

Property	Soil	Stone
Liquid Limit (%)	55.5	-
Plastic Limit (%)	24	-
Plasticity index	31.5	-
Specific Gravity	2.58	2.7
Soil Classification	CH	GW
Maximum Dry unit weight (kN/m^3)	15.1	17.5
Optimum moisture content (%)	19.6	

2.3 Preparation of Soft Clay Bed

Tank was filled with the required amount of soil placed in a layer of 15 cm with uniform compaction to achieve a uniform dry density of 15 kN/m^3. Each layer was levelled gently using a 50 × 150 mm wood tamper. This process was continued till the soil bed depth of 75 cm was obtained.

2.4 Construction and Design of Stone Column

Stone column diameter: Installation of stone columns in soils is basically a self-compensating process that is softer the soil larger the diameter of the stone column. Due to lateral displacement of stones during vibrations/ramming, the completed diameter of the hole is always greater than the initial diameter of the probe or the casing. In present study stone column diameter of 40 mm, 60 mm, and 80 mm were used.

Pattern of Stone column: Stone columns should be installed preferably in an equilateral triangular pattern which gives the densest packing although a square pattern may also be used. Fig.1 shows equilateral triangular pattern of stone column used in study. The spacing (S) of stone column was 2.5 times diameter of stone column (S = 100 mm, 150 mm & 200 mm for stone column having diameter 40 mm, 60 mm & 80 mm respectively).

The position of the stone columns was marked according to the proposed configuration patterns of stone columns given in IS 15284 (Part1):2003. The column was constructed by the replacement method [6]. A hollow steel pipe was pushed down the bed to the specific depth (i.e. l/d ratio= 10) at required spacing. After that, the casing was removed. The stones were placed in layer of 50 mm and compacted by using the tamping rod.

Fig. 1. Pattern of stone column in model

2.5 Test Procedure

The model tests were performed on prepared soil bed with and without stone column. The circular plate of size up to equivalent diameter was placed at the top of the centre of stone column, and dial gages were mounted to measure the settlements of the soil bed. Load was applied through hydraulic jacks and recorded using proving ring. Load per mm settlement was observed.

3 Results and Discussion

The tests were conducted on bed of untreated soil and treated soil. Fig 2 shows the effect of stone column on bearing pressure. The maximum bearing pressure of soil for 25 mm settlement with the 60 mm stone column was 91.23 kPa and for the 80 mm stone column was 82.56 kPa. The bearing pressure was increased with the stone column. The increase in bearing pressure was observed with increase in the diameter of stone column, however, with further increase in stone column diameter (80 mm) the bearing pressure was decreased. This may be attributed to the bulging of stone column in the large diameter stone column.

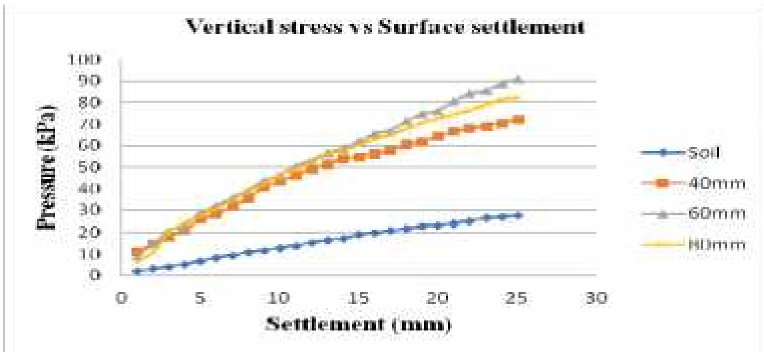

Fig. 2. Vertical stress vs Surface settlement on soil and soil having stone columns

4 Conclusions

- The bearing pressure on untreated soil, soil with stone columns of 40 mm, 60 mm and 80 mm was 27.72 KPa, 72.09 KPa, 91.23 KPa, and 82.56 KPa respectively for 25 mm settlement.
- The performance of the smaller (60 mm) diameter stone column was superior to that of the bigger (80 mm) diameter of stone column.
- The stone column was the good alternative to pile foundation.
- This may also promote the vertical drainage function by acting as a good filter.
- The mode of failure for an embankment model resting on untreated, very soft clay was close to local shear failure, whereas the mode gradually changed toward the general shear failure when using stone columns.

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