Effect of Tapered Rubberized Concrete Poles on Loose Sand

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ABSTRACT: Constructional activities in coastal areas are difficult due to loose and uniform nature of the sand deposits. This paper presents improvement in the bearing capacity of loose sand by introduction of precast rubberized concrete poles (RCPs). Rubberized concrete poles of uniform and tapered square sections (with the same volume) were used. Laboratory model studies using plate load tests were conducted on sand with 50% relative density and on sand densified using RCPs of different dimensions. The bearing capacity of sand was found to increase with the increase in the volume of the poles. Comparison of these two shapes was also made. The test results showed higher load carrying capacity of tapered sections than square sections.

1 INTRODUCTION

A good bearing soil stratum is essential for all construction works. The lack of availability of good bearing stratum is one of the challenging problems faced by the construction industries. In sandy soil deposits the major ground improvement methods adopted is the use of compaction sand piles. This method consists of driving a hollow casing to the desired depth, then sand is introduced in lifts with each lift compacted concurrently with the withdrawl of the casing. Compaction sand pile methods available nowadays need machinery and are costly. In addition, the difficulties in compaction sand pile installation, which is mainly due to the filling of sand in non-uniform manner. This leads to the density of filled sand is much less than the surrounding soil and also to differential settlement. In order to overcome these defects in the execution of compaction sand pile effectively, a new method is proposed in this paper to densify the loose stratum by inserting pre-cast rubberized concrete poles. Rubber powder is used to reduce the density of plain concrete to obtain rubberized concrete poles so that the latter should have the density value close to that of soils, otherwise the whole applied load would transfer directly to more densified plane concrete. Tyre rubber constitutes a large portion of waste which has turned into a worldwide environmental concern. So this will be cost effective and an environment friendly method to densify the sandy soils.

Verma and Char (1986) says that stress concentration is higher at the end of poles, since it is a structural member having higher value of density. So, for the purpose of reducing the density of concrete poles a certain percentage of fine aggregate is replaced with rubber powder. The addition of rubber powder is suitable for non-structural work as suggested by Eldin and Senouci (1993). Ling (2011) conducted studies on prediction of density and compressive strength for rubberized concrete blocks and he found that there is a systematic reduction in density and compressive strength of concrete blocks if the rubber content increases. Verma and Char (1986) got beneficial effects by using vertical reinforcements in sand sub-grades. Solymar et al (1986) conducted studies on compaction piling in loose silty fine sand and it is found to be a suitable ground improvement method and also it provides resistance to liquefaction. Cao et al., (2004) used Structurally disconnected piles under raft foundation for improving the properties of poorly graded uniform sand. The plate load results by varying raft stiffness, pile length, pile arrangement and pile number indicated that structurally disconnected piles are effective in reducing the settlement and bending moments in the model rafts. Gigi and Johnson (2010) found that circular concrete poles are effective in densifying loose sand deposits. Ergum and Akbult (1986) investigated the effect of expanding the cross section of a model driven pile on the bearing capacity and is found to be increased due to the expansion of driven piles after driving.

2 EXPERIMENTAL PROGRAMME

The bearing capacity improvement of sand achieved by the insertion of concrete poles was studied by conducting plate load test on unreinforced sand and sand reinforced with rubberized concrete poles. The poles were casted by replacing different percentages of fine aggregate of cement concrete with rubber powder.

The sand under study was collected from Veli, a beach near Trivandrum city. Its properties were determined by conducting sieve analysis. The particle size distribution of sand and rubber powder were shown in Fig. 1. The shear parameters of sand is; cohesion (c) of 0.01kPa and angle of internal friction (ϕ) of 38.62°. the properties of sand used for the experimental work is listed in Table 1.

Table 1. Properties of sand used in model tests

Property	Value
Specific gravity (G)	2.602
Angle of shearing resistance (^{0})	38.6
Maximum density (γ_{max}), kN/m^3	17.2
Minimum density (γ_{min}), kN/m^3	14.01
Maximum void ratio (e_{max})	0.86
Minimum void ratio (e_{min})	0.51
Effective particle size (D_{10}), mm	0.3
Uniformity coefficient (C_u)	1.67
Coefficient of curvature (C_c)	1.35
Medium sand %	77
Fine sand %	23

The concrete poles used were cast as M20 mix with 25% of the volume of fine aggregate is replaced with rubber powder. The specific gravity of rubber powder used was 1.34, so, its addition in concrete is meant for the reduction in density of concrete. And the density of concrete thus obtained was 19.39 kN/m^3, which is nearer to the value that of sand, shows agreement to the results obtained by Ling (2011).

For that nine different tapered square sections were made and dimensions of each sections were selected in such a way that the smaller sectional dimension is equal to the dimension of square pole and the higher cross sectional dimension is 20% greater than the smaller cross sectional dimension, the volume is kept as a constant and the corresponding height of the tapered section was computed.

A reinforcing bar of 3mm diameter was provided as a stiffening member, the sections of typical square and tapered concrete poles used for the work is shown in Fig. 2. For the smooth driving of concrete poles into the soil conical shoes were used. The conical shoes were made with cement mortar, i.e., concrete shoes were placed beneath the pole during the process of pole driving, facilitates smooth driving.

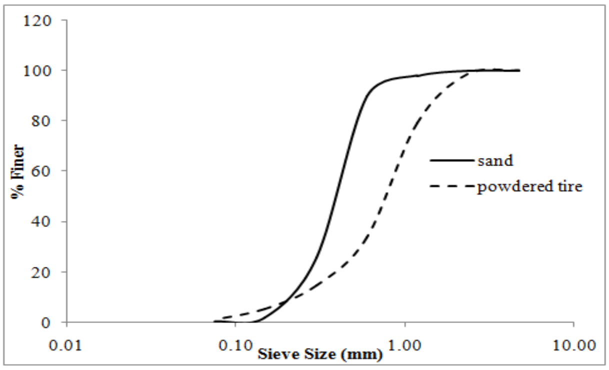

Fig 1Particle size distribution of sand and rubber powder

Table 2. Dimensions of rubberized concrete poles

Square		Tapered		
Width (cm)	Height (cm)	Bottom width(cm)	Topwidth (cm)	Height (cm)
2.50	15.00	2.50	3.00	12.40
2.50	20.00	2.50	3.00	16.50
2.50	25.00	2.50	3.00	20.60
3.50	15.00	3.50	4.20	12.40
3.50	20.00	3.50	4.20	16.50
3.50	25.00	3.50	4.20	20.60
4.50	15.00	4.50	5.40	12.40
4.50	20.00	4.50	5.40	16.50
4.50	25.00	4.50	5.40	20.60

The suitable mix for the casting of concrete poles were found by testing concrete cubes with varying percentage replacement of fine aggregate with rubber powder. For the experimental purpose concrete cubes of M_{15} and M_{20} mixes were casted with 5%, 10%, 15%, 20% and 25% replacement of fine aggregate with rubber powder. For each mix, four different sets of concrete cubes were cast. After 24 hours from casting the cubes were removed from the mould and immersed in water for 28 days. After 28 days curing the rubberized concrete cubes were taken out and weighed and the densities were computed. The optimum percentage replacement was selected corresponds to a rubberized concrete cube with minimum density. Square and tapered concrete poles of the required dimensions were cast using M_{20} concrete mix with 25% addition of rubber powder. The dimensions of square and tapered poles were listed in Table 2.

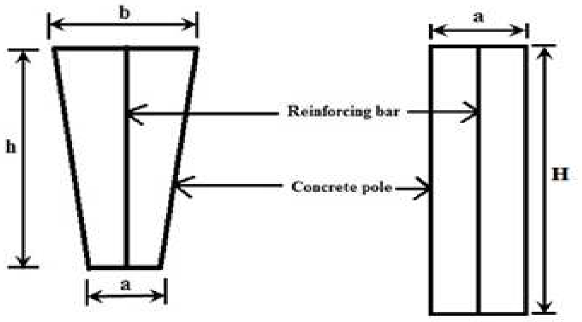

Fig. 2 Reinforcement details of square and tapered RCP

The plate load testing was conducted inside a circular tank, which had a diameter of 40 cm and a height of 40 cm. The relative density of sand inside the tank was kept as 50%, that is, the testing was conducted on sand of medium density. The required density of sand was achieved by filling weighed quantity of sand in four different layers. After the sand is filled the concrete poles were driven into that sand by displacement method. A hydraulic jack of 10 ton capacity was used for loading and a proving ring of 10 kN capacity was used for measuring the load values. The settlement of sand bed due to the applied load was measured with the help of two dial gauges placed on both sides of hydraulic jack and the average of the deflection values of these two dial gauges were reports as net deflection. The photograph as well as schematic diagram of load test setup is shown in Fig. 3. The plate load test was conducted on unreinforced sand as well as on sand reinforced with single concrete poles having different dimensions listed in Table 2, and the improvement in bearing capacity was found from the load test results. The effectiveness of concrete poles over compaction sand pile was analyzed by conducting load test on sand columns having same dimensions as that of concrete poles. For that three different sections of sand columns with 15 cm height and varying cross section were chosen.

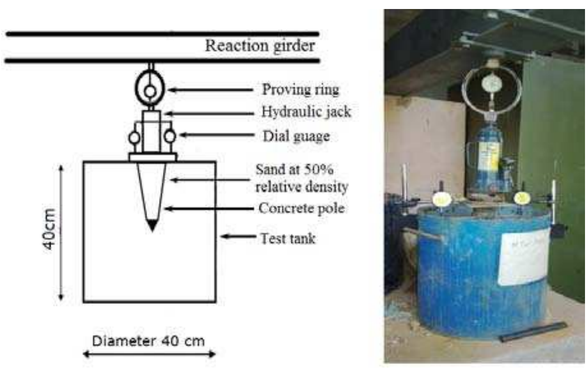

Fig. 3 Mini plate load test setup

3 RESULTS AND DISCUSSIONS

In the present study the mini plate load test was carried out. A rough mild steel square plate of width 8 cm and 1.25 cm thickness was used as footing. The test plate was placed at the centre of the sand bed above the pole. The load-deformation curves of footing on the loose sand with and without rubberized concrete poles were determined. The improvement in bearing capacity of sand (with relative density 50%) was studied by testing sand bed reinforced with uniform and tapered square sections and a comparison was also made on sections with equal volume.

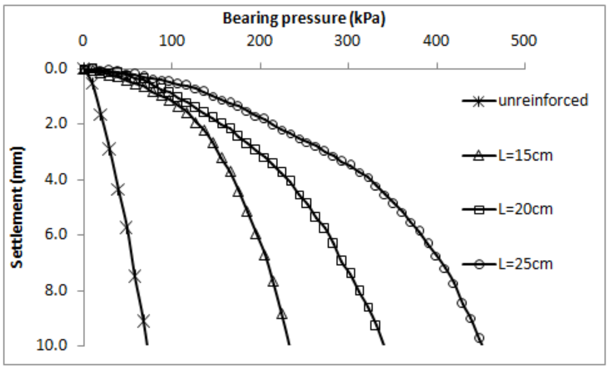

Fig. 4 Bearing pressure settlement plot for concrete poles with uniform section (a = 4.5cm)

Load-settlement plot of sand bed reinforced with RCPs of uniform cross section is shown in Fig. 4. From Fig. 4 it is clear that as length increases the bearing pressure also increases. Fig. 5 presents the comparison of load-settlement behaviour shown by sand bed reinforced with both sections of RCPs. For quantifying the improvement in bearing capacity and reduction in settlement two non-dimensional factors known as bearing capacity ratio (BCR) and settlement reduction factor (SRF) respectively were computed for each case of sand densification.

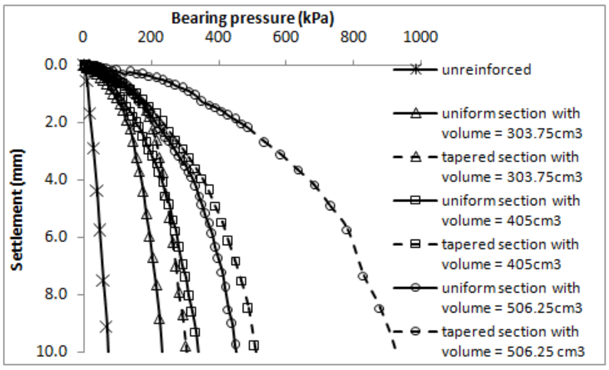

Fig. 5 Bearing pressure settlement plot comparing uniform and tapered sections

Bearing capacity ratio is taken as the ratio of bearing pressures of reinforced and unreinforced soil bed for a particular value of settlement (BCR corresponding to 5mm settlement was considered for the discussion). The variation in bearing capacity ratio with the use of uniform and tapered sections is shown in Fig. 6.

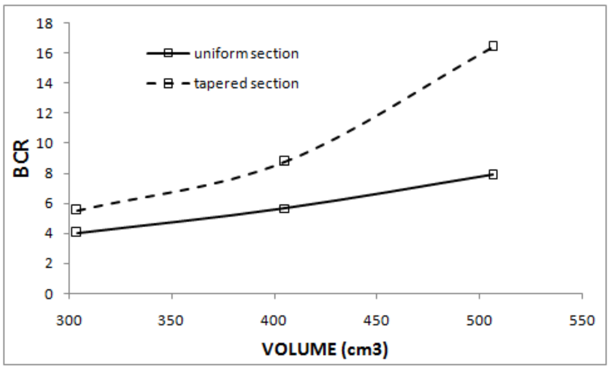

Fig. 6 comparison of the variation in BCR for uniform and tapered section

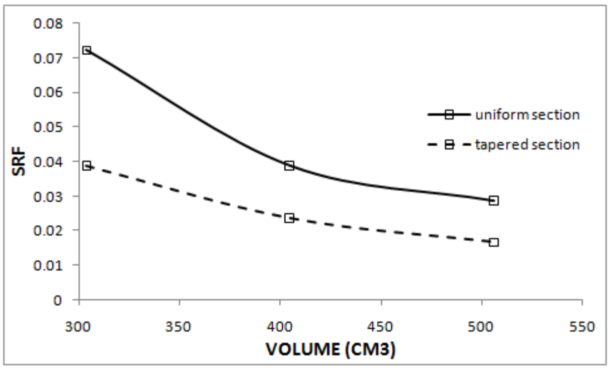

Fig. 7 comparison of the variation in SRF for uniform and tapered sections

Settlement reduction factor (SRF) is the ratio between settlement of reinforced and unreinforced sand at a particular bearing pressure (in the study SRF was computed corresponds to a bearing pressure of 50kPa). The variations in the value of SRF with volume for both uniform and tapered sections are shown in Fig. 7. From Fig. 6 it is clear that the value of BCR for sand reinforced with tapered section is higher compared to that with a uniform RCP section. It shows about 12.5% to 131.25% improvement in bearing capacity with tapering of the section. The plot for the variation of SRF shows that the amount of settlement of the sand bed with loading is less for the one reinforced with tapered sections.

4 CONCLUSIONS

In this study a new cost effective method (inserting rubberized concrete poles in to the loose sand) is introduced to improve the bearing capacity of sandy soil.

- The experimental study proved that the introduction of RCP in the sand improves the bearing capacity and reduces the settlement of the sandy soil.
- Comparison of the experimental results on reinforced sand bed with and without tapering of RCP shows that the bearing capacity value improves with tapering of the side of the concrete pole and the increase in bearing capacity was found to be 12.5% to 131.25%.
- The decrease in settlement due to the tapering of RCP was found to be 23% to 73%.

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