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Laboratory Investigation of CFG pile on sandy soil

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Abstract: *Nowadays, geo technical engineers are facing the problem of soft ground, which results in to low bearing capacity and excessive settlement. On contrary, Cement Fly-ash and Gravel (CFG) pile is one of the emerging ground improvement techniques, which can be applied to enhance the load carrying capacity of the soft ground. It also reduces the possibility of settlement associated due to soft ground. CFG pile composite foundation is applied in subsoil treatment widely and successfully. In order to have a further study of this kind of subsoil treatment technology, the influencing factors and calculation methods of the vertical bearing capacity of single CFG pile and the CFG pile composite foundation were discussed respectively. This paper addresses the practical real time results of laboratory model of single CFG pile. The laboratory model has been carried out considering variation in parameters such as diameter of the CFG pile, length to diameter ratio of CFG pile, cushion effect and gravel particle size. The results obtained from this analysis clearly proves superiority of CFG pile over soft ground in terms of enhancing load carrying capacity.*
Key Word : *– CFG (Cement Fly ash Gravel)Pile, Mix design, Load carrying Capacity.*

I.INTRODUCTION

This article provides a laboratory study of CFG pile on sandy soils. The stabilization of soft soil is one of the popular techniques in soil engineering. Many good techniques have been extensively used in deep ground improvement techniques. The Cement fly ash and Gravel (CFG) pile and Enhanced stone column (ESC) are the deep ground improvement techniques to improve soil'sinherentpropertieslikedeformationnatureandstrength.TheCFGpilesTechnology is widely applied to India's rapid development highway projects and high-speed railway embankment in China. It has a good bonding strength pile formed by cement, fly ash stone chips, gravel, and sand with a moderate amount of water. Moreover, CFG Piles used as a Marine structure are subjected to axial and lateral loads and are generally on plane and embankment supported ground.

CFG Pile is the abbreviation of Cement Fly-ash Gravel pile.CFG pile is consisted with macadam, gravel, sand, fly-ash mixed with cement and water, and the typical characteristic is its variable strength. Problematic soils exist almost everywhere on the globe. CFG (cement-fly ash-gravel) pile composite foundation system has been widely used in buildings, highways, railways and bridge transition sections owing to its proven engineering characteristics in soft ground treatment.

Fig.1SoftFoundationTreatedbyCFGPiles

Consumption of industrial wastes as dust and/or aggregate in geo technical application is developing globally. Cement- fly ash-gravel (CFG) piled composite foundation is a part of it where the by-product fly ash is used as a constituent material to improve poor engineering properties of soft or weak foundation soils using column technology. A CFG pile with higher bond strength is achieved by mixing cement, fly ash, crushed stone, stone chips, and sand with water.

II.MATERIALANDMETHODS

A. **Soil**

Fig.2 River sand

Table1: Basic properties of River sand

Jmnk	
Specific gravity	2.65
Effectivesize,D10(mm)	0.3
D30(mm)	0.6
D60(mm)	1.1
Uniformity coefficient, Cu	3.6
Coefficient of curvature, Cc	1.09
Gradation of sand	SP
Maximum density,(g/cc)	1.71
Minimum density,(g/cc)	1.50

Locally collected clean river sand was used in all the experiments as a soil medium. The basic engineering properties of soil were obtained by conducting various laboratory tests confirming to the corresponding IS codes and the results obtained are provided in table1.

B. Fly Ash

Coal is used as a major source of energy throughout the world. Burning coal produces coal combustion residuals , or byproducts, which include fly ash, bottom ash, boiler slag, flue-gas desulfurization residues and fluidized bed combustion ash. Fly ash is used as a supplementary cementitious material to produce Portland cement concrete.

Table2: Basic properties of Fly Ash

Properties	**Value**
Specific gravity	1.77
Maximum Dry Unit Wt.(kN/m3)	13.21
Optimum Moisture content (%)	21.5
Liquid limit (%)	27
Colour of fly ash	Dark grey

Fig.3 Fly ash

C. Cement and Gravels

In this experimental work, the cement of 53 grade ordinary Portland cement is used.53 Grade OPC provides high strength and durability to structures because of its optimum particle size distribution and superior crystallized structure.

Fig.4 Cement

In CFG pile, gravel plays significant role to transfer the load. Further the gravel enhances the strength of CFG pile. In this present study, two different sizes of particle sizes gravels have been used. These gravels are discussed as below.
(i)G1:ranges from 6.3mm-to-10 mm.(ii)G2:6.3mm-to-4.75mm.

Fig.5 Gravel G 1and G2

D. Test Tank

The square rigid test tank was fabricated using plain galvanized steel sheet of thickness 5mm as shown infig.6. The length and width of the tank was 850 mm.. Stiffeners were provided on the outer sides and bottom of test tank to make it rigid. The inside face of the tank was graduated at every 50mm depth intervals to prepares and bed in layers to achieve correct density of sand in the tank.

Fig.6 Test Tank

E. Model Piles

In this presented work, total 15numbersofexperimental cases have been developed generated by changing the parameters such as different gravel size, L/D ratio of pile, diameter of the pile etc. The piles having diameter 50 mm, 75 mm and 100 mm are provided .In CFG pile, gravel plays significant role to transfer the load. Further the gravel enhances the strength of CFG pile. In this present study, two different sizes of particle sizes gravels have been used. These gravels are discussed as below. (i) G1: ranges from 6.3 mm-to-10 mm. (G1: Cu = 2.19, Cc = 1.40) and (ii) G2: 6.3 mm-to-4.75 mm. (G2: Cu =2.86,Cc =0.38).

Fig.7Model Piles

F. CFG pile concrete mix

The CFG pile Mix designs based on its compressive strength which is laying between C-5 to C-25 design. The Mix design methods have been adopted from "China Academy of Building Research" guide line. The Making of concrete mixed was by the cement, sand, gravel, fly ash, water reducing agent and water. It is required the compressive strength of cubic would beapproximate28MPaaftercasting28-day.DesignofC-20gradeofconcretehavebeenconsidering for mix design proportional as per Shuang you, et al (2016)as the reference benchmark for study.

Table3.CFG Pile Mix Design Proportion

Material	Cement	Sand	Gravel	Fly ash	Water
Unit	kg/m3	kg/m3	kg/m3	kg/m3	kg/m3
Mix design	1	3.2	4.13	0.51	0.59
Unit wt.	265	848	1094	135	160

G. Testing Procedure

The plate loadtestisconductedbaseonIS1888-1982.The load is applied using a hand operated hydraulic jack and the load and deformations were measured with the help of proving ring and dial gauges. The load to the soil was applied in

cumulative increments up to 1kg/cm² or one fifth of the estimated ultimate bearing capacity whichever is less. After the test a graph of load versus settlement were plotted on an arithmetic scale with pressure (kN/m²) in X-axis and corresponding settlement (mm) in Y-axis. The ultimate bearing capacity can be found out from the load settlement curve.

III.RESULTS AND FINDINGS

Experimental test results of plate load tests on CFG pile in sand are discussing in this part.Inplateloadtestthevaryingparameterswereorientationofpilegroup, different diameters, different L/D ratios ,effect of gravel size, cushion effect, effect of reinforcement in 50% relative density of sand bed.

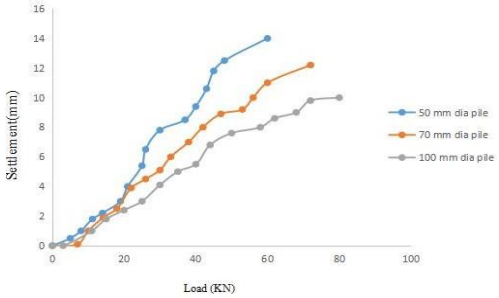

Fig.8 Effect of diameter on CFG pile

Fig.8 shows the experimental performance of 50 mm, 70 mm and 100 mm Diameter of CFG pile having 250 mm length on 50 % relative density sand bed. By analyzing the experimental results, it has been observed that the maximum load for 50 mm, 70 mm and 100 mm diameter CFG pile is 60 KN, 73 KN and 82 KN, respectively, i.e. the load carrying capacity of the 100mm diameter CFG pile is more than that of 50mm and 70 mm diameter pile. On contrary, the stress concentrations have been reduced increasing the diameter of pile.

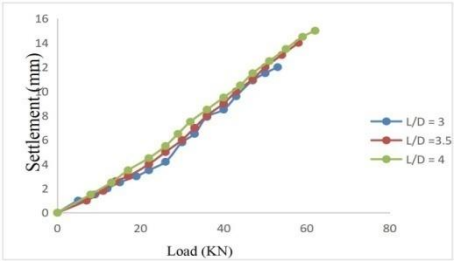

Fig.9 Influence of L/D ration CFG pile

Fig.10 shows the load settlement graph of different numbers of CFG piles at 50 % RD sand bed. It noted the comparison of efficiency of the single CFG pile and the group efficiency of the CFG pile. The load capacity is high in the case of pile groups and the settlement also decreases in the pile groups.

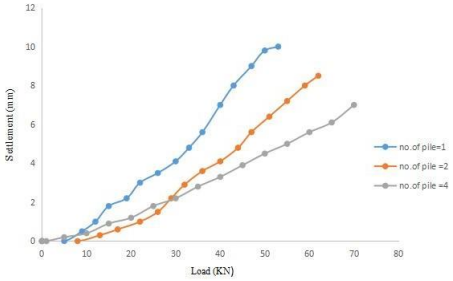

Fig.10 Effect of number of CFG pile

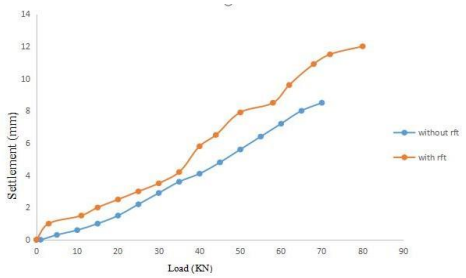

Fig.11 Influence of reinforcement on CFG pile

Fig. 11 shows that the study is carried out the comparison of pile with reinforcement and without reinforcement. . It was observed that settlement of the reinforced pile is greater than the without reinforcement CFG pile. But the load carrying capacity is high in the case of reinforced CFG pile.

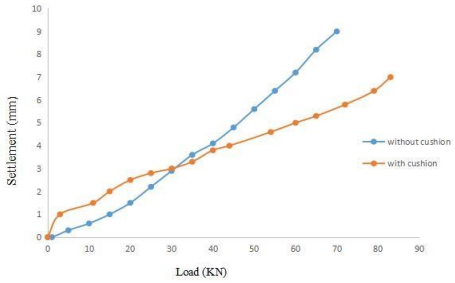

Fig.12 Effect of gravel cushion on CFG pile

Fig.12 shows the cushion effect on CFG pile. By the application of the load, first part the settlement of the cushioned pile increases with increasing load. And after the compression of the sand cushion the settlement become decreases. The load carrying capacity of cushioned pile is greater than without cushion pile.

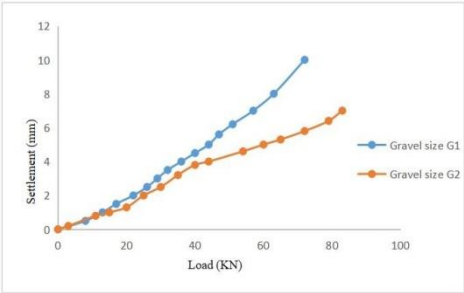

Fig.13 Effect of gravel size on CFG pile

In order to investigate the effects of gravels particle size on the axial load carrying capacity of single CFG floating pile for sandy soil, the laboratory tests have been performed. Here, sandy soil bed and single CFG Piles of 70 mm diameters with 250 mm length with using G1 size grave particle (10 mm < d < 6.3 mm) and G2 size grave particle (6.3mm<d< 4.75) are used.Further,inthiscase,drepresentstheaveragegravelsparticlesize.Fig.4.14illustratesexperimentalresults of load- settlement behaviour of the single CFG pile with G1 and G2 size gravel particle. It can be clearly seen from Fig.4.14 that the load carrying capacity of smaller size grave particles CFG pile is greater than CFG piles having bigger size grave particles (roughly 20%). This is due to the densest packing forms by small size of gravel particle provides more strength than the bigger particles.

IV.CONCLUSIONS

Experimental study has been done on model footing supported on small diameter CFG piles.

[1] It can be concluded that by increase in diameters of CFG pile, the stress concentration in soil settlement decreases. The load carrying capacity of the 100 mm diameter CFG pile is about 1.38 times more than that of 50 mm diameter pile. Stress concentrations have been reduced increasing the diameter of pile.

[2] It has been concluded that as the size of gravel increases the stress concentration of the CFG pile decreases. The load carrying capacity of smaller size grave particles CFG pile is greater than CFG piles having bigger size grave particles(roughly 20%).This is due to the densest packing forms by small size of gravel particle provides more strength than the bigger particles.

[3] By the application of the load, first part the settlement of the cushioned pile increases with increasing load. And after the compression of the sand cushion the settlement become decreases. The load carrying capacity of cushioned pile is greater than without cushion pile.

It is concluded that the CFG pile is considered as more suitable option compare to soft soil for ground improvement technique. In addition, compared with other foundation treatment technology, CFG pile can save cost for 1/2~2/3, and it has considerable economic benefit.

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