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Lateral and pullout behavior of vertical pile embedded in oil contaminated sand

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Abstract:-- **Rapid growth of industrialization results oil contamination. Oil spills and oil leakage from the storage tanks is one of the main problems facing the oil producing countries in the world. The contaminated soils are a challenge not only for the environment but also for the geotechnical engineers. It pollutes subsurface water, changes the behavior of soil and also its engineering properties and loss in strength of soil, which leads to differential settlement and cracks in existing foundation of structures. Thus main aim of the study was to discover the influence of oil contaminated soil on the lateral and uplift behavior of pile. Comparative model tests were performed on pile in clear sand. The investigations were done by changing the percentage of oil content, thickness of contaminated layer and relative density. For matching field conditions contaminated soil layer was prepared by mixing the sand with oil content of 0-3% with regard to dry soil. The results indicated that the uplift and lateral resistance was drastically reduced by oil contamination. The results from the study can be used for the geotechnical purpose and can benefit engineers for the safe and economic construction of a structure on the oil contaminated soil.**

Index Terms:- Oil contamination, uplift capacity, lateral capacity.

I. INTRODUCTION

Soil contamination or soil pollution as part of land degradation is caused by the presence of human- made chemicals or other alteration in the natural soil environment. It is typically caused by industrial activity, agricultural chemicals, or improper disposal of waste. The most common chemicals involved are petroleum hydrocarbons, polynuclear aromatic hydrocarbons, solvents, pesticides, lead and other heavy metals. Contamination is correlated with degree of industrialization and intensity of chemical usage.

Oil spills during transportation on the land or during oil drilling processes happen by accidents in most cases. When oil spills, soils might be contaminated by the leakage. Land contamination is not only harmful for the subsurface water aquifers but is also a detriment to the buildings and structures on it. Any change in the engineering properties and behavior of the soil strata may lead to a loss in the bearing capacity and an increase in the total or differential settlements of the foundation systems of structures. Oil contaminated soil cannot be used without conducting stabilization or remediation techniques.

A foundation is an important element of a structure which connects it to the ground, and transfer loads from the structure to the ground. Foundations are generally considered either shallow or deep. A shallow foundation is a type of foundation that transfer load to the very near the surface. If the soil and superficial ground content is not stable or thick enough to support heavy loads, deep foundations are provided. Deep foundations are achieved by forcing vertical structure components several feet below the ground's surface. Pile foundations are common type of deep foundation. These are relatively long, slender members that are commonly provided

under structures to transmit structural loads through zone of weak soil to greater depth so as to transmit the loads safely. If structural loads are heavy, pile groups are provided. Pile foundations under certain structures like offshore platforms, tall buildings, transmission towers, bridge piers etc. can be subjected to lateral forces in addition to vertical structural loads, due to wind force, wave force, ship impacts and other sources of loading.

The structures like offshore and onshore wind turbine foundations, offshore platforms (floating or submerged), wave barriers, retaining wall tie backs and elevated solar panels are exposed to various environmental loads such as high overburden pressure, wind, waves, earthquake, sea ice and icebergs (in cold oceans) and also loads act due to ship impacts. It leads to high amount of uplift loads, lateral loads and overturning moments.

II. EXPERIMENTAL SET-UP AND TESTING PROGRAMME

2.1 TEST TANK

The test tank used for model tests was a rectangular tank, made-up of galvanized iron sheet having 1 mm thickness. The dimensions of the test tank were fixed based on the criteria by K.Madhusothanan Reddy et.al, (2015). As per the criteria, for laterally loaded single pile, the boundary effect is more predominant within 10 times of the pile diameter from

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the pile periphery and for piles subjected to uplift load, the zone of influence is 3 to 8 times from the edge of the pile. So the sand bed was prepared in a tank of inside dimensions 600 mm length, 600 mm width and 800 mm height. It consists of a pulley system, fastened to the tank. Horizontal and vertical steel plate stiffeners were welded at the side of the tank to prevent any lateral deformation.

2.2 OIL PROPERTIES

Oil used in this study is diesel purchased from Bharath petroleum dealer. Diesel oil used has light yellow colour specific gravity at 40 degree centigrade is <.835 and kinematic viscosity at 50 degree centigrade is 73.5.

2.3 MODEL PILES AND PILE CAP

The model pile was casted in mechanical laboratory of IES College of Engineering. Model piles made up of smooth surface steel circular shaft of length 600 mm and outer diameter 20 mm. To facilitate loading, each pile had a small steel hook, which was welded on the square pile cap of dimension 50 mm x 50 mm and 3 mm thick, to attach the tension load via a steel wire. The tip of the pile had a conical driving shoe of apex angle 30 degree.

2.4 DIAL GAUGES

Deflections were measured by dial gauges having least count of 0.01mm

2.5 PROPERTIES OF CLEAN SAND

The soil used was beach sand and it was collected from Chavakkad beach, Thrissur. Air dried soil samples were used for laboratory model study.

Table 1 : Properties of the uncontaminated sand

Properties	Value
IS Soil classification	SP
Effective size in mm	0.22
Uniformity coefficient(Cu)	1.71
Coefficient of curvature(Cc)	1
Specific gravity(G)	2.66
Minimum dry density(g/cc)	1.41
Maximum dry density(g/cc)	1.71
Coefficient of permeability (k)	7.76 x 10-4 cm/s
Friction angle	36

2.6 PREPERATION OF OIL CONTAMINATED SAND

The amount of oil was calculated as a percent by weight of the dry sand. Contaminated-sand layers were prepared by mixing the sand with an oil content(O.C.) of 0, 1, 2, and 3% to match the field conditions. The mixed sand layers were put into closed containers for 1 days for aging and equilibrium, allowing possible reactions between soil and oil.

2.7 EXPERIMENTAL PROCEDURE AND TEST PROGRAMME

The experimental test procedure consisted of the placement of a pile, the placement of clean and contaminated sand, loading on a pile, and recording of load and displacement. The pile with a pile cap was vertically suspended and lowered into the empty tank to the desired elevation with the help of the pulling device. The weight of the soil required was divided into four equal parts, each part having a volume to be filled in the predetermined height, ensuring that the desired unit weight was attained. The compaction was done in layers of 200 mm height. The effect of the thickness of the contaminated-sand surface layer (LC/LP) was conducted by using 0- 3% O.C.

(i)Test Procedure for Uplift Load Test

The load was applied vertically through pulley fixed above the centre of the pile via a steel wire attached on the pile head, avoiding any eccentric load. The load was applied incrementally. To measure the uplift movement, a dial gauge of 25 mm capacity was used. Each load was kept constant until the difference between two successive displacement readings was less than 0.01 mm per minute.

As per Indian standard procedures, the safe uplift load shall be taken as the least of the following: (a) Two – thirds of the load at which the total displacement is 12 mm or the load corresponding to a specified permissible uplift (b) Half of the load at which the load displacement curve shows a clear break (downward trend) . Here the obtained load deflection curves show nonlinear nature. So the loading was continued until the complete length of the pile is pulled out from the sand bed.

(ii)Test Procedure for Lateral Load Test

The preparation of the sand bed and installation of model pile for lateral load test is same as for uplift load test. The load was applied laterally through pulley fixed on right side of the tank via a steel wire attached to the center of the pile head, avoiding any eccentric load. The load was applied incrementally. Each load was kept constant until the difference between two successive displacement readings was less than 0.01 mm per minute. A dial gauge, accurate to 0.01 mm was used to measure pile head lateral movement.The loading was continued until the total

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deflection of pile head reached 12 mm. The safe lateral load is taken as least of the following (IS 2911 Part IV-2010) : (a) Load corresponding to a total pile head deflection of 5 mm (b) Half of the load corresponding to a total pile head deflection of 12 mm. (c) Load corresponding to any other specified displacement as per performance requirements.

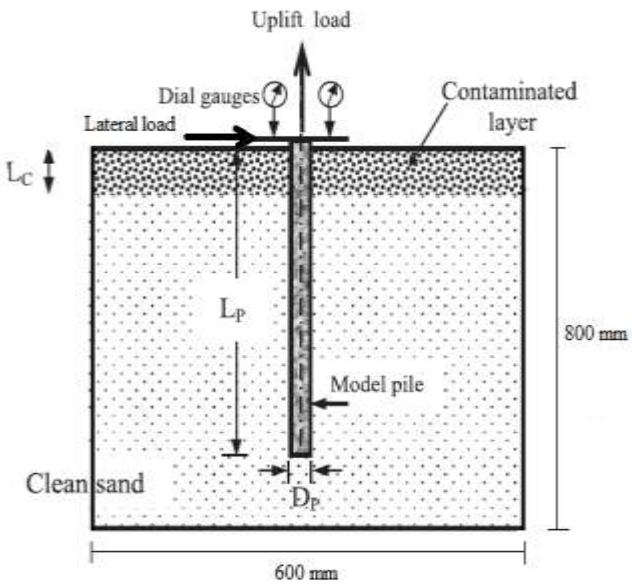

Fig. 1. Schematic view of test configuration

III. RESULTS AND DISCUSSION

Table 2. Angle of shear resistance of sand at different percentage of oil content

Percentage of oil	Friction angles	Reduction percentage(%)
0	35	-
1	33.7	3.68
2	32.4	7.36
3	31.6	9.47

Uplift behavior of vertical pile

Ultimate uplift load decrease with increase in oil content. The diesel oil content leads to decrease in the soil density and looses the soil particles, so it leads to the weakness of soil and decreases the strength.

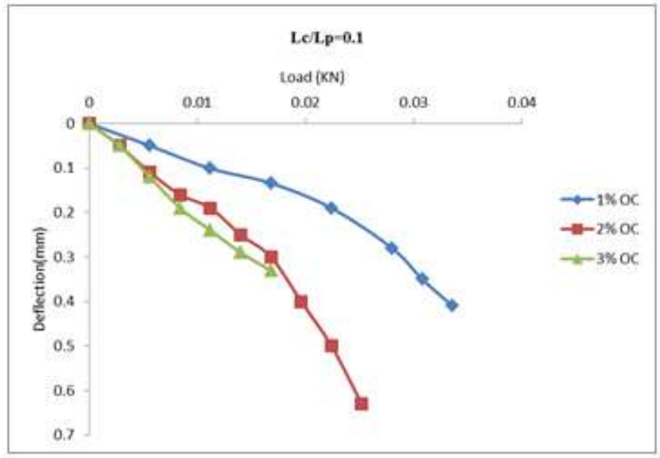

Fig. 2. Uplift load versus axial displacement for piles at different O.C.

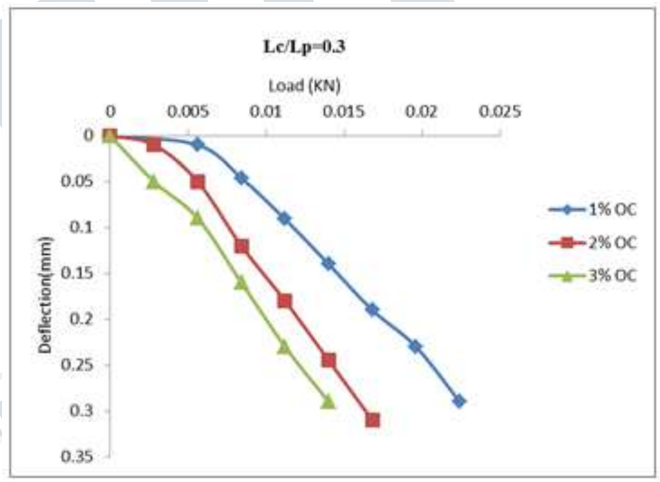

Fig. 3. Uplift load versus axial displacement for piles at different O.C.

From the comparing test data, the term uplift capacity ratio (PCR) is used and is described as

PCR =PU,oil,exp/PU,clean,exp

where PU,oil,exp= ultimate uplift load of the pile embedded in oil-contaminated sand from experimental tests; and PU,clean,exp = ultimate uplift load of the pile embedded in clean sand from experimental tests.

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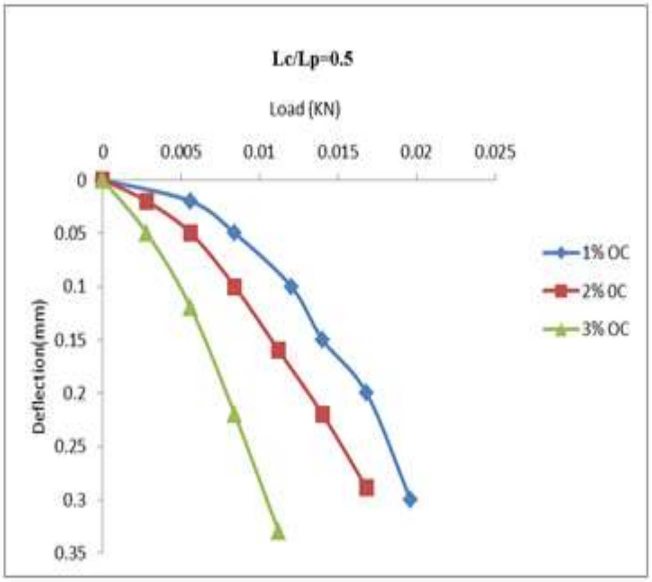

Fig. 4. Uplift load versus axial displacement for piles at different O.C.

Table 3 : Variation of PCR with LC/LP at different O.C.

Lc/Lp	Uplift capacity ratio(PCR)		
	1% o.c.	2% o.c.	3% o.c.
0	1	1	1
0.1	0.988	0.741	0.494
0.3	0.658	0.494	0.411
0.5	0.576	0.49	0.329

Figure 2, 3 and 4 shows the uplift load versus axial displacement of piles at different oil content at different thickness of contaminated layer. The rate of decrease of PCR increased when the LC/LP ratio increased from 0.1 to 0.3; thereafter, the rate of decrease in PCR reduces significantly.

Lateral behavior of vertical pile

Figures 5, 6 and 7 shows the variation of lateral load with lateral deflection for single pile on different layer of contamination. And it was observed that as we increases the percentage of diesel oil content in soil lateral load carrying capacity decreases.

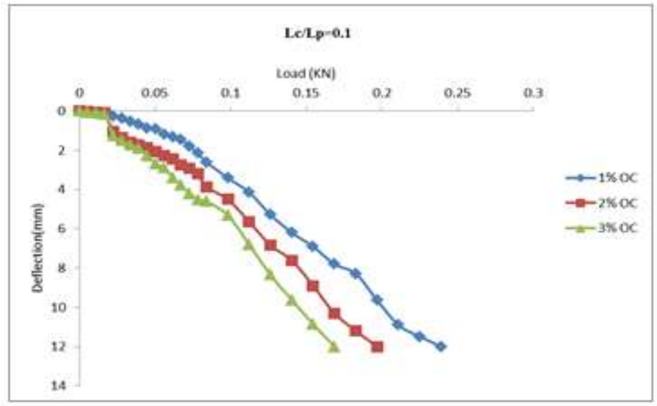

Fig. 5. Lateral load versus axial displacement for piles at different O.C.

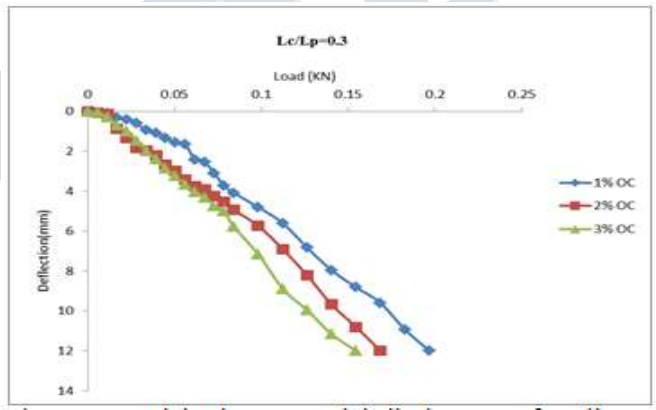

Fig. 6. Lateral load versus axial displacement for piles at different O.C.

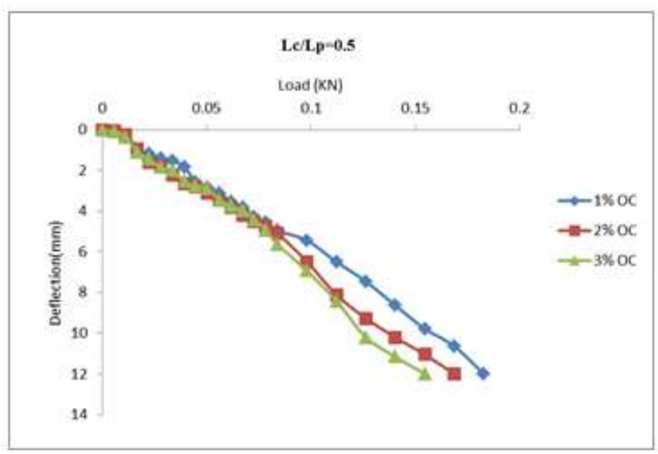

Fig. 7. Lateral load versus axial displacement for piles at different O.C.

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Table 4 : Variation of safe lateral load with LC/LP at different O.C.

Lc/Lp	safe lateral load (kN)		
	1% o.c.	2% o.c.	3% o.c.
0	0.128	0.128	0.128
0.1	0.119	0.098	0.084
0.3	0.098	0.084	0.078
0.5	0.085	0.082	0.077

CONCLUSIONS

Available information regarding behavior of oil contaminated sand is very limited. That's why, the pullout and lateral load tests for pile embedded in oil contaminated sand were performed by varying the thickness of oil contaminated layer, by varying the percentage of oil contents and following conclusion can be drawn.

Uplift capacity ratio PCR for piles is affected markedly by the thickness of the contaminated-sand layer. The rate of decrease of PCR increased when the LC/LP ratio increased from 0.1 to 0.3; thereafter, the rate of decrease in PCR reduces significantly.

As we increases the diesel oil concentration and thickness of contaminated layer lateral load carrying capacity decreases.

The percentage of O.C. has a significant effect on both the uplift capacity ratio and safe lateral load.

The observations and conclusions drawn in this study are valid only for the types of contamination used by the author. Moreover, the behavior of piles embedded in oil-contaminated sand involves a complex interaction between the pile and the surrounding contaminated soil. Nevertheless, the investigation is considered to have provided a useful basis for further research leading to an increased understanding of the behavior of piles embedded in oil contaminated sand under lateral and pullout loads.

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