RESEARCHERID
THOMSON REUTERS

[Sabale* *et al.*, 6(6): June, 2017] ISSN: 2277-9655
IC™ Value: 3.00 Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

PERFORMANCE OF SINGLE PILE IN OIL CONTAMINATED SAND UNDER AXIAL LOADING

Anant I. Dhatrak[1], Sanket Vasant Sabale[*2], Sanjay W. Thakare[3]

[1]Dean Academics, Govt. College of Engineering, Amravati, Maharashtra, India
[*2]P.G. Scholar, Department of Civil Engineering, Govt. College of Engineering, Amravati, Maharashtra, India
[3]Associate Professor, Department of Civil Engineering, Govt. College of Engineering, Amravati, Maharashtra, India

DOI: 10.5281/zenodo.817966

ABSTRACT

Every day, petrochemical activities, oil spills, and pipeline or reservoir leakage contaminate the ground. In addition to environmental concerns, such as groundwater pollution, the alteration of geotechnical properties of the contaminated soil is also cause for worry. Contamination has been proven to alter the geotechnical properties of soil, and researchers have extensively studied the properties of contaminated granular soils. However, the effect of oil contamination on the geotechnical properties of fine-grained soils has not yet been well evaluated. Therefore, a comprehensive set of laboratory pile load tests has been conducted in contaminated sand. The model parameter are varied, namely thickness of contaminated layer and percentage of oil contamination. The tests were performed with an oil content of 2.0, 2.5, and 3.0 % with respect to dry soil to match the field condition. This is an extensive program of work, done on single pile in oil content of 0, 0.5, 1.0, and 1.5 which were published earlier. From the results, it is observed that the maximum pile capacity in all percentages of oil contamination was found in the range of L_c/L_p = 0.50 to 1.0.

KEYWORDS: Soil pollution; Kanhan Sand; Pile capacity; oil contaminated sand; Length of pile to length of contamination ratio (L_c/L_p).

I. INTRODUCTION

Air, water, and land are being contaminated for short-term benefits by industrial, petrochemical, construction, and sanitary activities. Considering land contaminations, environmentalists are concerned about subsurface water aquifer contaminations, plant growth in contaminated soil, and environmental and health hazards. On the other hand, geotechnical experts should consider the effects of soil contamination on the geotechnical properties of the soil. The soil-bearing capacity, foundation settlement, shear resistance, compressibility, and plasticity are the factors that must be taken into consideration. Crude oil is one of the most common soil contaminants. Over two million tons of oil are produced all over the world every day, and about 10 percent is entering the environment due to pipeline breaks, leakage from reservoir tanks, tanker accidents, discharge from coastal facilities, and offshore petroleum productions [3].

Although scientists have evaluated the geotechnical properties of contaminated granular soils through comprehensive studies, few researchers have studied the effects of oil contamination on the geotechnical properties of fine-grained soils. Meegoda and Ratnaweera in 1994 examined the compressibility of contaminated fine-grained soils by performing consolidation tests. Their finite-element analysis showed that the settlement of the foundation increases due to oil contamination. Al-Sanad et al. in 1995 and Al-Sanad and Ismael in 1997 found that oil contamination leads to decreased permeability and strength. Vesic in 1973 found that the the angle of friction and bearing capacity factor N_Υ got reduced due to oil contamination. Ghaly (2001) performed direct shear tests on oil-contaminated sands which showed a reduction in angle of friction with an increase in the oil percentage. Shin et al. (2002) reported a significant reduction in angle of friction with oil contamination. According to Ratnaweera and Meegoda (2006), the shear strength of granular soil decreases with

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

an increase in pore fluid viscosity. Mashalah et al. (2007) carried an extensive laboratory testing program which shows that oil contamination induces a reduction in the permeability and strength of all soil samples.

The knowledge about the behaviour of axially loaded pile foundation embedded in oil-contaminated sand is very limited. However, the objective of the current study is investigating performance of single pile embedded in oil-contaminated by performing laboratory model pile load test. Based on the results, the effect of various parameters influencing the performance of pile group such as the percentage of oil content, thickness of contaminated sand layer and pile group configurations were investigated. In addition, the comparison between uncontaminated and oil-contaminated sandy soil are studied. Any change in the engineering properties and behaviour 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 [2].

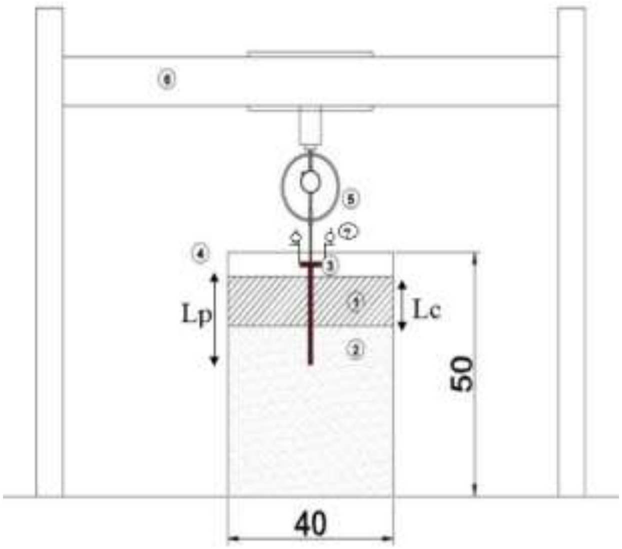
II. MATERIALS AND METHODS

Test Tank and Loading Frame

The experimental setup consist of the loading frame used as a reaction frame, hydraulic jack, load measuring unit, vertical displacement measuring unit and a test tank. A schematic diagram of the testing arrangement is shown in Figure 1.

The axial load was applied with the help of the hydraulic jack consisting of loading unit and pumping unit. Loading was recorded by using a proving ring (2.5 kN capacity) connected to a long screw from the upper direction and to the pile cap from the lower direction by using an eye bolt. The vertical displacements were measured using two dial gauges accurate to 0.01 mm.

Figure 1:



1- Contaminated sand layer; 2-clean sand; 3-pile attached with pile cap; 4-model tank; 5-proving ring; 6-reaction frame; 7-Dial Gauge

Schematic view of test configuration

Tests were conducted in a square steel tank with inner dimensions 400 mm long X 400 mm wide X 500 mm high. The tank was made of 3-mm-thick steel plate. The bottom and vertical edges of the tank were stiffened using steel angle sections. The inside walls of the tank are smoothly polished to reduce the friction with the sand as much as possible. The tank was designed to be large enough so that there will be no interference between the walls of the tank and the failure zone around the piles.

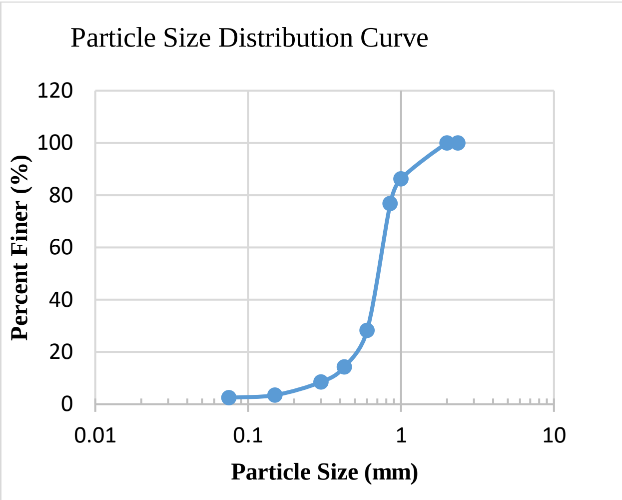
ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Sand Properties

For the model tests, cohesionless, dry and clean Kanhan sand was used as the foundation soil. This sand is available in Nagpur region of Vidharabha, Maharashtra. The test sand has angular shape, uniform yellow colour with small proportion of flint stone of black colour. The particle size of sand decided for the test was passing through 2 mm IS sieve. The various laboratory tests were performed to determine the different engineering properties of sand in accordance with the relevant IS codes. 40 % relative density was maintained in all the tests. The grain size distribution of the sand is shown in Figure 2.

The sand is poorly graded sand (SP) according to the IS Soil Classification System. The properties of clean and oil contaminated sand used are as shown in Table1.

Figure 2:



Grain size distribution curve for sand

Table 1: Properties of Sand Used

Properties	% of oil contamination			
	0(Uncontaminated)	**2.0**	**2.5**	**3.0**
Specific gravity (*G*)	2.71	2.55	2.50	2.44
γ_{max}(kN/m^3)	17.16	-	-	-
γ_{min}(kN/m^3)	15.86	-	-	-
Angle of internal friction, *Ø* (°)	45	24	22	18
Cohesion (kN/m^2)	0.0	30	33	36
Average grain size (D_{60}) (mm)	0.82	-	-	-
Effective grain size (D_{10}) (mm)	0.35	-	-	-
Coefficient of uniformity (C_u)	2.343	-	-	-
Coefficient of curvature (C_c)	1.472	-	-	-
I. S. Classification	SP	-	-	-
Relative Density (%)	40	40	40	40

Model pile foundation

The model piles for experimental investigation were made from M.S. rods. Clean sand was applied to the model pile with the help of epoxy glue to make it friction pile. The piles were provided with threads at one end for attachment of pile cap for ease of applying vertical load. The loads were applied with the help of hydraulic jack and were measured with the help of proving ring. The groove at centre of the pile cap was provided for applying the loads. Pile cap made up of 3 mm thick steel plate is used for model piles to be able to fix it to the proving

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

ring, which is attached to the long screw. L- Shaped angles were welded to the pile cap to place the dial gauge. Table 2 shows the details of model pile.

Table 2: Model pile foundation used in testing

Pile number	Shaft diameter	Pile length	Self weight
1	10 m	100	0.25 kN

Mazurkiewicz (1968) reported that the pile length/pile diameter ratio (L/D) of 10:1 is a good ratio for model pile tests. Consequently, the length of the model pile was set to be 100 mm and the diameter to 10 mm. The model pile used in an experimental investigation is as shown in Fig. 3.[1]

Figure 3:

Model Pile used in an investigation

Oil properties and preparation of contaminated sand

In experimental work, waste engine oil from garage was used to contaminate the sand bed in the model tests. Oil added for contamination of sand worked as a softener which caused decrease in the friction between sand particles and piles. The properties of oil use in the experiments are shown in the table 3.

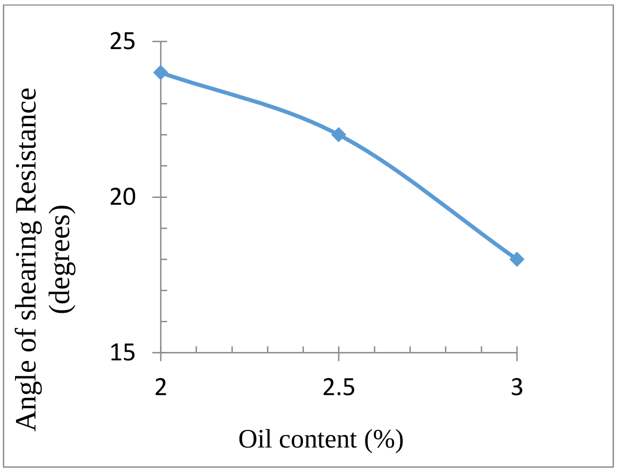
Table 3: Oil Properties

Type of oil	Kinematics Viscosity (m^2/s)	Density (kN/m^3)	Specific gravity
Waste Engine Oil	45×10^{-6}	8.3	0.83

For 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 2.0, 2.5, and 3.0 %. The mixed sand layers were put into closed bags for 2 days for aging and equilibrium, allowing possible reactions between sand and oil [1].

As pile shaft resistance is highly dependent on the friction angle of granular soil, direct shear tests were performed on clean as well as contaminated sands to examine the effect percentage of O.C. on the angle of shearing resistance values of sand. Variation of peak friction angle with oil content is shown in Figure 4.

Figure 4:



Variation of friction angle with O.C.

Installation of model pile in sand

The method for pile installation used in this investigation was the jacking method. Jacked piles are basically displacement piles pushed into the ground by static load. According to Li et al. (2003), in Hong Kong, the jacking process is often taken as an installation method. Jacked piles have the advantage that they cause little pollution to the environment in the form of noise, air, and vibration. In the model tests, the pile was pushed into the sand manually. After the pile has reached the final penetration depth, the proving ring was attached [1].

Experimental procedure

The procedure for these experimental tests consisted of the placement of clean and contaminated sand, placement of a pile, applying the axial load and recording of load and displacement.

The empty tank first of all was filled up with required level of clean sand. Sand rainfall technique was used for placement of clean sand. . The sand was poured in the tank by sand rainfall technique keeping the height of fall as 50 cm to maintain the constant relative density 40% corresponding bulk density 16.31 kN/m^3 throughout the test.

In case of contaminated sand a raining technique (pluviation) for soil placement in the test tank was not suitable and did not provide uniform compaction. Therefore, the sand unit weight was controlled by pouring the precalculated weight of contaminated sand into the box for each layer separately, then the sand was placed and surface was leveled [1]. Centering of the tank was done to locate the centre of the tank and pile was embedded at that centre into the sand bed upto a pile length with the help of hydraulic jack.

Finally, the dial gauges were placed on welded portion opposite sides across the center of the pile cap, and load was applied incrementally. The pile loading was carried out with approximately (0.003 kN) incremental steps, and the pile was permitted to stabilize. Each load increment was maintained constant until the pile vertical displacement was stabilized. The axial load was recorded with the help of the proving ring, whereas the vertical displacements of the pile were recorded by the dial gauges. After completing the test, the whole tank had to be emptied, and then, the preparation for the next set had to be made. Experimental setup used in investigation is shown in Fig. 5.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Figure 5:

Experimental Setup used for experimental investigation

Test Program

The model testing program included a parametric study that investigated different variables. Table 4 shows a summary of model test parameters and their values. To study the effect of contaminated sand, the test on pile embedded in clean sand was also carried out as a reference. A total of 18 tests were conducted to study the effect of oil contamination on performance of pile under axial load in oil contaminated sand.

Table 4. Model Test Program

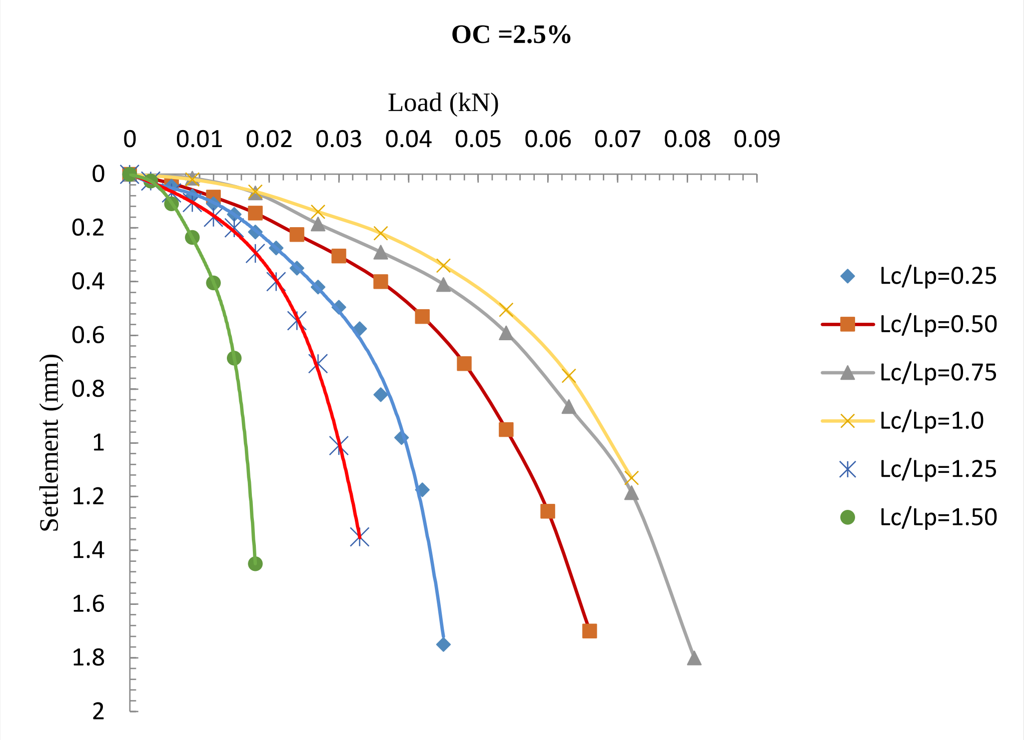
Series	Constant parameter	Varying Parameter
I	OC = 0 %	-
II	OC = 2.0 %	L_c/L_p=0.25,0.50,0.75,1.0,1.25,1.50
III	OC = 2.5 %	L_c/L_p=0.25,0.50,0.75,1.0,1.25,1.50
IV	OC = 3.0 %	L_c/L_p=0.25,0.50,0.75,1.0,1.25,1.50

III. RESULTS AND DISCUSSION

The results of each test were plotted in terms of load versus settlement. Figure 6 shows load settlement curves for pile in 2.5 % of oil contamination for all L_c/L_p ratios. The laboratory study would give an idea about the behaviour of pile group on oil contaminated sand bed with various oil content and depths of contamination. During the experimental investigations, depth of contamination, and augmented whereas the other parameters viz., diameter of pile, length of pile, type of soil, type of oil and density of sand were kept constant.

Figure 6:

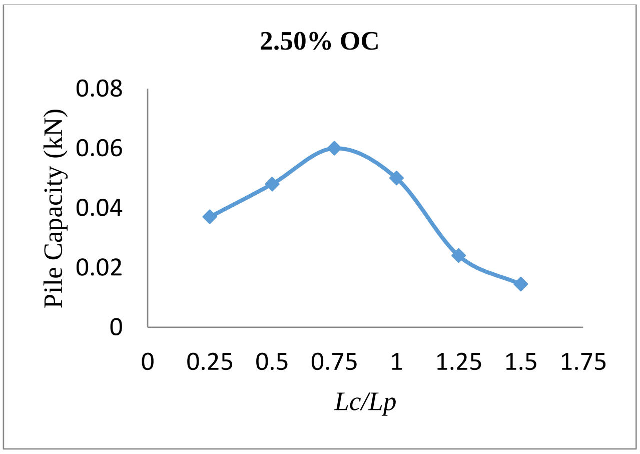
ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7



Load settlement curve for 2.5 % OC Sand

The variation of Pile Capacity with L_C/L_P for single pile in 2.5 % oil contamination is shown in Figure 7. Table 5 shows tests results for pile foundation embedded in clean and oil contaminated sand for L_c/L_p= 0.25 to 1.50.

Figure 7:



Variation of Pile Capacity with L_C/L_P for single pile in 2.5 % O. C.

Table 5: Pile capacities values of pile embedded in clean and oil contaminated sand bed

% OC	**Pile capacities for various L_c/L_p (kN)**					
	0.25	**0.50**	**0.75**	**1.0**	**1.25**	**1.50**
0	0.047					
2	0.04	0.053	0.052	0.044	0.0285	0.0225
2.5	0.037	0.048	0.06	0.05	0.024	0.0144
3	0.028	0.048	0.06	0.043	0.02	0.016

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Influence of Depth of Oil Contamination

One of the most important objectives of the present experimental study was to investigate the influence of the depth of oil contamination on the behavior of pile under axial loading. Therefore, a series of tests were conducted with various percentages of oil content (O.C.) viz., 0, 2.0, 2.5, and 3 % and for various L_C/L_P ratios viz., 0.25, 0.50, 0.75, 1.0, 1.25, and 1.50. For comparing the test data, the term Pile Capacity Ratio (PCR) is used and is defined as

$$PCR = \frac{P_{U,oil}}{P_{U,uncontaminated}}$$

where,

$P_{U,oil}$ = Pile Capacity of the pile/pile group embedded in oil-contaminated sand from experimental tests; and

$P_{U,uncontaminated}$ = Pile Capacity of the pile/pile group embedded in uncontaminated sand from experimental tests.

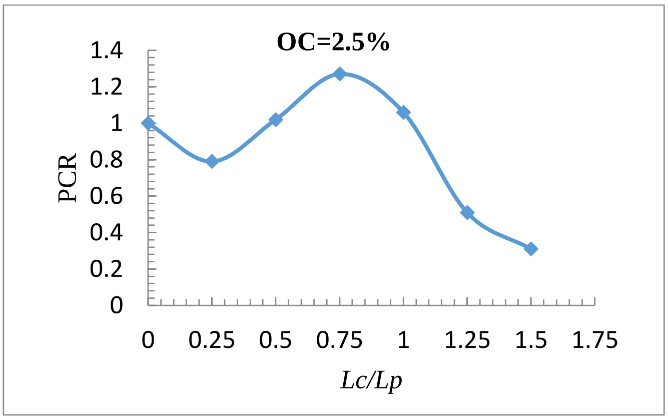
Summary of PCR values for single pile in oil contaminated sand for different percentages of oil and depths of contamination is given in Table 6.

Table 6: PCR values for different depths of contamination and percentage of oil contamination

% Oil Contamination	**PCR for various L_C/L_P ratios**					
	0.25	0.5	0.75	1	1.25	1.5
0	1	1	1	1	1	1
2	0.85	1.13	1.11	0.94	0.61	0.48
2.5	0.79	1.02	1.27	1.06	0.51	0.31
3	0.59	1.02	1.27	0.91	0.42	0.34

The variation of PCR with L_C/L_P for single pile in 2.5 % of oil contaminated sand is shown in Figure 8.

Figure 8



Variation of PCR with L_C/L_P for single pile in 2.5 % O. C.

From figure 8, it is observed that the PCR is affected remarkably by the thickness of the contaminated-sand layer with respect to the length of pile. However, this variation is neither of increasing or decreasing trends, and is non uniform in nature. It decreases initially and then increases upto a certain value of L_C/L_P depending upon percentage of oil contamination. With further increase in L_C/L_P, PCR decreases.

IV. CONCLUSION

The main purpose of the current study was to perform laboratory testing programs to determine the effects of oil contamination of sandy soil on the pile capacity and settlement of a model pile foundation. In addition, the comparison between uncontaminated and oil contaminated sandy soil are studied.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

The following main conclusions emerged from this study:

1. Friction angle was decreased as percentage of oil increased.
2. The range of L_C/L_P for which the pile capacity is maximum is 0.5 to 1.0
3. PCR is affected remarkably by the thickness of the contaminated-sand layer with respect to the length of pile. However, this variation is neither of increasing or decreasing trends, and is non uniform in nature. It decreases initially and then increases upto a certain value of L_C/L_P, depending upon percentage of oil contamination. With further increase in percentage of oil contamination, PCR decreases.

V. ACKNOWLEDGEMENTS

The author appreciates the valuable comments and continuous encouragement of Prof. Dr. A. I. Dhatrak. The author thanks Prof. S. W. Thakare for his valuable suggestions and assistance.

VI. REFERENCES

1. Nasr A. (2013). "Uplift Behavior of Vertical Piles Embedded in Oil-Contaminated Sand", *J. Geotech. And Geoenviron. Eng.*, ASCE, 139(1), 162-174.
2. Nasr A. (2009). "Experimental and Theoretical Studies for the Behavior of Strip Footing on Oil-Contaminated Sand", *J. Geotech. and Geoenviron. Eng*., ASCE, 135(12), 1814-1822.
3. Kermani M., and Ebadi T. (2012). "The Effect of Oil Contamination on the Geotechnical Properties of Fine-Grained Soils", *Int. J. Soil and Sediment Contamination*, 21(5), 655-671.
4. Khamehchiyan M., Charkhabi A. H., and Tajik M. (2006). "The effects of crude oil contamination on geotechnical properties of Bushehr coastal soils in Iran", *The Geological Society of London*, IAEG Paper No. 214, 1-6.
5. Nasr A. and Rao S. V. (2015). "Behaviour of laterally loaded pile groups embedded in oil-contaminated sand", *ICE Publishing, Geotechnique*, 66(1), 58-70.
6. Indian Standards Institution, *Design and Construction of Pile Foundation, Load Test on Piles,* CED 43: Soil and Foundation Engineering, IS: 2911 (Part-4):1985.

CITE AN ARTICLE

Dhatrak, A. I., Sabale, S. V., & Thakare, S. W. (2017). PERFORMANCE OF SINGLE PILE IN OIL CONTAMINATED SAND UNDER AXIAL LOADING. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 6*(6), 574-582. doi:10.5281/zenodo.817966