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Effect of Crude Oil on Some Consolidation Properties of Clayey Soil

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Abstract-- **The study has been carried out with two broad objectives – to observe the effect of crude oil contamination on consolidation properties of soil and to predict the change in the properties in the form of mathematical correlation. The properties studied here are co efficient of compression (C_v) and compression index (C_c). Four types of naturally available soil (CH, CL, CI and SC) collected from different parts of Assam, India were used for this study. Laboratory tests were conducted on uncontaminated soil samples and soil samples contaminated at different level of contamination. Change in the properties of crude oil contaminated soil was observed. Variance analysis was performed and insignificant relationship between soil properties and level of crude oil contamination was discarded. Significant relationship between C_v and level of contamination was observed only in case of CL type of soil. Mathematical correlation between the soil property and the level of contamination was also determined. Coefficient of compression was observed to decreases linearly with the increase in the percentage of crude oil contamination. Change in compression index was not statistically significant.**

Keywords-- **Coefficient of compression, compression index, variance, correlation, significant.**

I. Introduction

Exploration, production, storage, refining and transportation etc. are some of the major activities related to crude oil. These are potential sources for spills or releases of crude oil and its products to the soil. Oil spills also occur at the oil collection centers, where oil is separated from water. These spills or releases may be either accidental or natural. The total number of damaged oil well in the Gulf War in 1991 was 1120 (Khuraibet and Attar, 1995). Out of these, 639 wells were on fire, crude oils were flowing into desert from 42 wells and 439 wells were damaged. The Annual Report (1999) of the National Oil Spill Disaster Contingency Plan has reported major oil spills at the port terminals of Vadinar, Kandla and Haldia amounting to 16,000 m^3, 4000 m^3 and 5000 m^3 respectively (TERI Vision, 2004). Contamination of soil by crude oil in India is a major concern considering the huge network of oil pipelines that transport crude oil to and from various refineries (Bhattacharya 2004).

An accidental release of petroleum products amounting to 240 million gallon (approx) during the gulf war (1991) alone which represents the largest petroleum release event since record began to be kept consistently from 1978 (Singh, Srivastava and John, 2005). Hence, it is observed that, leakage, spills or accident in oil well is unavoidable. The spilled or gushing oil moved down to the ground water under gravity. The soil is partially saturated by the oil on its pathway. After reaching the ground water, the liquid have spread horizontally by migration within the capillary zone (Shroff 1997). This may lead to serious soil contamination. The petroleum hydrocarbons wastes released on the ground ultimately find its way to the soil system changing the properties of pore fluid. Change of liquid limit (LL), plastic limit (PL), plasticity index (PI), unconfined compressive strength (UCS), free swell index (SFI), differential free swell index (DFSI), pH value and electrical conductivity (EC) of soil with increase in the level of contamination of crude oil in case CL and CH type of soil was also observed (Talukdar and Saikia, 2010, 2011,2012).

Consolidation is the process of reducing the void ratio of soil by application of long term static loads. The study of compressibility is important for safe engineering design and for determination of probable settlement of structures. The consolidation properties of soil, such as, coefficient of compression and compression index, coefficient of permeability (k) etc. depend upon many factors like type of soil, void ratio, degree of saturation, soil structure, stress history, nature of pore fluid etc. and is selected to study the effect of crude oil contamination on these properties. Greater vertical settlement and change in water permeability is there in case of sand contaminated with crude oil (University of Maine 2004). The permeability of Kuwaiti sand decreased and compressibility increased with increase in oil content (Sanad, Eid and Ismae 1995). (Srivastava, Singh and Tiwari, 1997) observed the increase in coefficient of compressibility and coefficient of permeability of typical alluvial (CL-ML) soil due to contamination by industrial waste. Failure of three industrial buildings is due to large settlements of soil caused by accidental spillage and substantial reduction of SPT blow counts were observed due to contamination (Yaji Ramakrishnegowda and Thomas, 1997).

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Consolidation settlement for CH type of soils contaminated with petroleum hydrocarbons increased due to increase in the value of compression index (Singh, Srivastava and John, 2005). Although many researchers are working on the aspect of effect of soil contamination; the problem is mostly local due to the varied types of soil at different localities of a region. Different types of soil respond differently with contaminants and the sensitivity of soil to the contaminants depends not only on the local environment but the response also influenced by mineral structure such as particle size, bonding characteristics between particles, ion exchange capacity etc.(Singh, Srivastava and Hohn, 2005). Obviously, there is a great possibility of variation of the consolidation properties of soil, due to change of pore fluid or contamination of soil. The change in properties can be represented in the form of tables and graphs with respect to the percentage of contamination. The variations shown by tables and graphs do not provide quantitative information regarding prediction, judgment or decision making. A mathematical description of the sets of variables is the best way of scientific explanation, because in a graphical presentation, there is always an element of biasness or misleading presentation. It is observed that statistical regression technique is used in many Engineering applications.

There are several oil fields and oil refineries in different parts of Assam. Accidental fire on oil wells or intentional burning of natural gas etc. is a regular feature in this region. Therefore, change in soil properties of this region due to crude oil contamination is an important geotechnical problem to be investigated.

This paper deals with the experimental evaluation of consolidation properties of artificially contaminated clayey soil of low compressibility (CL) collected from different parts of Assam. Different levels of contamination of crude oil have been chosen for this purpose. Mathematical relationship between the above properties with the level of contamination is determined by statistical analysis of the observed data.

II. Materials

The materials used in this study are soil samples and crude oil.

Soil

Disturbed soil samples were collected from different sites of Assam. Grain size and Atterberg limit of all uncontaminated soil samples were determined. The soils are then classified as per IS (IS: 1498-1970). Out of total thirty numbers of samples, eight clayey soil samples of high compressibility (CH), seven clayey soil samples of low compressibility (CL), eight clayey soil samples of intermediate compressibility (CI) and seven clay-sand (SC) soil sample have been taken for this study.

Lime and Crude Oil

The crude oil used for this purpose was procured from Lakua oil fields, Assam. The API gravity was calculated by using the relation between the specific gravity and API of crude oil. The pH value and electrical conductivity of crude oil were determined by taking 1 : 1 soil and distilled water mixture and by using Systronics digital pH meter - 335 and digital conductivity meter–306 respectively and the properties are shown in Table 1.

Table 1
Properties of Crude Oil

Location	API gravity	pH value	EC ms/cm^2
Lakua oil field, Assam	30.77	5.4 9	0.8689

III. Level Of Contamination

Level of contamination was defined as the percentage weight of crude oil with respect to dry weight of soil. The maximum percentage of crude oil present in disturbed and undisturbed contaminated soil samples is within 10% (Shroff, 1997). Based on this consideration, soils were contaminated at 3%, 6% and 9% level of contamination in the present investigation.

IV. Preparation Of Crude Oil Contaminated Soil

Each type of disturbed soil sample is air dried, ground and foreign matter present, if any, is removed. The air dried soil is then sieved through 4.75 mm IS sieve and mixed at optimum moisture content (OMC) and stored for 24 hours in air tight polythene bags so that no loss of water takes place due to evaporation. Optimum moisture content was chosen because at OMC crude oil absorption of soil will be uniform. The soil samples so prepared are then mixed thoroughly with crude oil at 3%, 6% and 9% by weight of the soil and allowed to cure for ten days before testing.

V. Determination Of Consolidation Properties Of Soil

The main aim of the test programme is to determine the effect of different percentages of crude oil contamination on consolidation properties of soil. The consolidation test was performed as per IS: 2720 (PartXV)-1965 in a ring of 60 mm diameter and 20 mm thick in a fixed ring consolidometer under a pressure range from 0 – 800 kN/m^2. Remoulded soil samples were prepared at OMC and maximum dry density in all cases and were saturated before application of loads. On the basis of the consolidation test data the coefficient of consolidation are determined by root time method of curve fitting and compression index are determined by slope of the straight line portion of the void ratio (e) versus log p (pressure) curve.

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Behaviour of coefficient of compression

Coefficient of compression (C_v) are observed to be decreased as crude oil contamination increases in most of cases. Decrease in permeability may be due to reduction in pore volume of soil. Because of lower permeability, the time required for consolidation is increased and hence the coefficient of compression is decreased as C_v is directly proportional to the hydraulic conductivity of soil (Mitchell 1976).

Behaviour of Compression Index

It is observed from Table 2 that values of compression index increases as the level of crude oil contamination increases in soils. The lubricating effect of crude oil facilitates the sliding of soil particles and this will cause the increase in the compression index. It is in conformity with the findings of Sanad, Eid and Ismae (1995) in case of Kuwaiti sand and Yaji and Ramakrishnegowda and Thomas (1997) in case of shedi soil.

Table 2
Value of C_v and C_c of Soil Mixed With Crude Oil

Soil Type	Soil No.	C_v (cm^2/min) of soil contaminated with crude oil at				C_c of soil contaminated with crude oil at			
		0%	3%	6%	9%	0%	3%	6%	9%
CH	1	0.0056	0.0042	0.0040	0.0039	0.0885	0.0845	0.0945	0.0945
	2	0.0046	0.0042	0.0042	0.0039	0.0810	0.0820	0.0850	0.0860
	3	0.0052	0.0050	0.0049	0.0049	0.0856	0.0849	0.0884	0.0925
	4	0.0047	0.0047	0.0047	0.0045	0.0875	0.0845	0.0840	0.0867
	5	0.0068	0.0068	0.0065	0.0063	0.0859	0.0916	0.1057	0.1113
	6	0.0048	0.0045	0.0043	0.0042	0.0869	0.0908	0.0971	0.0979
	7	0.0050	0.0049	0.0047	0.0042	0.0820	0.0869	0.0937	0.0949
	8	0.0054	0.0047	0.0047	0.0045	0.0820	0.0846	0.0858	0.0941
CL	1	0.0076	0.0046	0.0048	0.0045	0.0788	0.0877	0.0931	0.0999
	2	0.0074	0.0045	0.0042	0.0036	0.0745	0.0801	0.0890	0.0941
	3	0.0046	0.0040	0.0037	0.0034	0.0781	0.0776	0.0792	0.0806
	4	0.0044	0.0041	0.0039	0.0042	0.0872	0.0878	0.0880	0.0941
	5	0.0065	0.0058	0.0051	0.0043	0.0798	0.0819	0.0824	0.0839
	6	0.0049	0.0049	0.0040	0.0037	0.0808	0.0808	0.0813	0.0852
	7	0.0055	0.0045	0.0040	0.0036	0.0860	0.0922	0.0925	0.0951
CI	1	0.0075	0.0079	0.0075	0.0075	0.0767	0.0743	0.0733	0.0729
	2	0.0037	0.0035	0.0035	0.0037	0.0814	0.0817	0.0822	0.0833
	3	0.0065	0.0047	0.0043	0.0037	0.0856	0.0880	0.0887	0.0912
	4	0.0048	0.0043	0.0048	0.0050	0.0723	0.0727	0.0727	0.0723
	5	0.0075	0.0050	0.0049	0.0048	0.0738	0.0743	0.0748	0.0757
	6	0.0040	0.0037	0.0041	0.0041	0.0865	0.0868	0.0841	0.0839
	7	0.0056	0.0044	0.0041	0.0037	0.0823	0.0847	0.0867	0.0879
	8	0.0043	0.0047	0.0037	0.0035	0.0729	0.0742	0.0732	0.0774
SC	1	0.0073	0.0059	0.0057	0.0050	0.0703	0.0703	0.0717	0.0736
	2	0.0079	0.0051	0.0065	0.0059	0.0591	0.0597	0.0611	0.0652
	3	0.0087	0.0097	0.0111	0.0097	0.0644	0.0673	0.0671	0.0674
	4	0.0083	0.0079	0.0072	0.0065	0.0713	0.0724	0.0729	0.0741
	5	0.0079	0.0060	0.0073	0.0071	0.0698	0.0698	0.0695	0.0704
	6	0.0079	0.0071	0.0065	0.0063	0.0594	0.0625	0.0646	0.0658
	7	0.0093	0.0093	0.0087	0.0050	0.0576	0.0581	0.0585	0.0736

VI. Statistics For Analysis Of Soil Properties

The properties of crude oil contaminated soil are essentially random variables as they depend on the extent of contamination and type of soil.

Hence, values of soil properties from table 2 are used for determination of statistical correlation with the percentage of crude oil.

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For this purpose, analysis of variance has been performed and insignificant relationships between the soil properties and the percentage of crude oil are discarded. The equation of line of regression and correlation ratio (r) also determined. Level of significance considered in all cases for this study is considered as 5%. The graphical representation of the line of regression of Cv with respect to crude oil contamination in case of CL type of soil is shown in Figures 1.

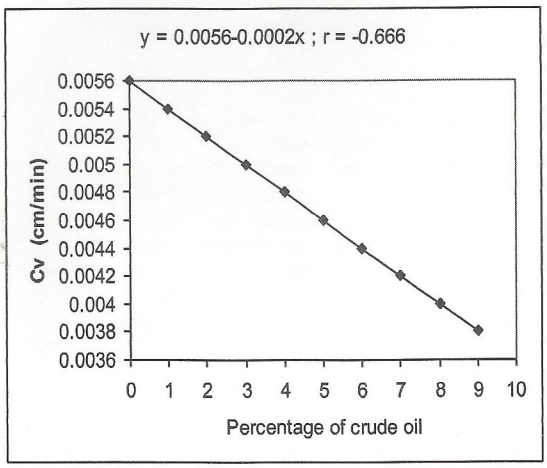

Fig.1 Change C_v due to Crude Oil in CL type of soil.

VII. CONCLUSIONS

- C_v observed to be decreased as crude oil contamination increases.
- C_c increases in presence of crude oil as contaminant.
- Mathematical correlation between C_v and C_c with the level of crude oil contamination exist in case of CH, CL and SC type of soil.
- Correlation of C_v with level of contamination is significant only in case of CL type of soil.
- C_v decreases linearly with the increase in the level of crude oil contamination.
- Correlation of C_c with level of contamination is insignificant in all type of soil.

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