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Effect of Petroleum Sludge on Shear Strength of an Acidic Clay Soil

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Abstract

Many infrastructure projects such as highways, railways, water reservoirs, reclamation etc. require huge earth material. Various techniques of soil stabilization are widely used for the construction of road pavement and foundation construction to enhance engineering properties such as strength, volume, stability and durability. In this context, shear strength of soil deserves importance. Soil is a peculiar material. Some waste materials such as fly ash, rice husk ash, pond ash may be used to improve the stability of soil. Addition of such materials increases the physical properties of it. With a view to utilise another waste material (petroleum sludge) in this work, effect of petroleum sludge on shear strength of soil is examined in a limited time period of ten weeks.

It has been found that shear strength of a slightly acidic clay soil is remarkably enhanced by petroleum sludge. The change in Unconfined Compressive Strength ranges from (-) 16.17% to 542.89% in this 70 days period of experiment. 3% petroleum sludge in soil gradually increases the shear strength of a soil from 0.31% in first week to 495.67% in ten weeks. Further, it has been found that the pH of the soil, containing 7% of the petroleum sludge, slightly decreases with time indicating possibility of degradation of remaining hydrocarbons. In spite of the possibility of biodegradation, there is 121.74% increase in the UCS value over the initial value of the shear strength of the polluted soil sample. The remarkable increase in UCS value of the soil under the influence of petroleum sludge needs further study in order to utilise it for improvement of soil engineering property and to mitigate the disposal problem of petroleum sludge.

Keywords: Petroleum Sludge, Shear Strength, Soil Texture, Unconfined Compressive Strength (UCS).

Introduction

Human race is dependent on a number of gifts of the nature. Apart from very common natural resources such as air, soil, water there are forests, minerals including coal, petroleum, lime stone etc. Man is empowered to use these natural resources rationally for their development and comfort. Different construction works on the earth's surface are supported by soil through its anchorage. Many a time, man has planted construction on soil to an extent which is beyond the supporting capacity of the soil at the site. Attempts have been made by different workers to improve soil quality for a targeted objective. While an agricultural scientist is busy to improve the soil quality to maximize production of crops, an engineer is busy to improve its quality such that it can support a heavy, technologically sophisticated, critical construction.

When not disposed of properly, petroleum sludge is not good for environment. It can cause serious damage to local water supply and also can be problematic for wildlife. Dumping waste oil can cause damage to sewer and septic systems. Dumped oil actually causes a large numbers of issues with sewer and septic systems because as petroleum cools and settles it congeals, which can clog up pipes and cause corrosion of certain materials.

Review of Literature

Different workers have been trying worldwide to improve the UCS of soil by using different addendums. Sawangsuriya and his co-workers studied UCS of soil- cement at 7 days. They collected cement stabilized bases from a number of highway construction projects in Thailand. Results from the statistical analysis indicated that the most important factors affecting the UCS were the California Bearing Ratio (CBR) and the water to cement ratio. The UCS was however independent on the dry density. A statistical model was developed in the study to predict the UCS of cement stabilized bases. A model was developed based on the following criteria: (i) the dry density of the sample shall be greater than 95 percent of the maximum dry density based on the modified proctor compaction, (ii) samples shall be soaked for at least 2 h prior to testing, and (iii) the CBR shall be measured at 0.1 inch (2.5 mm) penetration [1].

Rahman Z.A, Hamzah U, TahaMohd R, Ithnain N S & Ahmad N studied the geotechnical properties of oil-contaminated soils as well as uncontaminated soils for comparison. Testing programs performed on the studied soils included basic properties, Atterberg's limit, compaction, permeability and unconsolidated undrained triaxial tests. The base soils used were originated from weathered basaltic rock of grades V and VI. Soil samples were artificially contaminated with 4, 8, 12 and 16% oil of the dry weight of based soils. The results showed that the oil contamination decreased the liquid limit and plastic limit values for both grades of weathered soils. For soil grade V, the decrease in plastic limit and liquid limit were represented by 21 and 39%, respectively. Meanwhile, for soil grade VI, the drop was significantly high for liquid limit (39%) and lower for plastic limit (19%) if compared to soil grade V. The oil-contaminated soils also indicated a lower Maximum Dry Density (MDD) and optimum water content if compared with uncontaminated soils. The MDD for soil grade V and VI decreased from 1.67-1.50 and 1.60-1.55 g cm −3, respectively. The OMD values dropped from 23.5-17.5% for soil grade V and 23.0-16.5% for soil grade VI when oil contents were increased. A reduction in permeability was observed as a result of the oil contamination. The permeability of soil grade V and VI decreased from 3.74-0.22 and 2.65-0.22 cm sec −1, respectively. In terms of undrained shear strength, Cu was clearly affected by the increase in oil content in contaminated soils. Both soil grades showed stress dependent behaviour with a brittle mode of failure. The Cu values for uncontaminated soils of both grades were 126 and 106 kPa and then dropped to very close values of 35 and 32 kPa at oil content of 16%. The results showed that the addition of oil has adverse effects to the geotechnical properties of the studied residual soil. Contaminated residual soils might be used for geotechnical purposes and these results will benefit to engineers or decision makers in recycling or re-using of contaminated soils [2].

Ahmad S and his co-workers used waste materials such as fly ash, rice husk ash, pond ash to make soil stable and found that addition of such materials increases the physical properties of it. Fly ash is generated by the combustion of coal for energy production. It is an industrial by product. In the said investigation compaction and unconfined compressive strength of cohesive soil by using fly ash mixtures are evaluated. It was found that the maximum shear strength increased by 4% when 10% of fly ash by weight was mixed in soil and no remarkable change in internal friction [3].

Objective of the Study

To examine the possibility of conversion of a solid waste into a resource by applying it in a particular type of soil, where effects on chemico-engineering properties have been monitored.

Experiment

The soil sample is collected from the city of Guwahati (coordinates $26^{0}11^{/}$N $91^{0}44^{/}$E), Kamrup (M) district of Assam, India. The soil is then air dried, sieved by a fine sieve and petroleum sludge is mixed by taking samples in four polythene bags as per the following specification (Table-1). Samples are then mixed thoroughly and placed inside the laboratory in contact with air, water vapour, and sun light. Water was added from outside at a regular interval of time.

Table 1: Composition of Samples

Sample Name	Soil Taken	Petroleum Sludge added	Total mass	Percentage of Sludge
	(g)	(g)	(g)	%
A	495	5	500	1
B	485	15	500	3
C	475	25	500	5
D	465	35	500	7

The four parameters selected for study are Texture, Electrical Conductivity (EC), pH and Unconfined Compressive strength (UCS). All theses parameters are determined by standard methods as listed in Table-[2 4, 5, 6, 7.]

Table 2: Parameters Studied

Parameters	Name of the method	Particulars
Texture	Bouyoucos Hydrometer method	Based on Stoke"s Law
pH	Digital pH meter method	Method using Glass Electrode
EC ($m.S.cm^{-1}$)	Conductivity meter method	Calibrated by standard KCl solution
UCS (kN/mm^{2})	Unconfined compression apparatus, proving ring type	

Results and Discussion

The texture of the soil sample is found to be clay with percentages viz. Clay % = 51.2%, Silt%= 20%, Sand % = 28.8% [Table-3]. The pH and EC values are reported in Table 4. The final comparison of all the UCS tested is given in Table-5.

Table 3 : Texture Determination (Laboratory Temperature: 29^{0}C)

Sample	Hydrometer Reading		Silt+ Clay	Clay	Silt	Sand	Texture
	at 40 s	at 2 hrs	%	%	%	%	
Blank	995						
Soil	1006	1002	71.2	51.2	20	28.8	Clay

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Table-4: EC and Ph Values of the Samples

Sample	EC at 1^{st} week ($mScm^{-1}$)	EC after 10 weeks ($mScm^{-1}$)	pH values at 1^{st} week	pH values after 10 weeks
Blank	0.117		6.68	6.68
A	0.108	0.032	6.76	6.77
B	0.190	0.020	6.77	6.77
C	0.178	0.018	6.69	6.68
D	0.247	0.028	7.12	6.90

Table 5: Comparison of UCS

Sample	Values of UCS after a lapse of time in week, (10^{-6} $kNmm^{-2}$)				
	0	1	2	4	10
Blank soil	26.09	-	-	-	-
A	23.94	28.40	69.60	167.73	54.50
B	26.25	26.17	43.50	90.88	155.41
C	21.88	32.71	37.20	119.87	96.81
D	42.69	30.45	91.79	68.49	94.66

The plots of different values of shear strength of the samples are given in figures 1-4.

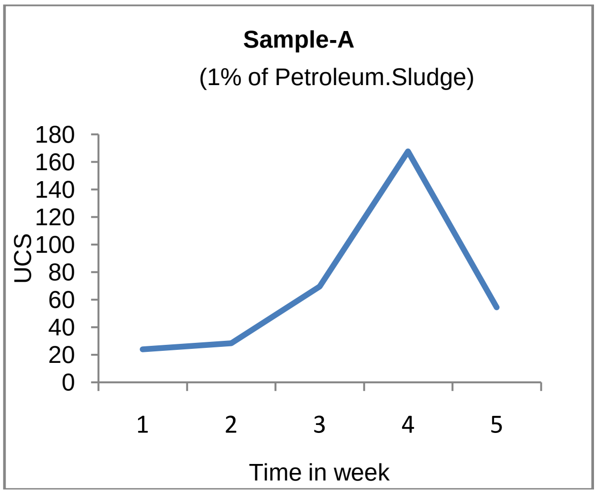

Fig. 1 Values of shear strength of sample A against time in weeks 0(1), 1(2), 2(3), 4(4), 10(5).

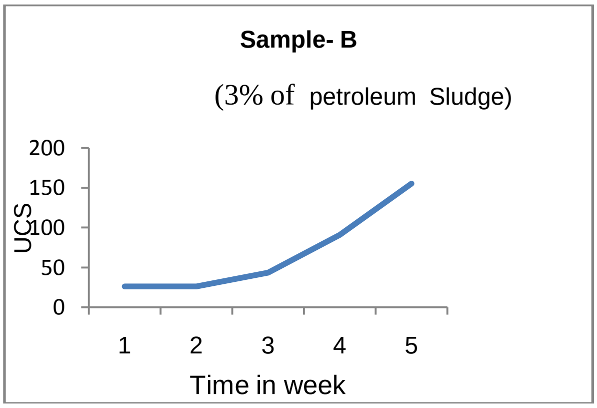

Fig. 2 Values of shear strength of sample B against time in weeks 0(1), 1(2), 2(3), 4(4), 10(5).

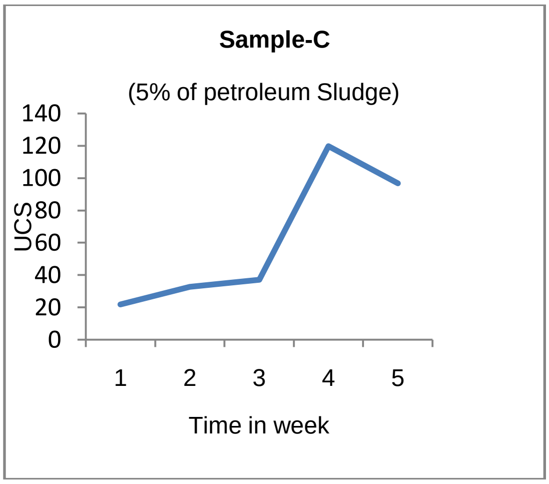

Fig. 3 Values of shear strength of sample C against time in weeks 0(1), 1(2),2(3),4(4),10(5)

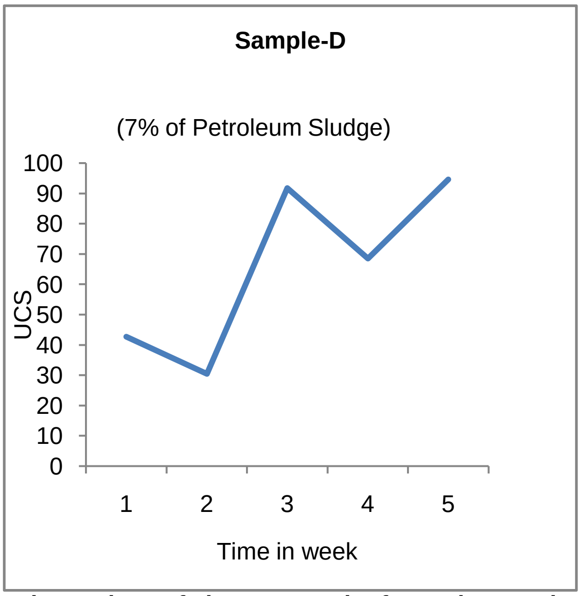

Fig.4 Values of shear strength of sample D against time in weeks 0(1), 1(2), 2(3), 4(4), 10(5).

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It has been found that the shear strength of the soil gradually increases up to the fourth week in most cases, on mixing of petroleum sludge with soil. This increase has been found to continue up to the tenth week in the sample number B i.e. in the sample having 3% of sludge. Within the time limit of the experiment it has been found that the shear strength remained increased up to the tenth week. However the optimum time period for the enhanced shear strength is found to be the fourth week, which was examined on that period.

The increase of shear strength in percentage over the blank soil shear strength is given in Table 6.

Table 6: Change of shear strength in % over that of blank soil against time

Sample	at 0 week	after 1 week	after 2 weeks	after 4 weeks	after 10 weeks
	%	%	%	%	%
A	(-)8.24	8.85	166.77	542.89	108.89
B	0.61	0.31	66.73	244.50	495.67
C	(-)16.17	25.37	42.58	359.45	232.73
D	62.63	16.71	251.82	162.51	262.82

It is clear that the shear strength is remarkably increased by petroleum sludge. In sample B, the increase in shear strength is uniform starting from the first week (0.31%).

Biodegradation is the promising technology for the treatment of petroleum contaminated sites since it leads to complete mineralization [8]. The activities of microorganisms are highly dependent on ambient temperature. The optimal range for most soil microorganisms is about 25-35°C. Many grow quite well over the range of 10-40°C [9]. S Pinaki and his co-workers reported a detrimental effect on growth and biodegradability of bacteria on petroleum sludge with increase in temperature in an experiment at three different temperatures namely, 30°C, 40°C and 50°C [10]. During the period of the experiment the temperature of the city of Guwahati ranges from 13.7 to 33.3°C [Table-7] indicating no obstruction on the possibility of microbial attack on the remaining hydrocarbons of petroleum sludge.

Table 7:Average maximum and minimum temperature of the city of Guwahati during the period of the experiment.

15 days times period	Average daily maximum temperature °C	Average daily minimum temperature °C
01/10/2015 to 15/10/2015	33.33	21.67
16/10/2015 to 31/10/2015	31.89	18.50
01/11/2015 to 15/11/2015	29.81	16.00
16/11/2015 to 30/11/2015	29.01	14.39
01/12/2015 to 15/12/2015	26.22	13.70
Average	30.05	16.85

Conclusion and Suggestion

Petroleum sludge disposal is a problem throughout the world. This is specially a problem in the small state of Assam, India, having four refineries and a lot of oil fields in a geographical area of 78,000 km^2. A waste is a substance, the utility of which is not known to us. A waste may become a resource when an economically viable process is invented to utilize the so called waste for the benefit of the society. Petroleum sludge is also such a waste, presently whose utility is not known. In case, some beneficial use of this substance comes to light, disposal problem to a certain extent will get solved. In this small experiment, such an attempt has been made. It has been found that shear strength of a slightly acidic clay soil is remarkably enhanced by petroleum sludge. 3% petroleum sludge in soil gradually increases the shear strength of a soil, at least up to ten weeks.

Petroleum sludge contains soil particles, heavy hydrocarbons, and some undesirable substances. Although, most of such hydrocarbons are persistent in the natural environment, even then, their ultimate fate is to undergo biodegradation, unless within this time they cannot enter into the food chain. Bioremediation is the nature's way to a cleaner environment. It is a process of oxidation, limited by several factors. During oxidation some oxygenated derives are produced which may contain phenol, carboxylic groups etc. These groups are acidic; as such pH of the samples should decrease. In the experiment, it has been found that the pH of the sample D, which contains 7% of the petroleum, there is decrease in the value of pH. This might be due to degradation of a portion of the hydrocarbons present in the experimental sludge. In spite of this possibility of biodegradation, there is 121.74% increase in the UCS value over the initial value of the shear strength of the polluted soil sample. Further study in this field may lead towards solution of a solid waste disposal problem and also it will lead to recycling of a non-renewable natural resource for a beneficial purpose..

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