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Study on Bio-remediation of Oil Contaminated Sand

K. S.Vignesh[1], R. Thenmozhi[2]
[1]*PG Scholar, Geotechnical Engineering, Government College of Technology, Coimbatore*
[2]*Professor, Department of Civil Engineering, Government College of Technology, Coimbatore.*

Abstract: ***The consumption of oil is getting raised day to day in our country. Its availability is limited to only a few countries. So, it has to be transported from such countries to other parts of the world. Leakage of oil occurs during drilling process and transportation through pipe lines. Due to this leakage the surrounding sand or water gets contaminated. Because of this, contamination sand is getting polluted and its engineering properties are altered. This study is carried out to determine the effects of crude oil contamination on the engineering properties of sea sand and to improve the properties of oil contaminated sea sand by the process Bioremediation. The soil samples are collected from Ganagalla Peta Beach, Andhra Pradesh. The samples are then artificially contaminated using crude oil in varying percentages of 2%, 4%, 6%, 8%, 10% and 12% for 2, 7 and 14 days. Sea sand is considered for this study. The laboratory tests such as direct shear, Standard proctor and chemical analysis was carried for both contaminated and bioremediated sand. As the bioremediation improves the shear strength of the soil, it is carried out for contaminated sand by using bacteria Bacillus amyloliquefaciens as it removing hydrocarbons from the contaminated sand. The Engineering properties of bioremediated sand are compared with contaminated sand.***
Keywords: Sea sand, Crude oil, Contamination, Bacillus amyloliquefaciens and Bioremediation.

I. INTRODUCTION

Oil is a vital source of energy for the world and will likely remain so for many decades to come, even under the most optimistic assumptions about the growth in alternative energy sources. Most countries have become oil users in a big way. The International Energy Agency (IEA) projects that oil will provide 30% of the world's energy mix in 2030. In many developed countries about 2/3 of oil is used for transportation. In most of the rest of the world, oil is more commonly used for space heating and power generation than for transportation.

Oil is a key product for the world's agriculture industry, which helps feed the world's population of more than six billion. Middle East countries have potential for vast amounts of oil wells. The increase in oil wells is higher because of their geographic location, so every country is importing oil from Middle East countries depending upon their requirements. The import is mainly done through shipping and pipeline transportation. By shipping, only limited quantity of oil can be transported and it takes long time to reach the destination which is not economical too. Due to these constraints most of the countries prefer the transportation of oil through pipe line.

Most pipelines are typically buried at a depth of about 3 to 6 feet (0.91 to 1.8 m), to protect pipes from impact, abrasion, and corrosion. The oil is kept in motion by pump stations along the pipeline, and usually flows at speed of about 1 to 6 meters per second (3.3to20ft/s). Oil spills are accidental in most cases. During transportation both by land and sea as leakage from storage Tanks or during oil drilling processes.

There are also cases where oil might be spilled purposely as what was happened in the Persian Gulf War in 1991. When oil spill or leakage occurs, soils might be contaminated with the leakage. In these cases, major tasks are needed for remediation and reclamation of the contaminated sites. Several proposals were made by companies for remediation of heavily polluted soils after the oil lakes are drained of liquid crude. These included conversion of oily soil to road base material or a topping layer for car parks and roads after mixing with aggregate or consolidation agents. Other methods include contain mention large burial sites, incineration, biological methods, absorption methods, soil washing.

II. MATERIALS USED

A. Crude Oil

Crude oil was commercially bought from CPCL (Chennai Petroleum Corporation Limited). Contamination was done artificially by mixing virgin sand with 2%, 4%, 6%, 8%, 10% and 12% of crude oil.

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B. Sand Sample

After particle size classification, the SP (Poorly Graded) sample was dried by oven at 105ºC. The samples were mixed with crude oil and individually in different percentage by weight of the dry samples. Care was taken to ensure the uniform mixing of the contaminant. The chemical characteristics and geotechnical properties of the uncontaminated sand is also found and it is shown in the table 1 and table 2.

Table 1: Geotechnical properties of the uncontaminated sand.

SI. No	Property	Value	IS Method
1.	Specific Gravity	2.65	IS 2720 Part 3 1980
2.	Particle Size Distribution		
	Gravel (%)	0	IS 2720 Part 3 1985
	Sand (%)	100	
	Fines (%)	0	
3.	IS CLASSIFICATION	SP	IS 2720 Part 4 1970
4.	Shear Parameters		
	Angle of internal friction	32°	IS 2720 Part 13 1986

Table 2: Chemical characteristics of the uncontaminated sand.

SI. No	Property	Value	IS Method
1.	pH	6.97	IS 2720 (Part 26) - 1987
2.	Electrical Conductivity(dS/m)	13.74	IS 14767 – 2000

C. Bacillus Amyloliquefaciens

Bacillus amyloliquefaciens is a gram-positive, rod-shaped, aerobic, endospore producing soil bacteria found in the root zone [10]. These bacteria collected from Pathology Department, Agriculture University, Coimbatore. Bacillus amyloliquefaciens is related to Bacillus subtilis on the basis of molecular genetic data. The ideal temperature for cell development is in the range of 30°C - 40°C. In these bacteria highest growth was obtained at 30°C -37°C.

D. Methodology

The physical and chemical analysis of the crude oil contaminated sand were done. Table 1 and Table 2 represents the geotechnical properties and chemical analysis of the uncontaminated soil sample. The crude oil was added to contaminated sand at various percentages 2%, 4%, 6%, 8%, 10% and 12%. The optimum moisture content and dry density at various percentage of crude oil contaminated sand and bio remediated sand were obtained using Compaction test. The variation in the shear parameters with various percentage of oil contaminated sand and bioremediated sand was also obtained using Direct Shear test [2][3]. The remediation potential of contaminated sand was analysed using pH test and also chloride content test. The physical and chemical analysis were performed for 2, 7 and 14 days of curing.

III. RESULTS AND DISCUSSION

A. Compaction Test

Standard Proctor compaction tests were carried out on the artificially oil contaminated soils samples. They generally show a reduction in maximum dry density with increasing oil content. The reduction of dry density in SP samples is very low, because the pore spaces are larger in these samples and oil can move through the soil particles with the same rate as water and it has similar lubricating effect.

However, with increase of the oil content the shape of compaction curves changes [10]. In Poorly graded sands (SP) the dry unit weight has a general tendency to decrease as water content increases, and then to increase to a maximum value with further increase of water content.

Table 3: Variation of OMC with oil contamination and bio remediated sample.

% of oil	Days	Oil contaminated sand (OCS)	Bio Remediated Sand (BRS)				
			4% Bacteria	6% Bacteria	8% Bacteria	10% Bacteria	12% Bacteria
2%	2 days	8.0	7.0	5.0	6.0	9.0	8.0
	7 days	8.0	6.0	7.0	7.0	7.0	7.0
	14 days	8.0	6.0	7.0	7.0	6.0	6.0
4%	2 days	8.0	7.0	5.0	4.0	4.0	4.0
	7 days	7.0	7.0	5.0	7.0	7.0	6.0
	14 days	7.0	6.0	5.0	7.0	6.0	6.0
6%	2 days	7.0	7.0	6.0	7.0	5.0	6.0
	7 days	7.0	8.0	7.0	7.0	7.0	7.0
	14 days	7.0	7.0	7.0	7.0	7.0	7.0
8%	2 days	6.0	8.0	8.0	7.0	7.0	6.0
	7 days	6.0	7.0	7.0	7.0	6.0	5.0
	14 days	6.0	7.0	7.0	7.0	6.0	5.0
10%	2 days	5.0	5.0	6.0	5.0	5.0	5.0
	7 days	5.0	5.0	6.0	6.0	5.0	5.0
	14 days	5.0	4.0	6.0	5.0	5.0	4.0
12%	2 days	4.0	4.0	5.0	5.0	4.0	3.0
	7 days	4.0	4.0	5.0	4.0	3.0	3.0
	14 days	4.0	3.0	4.0	4.0	3.0	2.0

Table 4: Variation of MDD with oil contamination and bioremediated sample.

% of oil	Days	Oil contaminated sand (OCS)	Bio Remediated Sand (BRS)				
			4% Bacteria	6% Bacteria	8% Bacteria	10% Bacteria	12% Bacteria
2%	2 days	1.874	1.440	1.714	1.703	1.820	1.523
	7 days	1.874.	1.443	1.757	1.750	1.843	1.549
	14 days	1.855	1.445	1.784	1.731	1.798	1.532
4%	2 days	1.994	1.948	1.788	1.871	1.844	1.880
	7 days	1.994	1.938	1.798	1.905	1.879	1.893
	14 days	1.994	1.931	1.774	1.912	1.852	1.882
6%	2 days	1.967	1.433	1.860	2.172	1.892	1.736
	7 days	1.983	1.938	1.817	1.882	1.889	1.903
	14 days	1.975	1.911	1.845	1.876	1.991	1.854
8%	2 days	1.963	1.802	1.868	1.530	1.883	1.750
	7 days	1.963	1.956	1.889	1.905	1.889	1.547
	14 days	1.963	1.987	1.865	1.911	1.846	1.687
10%	2 days	1.979	1.776	1.881	1.518	1.891	1.747
	7 days	1.972	1.957	1.862	1.887	1.877	1.550
	14 days	1.974	1.983	1.782	1.781	1.854	1.689
12%	2 days	1.899	1.857	1.841	1.945	1.789	1.833
	7 days	1.825	1.754	1.860	2.010	1.892	1.736
	14 days	1.753	1.864	1.901	1.875	1.912	1.815

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B. Direct Shear Test

Direct shear test was carried out to find the effect of oil contamination on strength parameters of soils. For studying the effect of contamination on shear strength, tests were conducted on contaminated sand samples with varying contamination percentages of 2%, 4%, 6%,8% ,10% and 12%. From the results it is clear that the shear strength of poorly graded sand sample contaminated with crude oil decreases with increase in the percentage of oil content. Direct shear tests performed on oil-contaminated sands showed a reduction in Φ with the increase of oil percentage [8][9]. It may be due to the fact that, as day increases there is a loss of contact between the sand particles therefore, friction reduces.

Table 5: Variation in angle of internal friction values.

% of oil	Days	Oil contaminated sand (OCS)	Bio Remediated Sand (BRS)				
			4% Bacteria	6% Bacteria	8% Bacteria	10% Bacteria	12% Bacteria
2%	2 days	21°	20°	19°	21°	21°	23°
	7 days	21°	19°	20°	22°	23°	25°
	14 days	20°	20°	20°	21°	22°	23°
4%	2 days	21°	17°	17°	19°	18°	23°
	7 days	19°	19°	19°	20°	19°	24°
	14 days	20°	19°	18°	19°	18°	24°
6%	2 days	17°	19°	20°	21°	20°	16°
	7 days	19°	20°	22°	23°	19°	20°
	14 days	18°	20°	22°	21°	20°	18°
8%	2 days	13°	17°	19°	19°	21°	20°
	7 days	13°	17°	19°	20°	22°	21°
	14 days	13°	17°	20°	21°	23°	21°
10%	2 days	10°	18°	20°	19°	17°	17°
	7 days	10°	19°	20°	20°	19°	17°
	14 days	10°	18°	21°	22°	20°	19°
12%	2 days	11°	17°	17°	19°	18°	23°
	7 days	10°	19°	19°	20°	19°	24°
	14 days	9°	20°	18°	21°	20°	21°

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Table 6: Variation of cohesion values.

% of oil	Days	Oil contaminated sand (OCS)	Bio Remediated Sand (BRS)				
			4% Bacteria	6% Bacteria	8% Bacteria	10% Bacteria	12% Bacteria
2%	2 days	0.05	0.05	0.04	0.05	0.05	0.05
	7 days	0.05	0.04	0.04	0.05	0.04	0.03
	14 days	0.05	0.04	0.04	0.05	0.04	0.03
4%	2 days	0.05	0.03	0.05	0.05	0.05	0.04
	7 days	0.05	0.02	0.04	0.05	0.04	0.04
	14 days	0.05	0.03	0.04	0.05	0.04	0.04
6%	2 days	0.07	0.04	0.06	0.06	0.06	0.07
	7 days	0.07	0.04	0.06	0.04	0.05	0.06
	14 days	0.07	0.04	0.05	0.03	0.05	0.06
8%	2 days	0.10	0.07	0.05	0.07	0.05	0.05
	7 days	0.10	0.06	0.06	0.06	0.05	0.05
	14 days	0.10	0.06	0.05	0.05	0.05	0.04
10%	2 days	0.12	0.11	0.09	0.09	0.06	0.05
	7 days	0.12	0.11	0.09	0.07	0.05	0.05
	14 days	0.12	0.11	0.09	0.08	0.06	0.06
12%	2 days	0.13	0.12	0.10	0.09	0.07	0.07
	7 days	0.13	0.12	0.10	0.09	0.08	0.07
	14 days	0.13	0.12	0.10	0.09	0.07	0.08

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C. pH TEST

The pH of the contaminated sand and various percentage of crude oil was found as per IS 2720, part 26, 1987. The pH value decreases gradually by increasing the percentage of oil contamination. pH values for 2% contamination found to be maximum when compared with other percentages of contaminations.

Table 7: Variation in pH values.

% of oil	Days	Oil contaminated sand (OCS)	Bio Remediated Sand (BRS)				
			4% bacteria	6% bacteria	8% bacteria	10% bacteria	12% bacteria
2%	2 days	7.21	10.3	10.5	9.5	9.6	10
	7 days	7.11	10.5	10.7	9.7	10.4	9.7
	14 days	7.23	10.8	10.9	10.1	10.5	10.2
4%	2 days	6.71	10.0	9.8	9.8	10.2	10.3
	7 days	7.01	9.5	9.7	10.2	10.3	9.8
	14 days	7.01	9.9	9.8	10.3	10.2	9.7
6%	2 days	6.99	10.2	9.3	10.6	10.4	9.5
	7 days	7.01	10.2	10.5	10.6	9.8	10.8
	14 days	7.01	10.1	10.5	10.4	9.6	10.5
8%	2 days	6.51	9.7	9.4	9.8	10.1	9.4
	7 days	6.96	9.6	9.7	10.0	10.2	9.9
	14 days	7.05	9.5	9.6	9.5	9.8	10.0
10%	2 days	6.50	10.2	10.1	9.7	9.5	9.8
	7 days	6.92	10.4	10.6	9.8	10.0	10.2
	14 days	7.01	10.5	10.3	9.7	9.8	10.1
12%	2 days	6.51	10.3	10.2	9.7	9.8	10.3
	7 days	6.94	10.2	10.2	10.1	9.9	9.8
	14 days	7.02	10.3	10.0	10.3	10.2	10.0

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D. Chloride Test

In chloride content values maximum value obtained at 2 days curing period was 173.13 mg/l of 12% contamination of oil. In chloride content values maximum value obtained at 7 days curing period was 180.42 mg/l of 4% contamination of oil. In chloride content values maximum value obtained at 14 days curing period was 177.77 mg/l of 4% contamination of oil After bioremediation the chloride results are plotted in table 8. The optimum value cannot be concluded by these chloride content test as the values does not increase or decrease gradually.

Table 8: Variation in Chloride content values.

% of oil	Days	Oil contaminated sand (OCS) / (mg/l)	Bio Remediated Sand (BRS) / (mg/l)				
			4% bacteria	6% bacteria	8% bacteria	10% bacteria	12% bacteria
2%	2 days	157.45	142.46	149.95	144.96	147.45	154.95
	7 days	162.30	142.46	149.95	147.45	144.95	154.95
	14 days	161.20	142.55	150.08	148.53	146.87	155.63
4%	2 days	152.45	157.45	154.95	147.45	152.45	162.45
	7 days	180.42	147.45	149.95	157.45	149.95	159.95
	14 days	177.77	152.43	151.22	155.23	150.42	160.54
6 %	2 days	162.44	149.95	154.95	157.45	159.95	169.95
	7 days	177.22	152.45	147.45	157.45	159.95	162.45
	14 days	170.85	153.82	149.54	155.62	158.75	165.23
8%	2 days	160.22	147.45	157.45	167.45	159.95	154.95
	7 days	173.13	159.95	152.45	167.45	154.95	157.45
	14 days	171.22	165.87	155.44	169.69	160.52	155.87
10%	2 days	158.81	162.45	169.95	167.45	159.95	164.95
	7 days	171.12	154.95	159.95	157.45	159.95	164.95
	14 days	167.50	159.34	154.21	153.28	160.61	157.35
12%	2 days	173.13	159.95	152.45	167.45	154.95	157.45
	7 days	177.77	152.43	151.22	155.23	150.42	160.54
	14 days	161.20	142.55	150.08	148.53	146.87	155.63

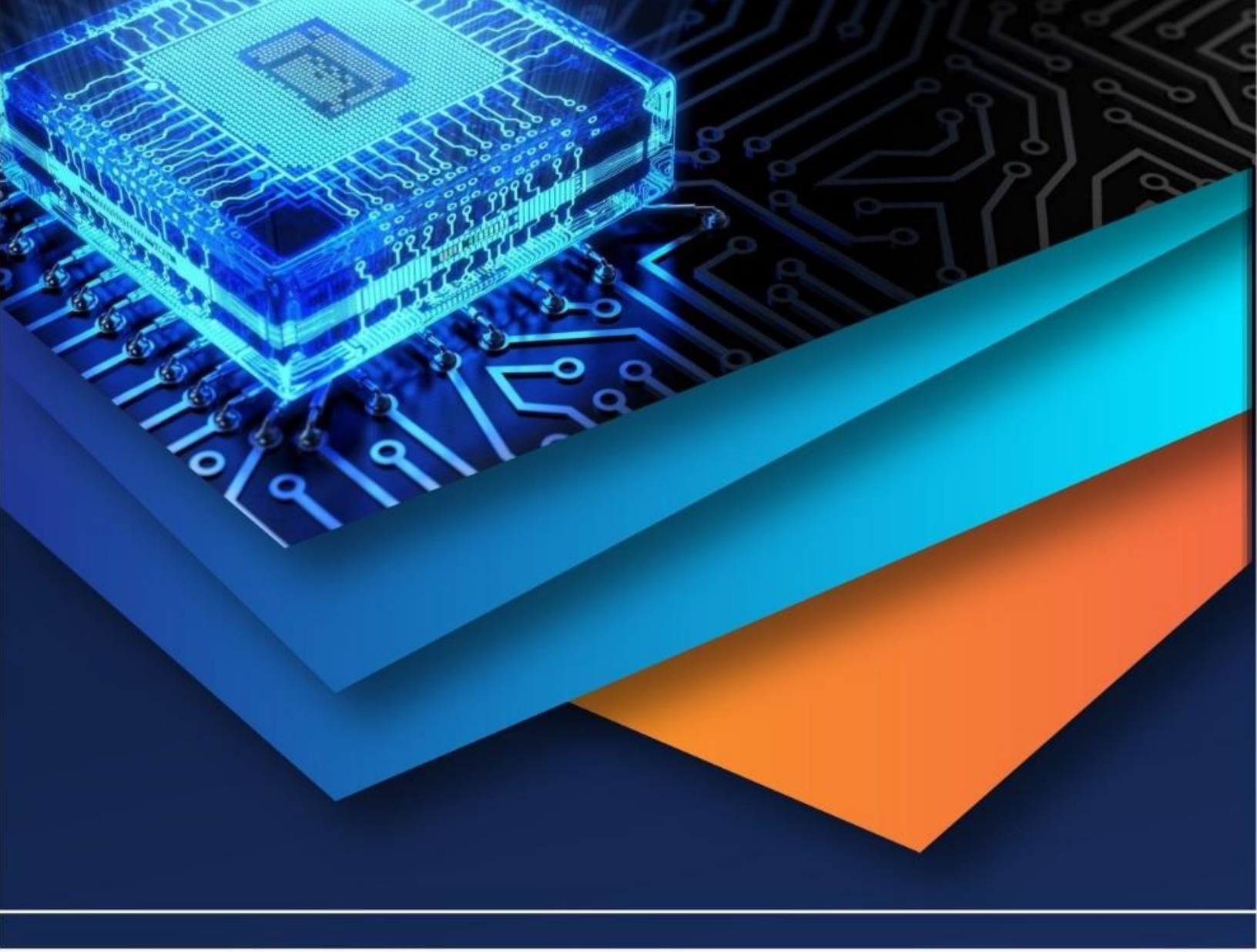
IV. CONCLUSIONS

An extensive laboratory testing program was carried out to study the effects of crude oil contamination on poorly graded sand sample. The crude oil was added from an increment of 2% by weight of dry samples to make the soil sample artificially contaminated. The oil concentration used in the current study is in the range of 2 - 12%. The following conclusions were drawn from the experimental study.

1) The angle of internal friction of the contaminated sand decreases with increase in oil content. As the days of contamination increases angle of internal friction value reduces. The values of cohesion and angle of internal friction decreased as the crude oil content increased in contaminated samples. However, for bioremediated samples, the values of cohesion are slightly more than the values of initial percentage of oil contaminated samples and somewhat lower than the value for maximum percentage of oil contaminated sand.
2) Oil contamination lowered the shear strength, cohesion, and internal friction angle of soil, which may be related to the lubricating effect of oil. Bioremediated soil has high shear strength, cohesion, and angle of internal friction as compared with contaminated sand.
3) The reason for such behaviour could be found in viscosity differences of the crude oil and the water. As the viscosity of the pore fluid increases, the shear strength of the granular sand decreases. A decrease in angle of internal friction by an increase in initial crude oil content for bioremediated samples were evident.
4) The results of compaction test are in the form of dry density versus optimum moisture content for OCS and BRS samples. An increase in MDD of OCS sample may be attributed to the fact that when oil content increases to a maximum limit, it also efficiently surrounds the coarser sand particles and acts as a lubricant between the particles. The oil presence reduces water absorption and dissipates applied energy, which leads to low compaction.
5) The changing trend of MDD and OMC versus oil concentration is compared for OCS and BRS samples. The crude oil has a lower density compared to water, thus as the oil occupies a part of the pore space instead of water, it will lower the density of pore fluid totally.
6) The pH value for oil contaminated sample decreases when percentage of oil increases. For the bioremediated sand have been increased by increasing percentage of oil contamination and bacteria. The bioremediate sand changes from acidic to alkaline in nature.
7) The chloride test for oil contaminated sample drastically increases when the oil percentage increases. For Bioremediated sample the value decreases when percentage oil contamination decreases and bacteria percentage decrease.

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