Journal of Civil & Environmental Engineering

Chaudhary and Singh, J Civil Environ Eng 2016, 6:2
DOI: 10.4172/2165-784X.1000217

Review Article Open Access

Study of Behavioural Change in the Soil Contaminated with Petrol

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Abstract

One of the legacies of the past in industrialized countries is that land has been contaminated due to mining, industry and society disposing of waste with little regard for future consequences. Contamination of the soil layers forms one of the major topics of Environmental Geo-technology. The accidental spillage or leakage of highly aggressive industrial effluents has detrimental effects on the properties of soil. The addition of these effluents in to the subsoil directly affects the use and stability of the supported structure. In the present day Geotechnical engineering, little consideration has been given to the potential influence of physico-chemical interactions on the mechanical performance of soil confronted with increasing occurrence of soil contamination. The modern construction requires a detailed study of the foundation material as well as its working during the course of lifetime of the structure supported by it. In this study, an experimental investigation is done to quantify the influence of contamination in two different types of locally available soils i.e. sand (SP) and clay (CL-ML), so as to understand the engineering behaviour of the soil under the effect of pollutants. Therefore, due to the multitude of these pollutants the study was restricted to the contaminant fluid, Petrol. Through this study it has been found that, the contamination of soil with petrol has a significant influence on the engineering behaviour of the soil and the consequent change in the engineering properties of the soil has been reported in this paper.

Keywords: Contamination; Clay; Effluents; Petrol and sand introduction

Introduction

Soil has been defined differently by workers in different fields. Thus, for an agriculturist, the soil is simply the upper layer of ground which is useful for supporting life. Geologists define it as a surface layer of rock waste in which the physical and chemical processes of rock weathering cooperate intimately with organic processes. All important civil engineering projects like dams, reservoirs, tunnels, roads, bridges and buildings etc. are constructed on soil or rock strata. But in recent years, due to population growth, a progressive living standard and industrial progress, much of air, water and land have become polluted. These in turn, affect the durability of the structure tremendously. For contaminated land, the consequences may require a complete redesign of the project. It is, therefore, essential that the engineer should have the fullest knowledge possible of the strata or soil through which the works of construction are to be carried or on which these have to rest. In the present day scenario, soil contamination is posing a great threat to the geological as well as structural engineers. Contaminated land is found typically, but not exclusively, in urban or industrial areas. The bulk of contaminants occur naturally, in varying concentrations. But hydrocarbon contamination is the most obvious concern of the industrial age since most of the industries existing today, from oil exploration, production, processing and transportation on one hand to refining, storage (surface and subsurface), transportation and distribution on the other, are using and discharging hydrocarbons in one form or another. Petroleum contamination is encountered during most of transportation projects. It occurs in two scenarios- at state owned maintenance facilities and along the right of way during highway construction. Spills during product delivery can also contaminate soil in fill areas. In addition, hydraulic lift systems can fail and release hydraulic oil into soil beneath buildings. Petrol contamination may occur on right of way due to leakage of petrol from leaking oil heaters, transport spills, buried pipelines etc. Investigations at the various gasoline service stations revealed that oil and groundwater below the sites were contaminated by polynuclear aromatic hydrocarbons (PAHs) and volatile aromatics including benzene, toluene, ethyl benzene and total xylenes (BTEX). The resulting environmental degradation is colossal [1]. Not only the agricultural property of the soil has been destroyed, the performance of soil as a construction material or as a supporting material of engineering structures has been greatly affected. Research has shown that leakage of petrol into sub soil directly affects the use and stability of supported structure.

Methodology

The main thrust of present work is to study the changes in the engineering properties and characteristics of soil contaminated with varying percentages of petrol so that suitability of a site contaminated with petrol for a proposed structure can be assessed. This study is also helpful in planning cleanup/reclamation of contaminated site to render it to make amenable for safe and economical structure over it. The study also throws light on the causes of distress in already constructed structure over contaminated land and hence restoration measures can be planned accordingly. For the course of this study, an extensive laboratory-testing programme was carried out to determine the effect of petrol contamination on engineering properties of soil and the subsequent changes in its behaviour with varying degree of contamination [2,3]. For this, following tests were conducted on both contaminated and uncontaminated soil samples as shown in Table 1 below. Dry sand was used in case of test on sand. Test on sand mixed with different percentage of fine, first fine was added to the sand. Then water was added to the mixture of sand and fine to achieve OMC. The mixture was compacted to achieve maximum bulk density. All tests on sand mixed with different percentages of fine were carried out with maximum bulk density at OMC [4]. Standard proctor tests were performed to

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Received January 16, 2016; **Accepted** February 02, 2016; **Published** February 05, 2016

Citation: Chaudhary A, Singh A (2016) Study of Behavioural Change in the Soil Contaminated with Petrol. J Civil Environ Eng 6: 217. doi:10.4172/2165-784X.1000214

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get the optimum water content and maximum dry density of soils samples as shown in Table 2 below. The difficulty in studying petroleum evaporation is that petroleum is a mixture of hundreds of compounds and petroleum composition varies from source to source and even over time. The petroleum evaporation from the specimens was examined by measuring the daily change in the weight of samples contaminated with different percentages of petroleum. Results showed that the evaporation occurred at a fairly high rate during the first week, but it continuously decreased with time until it ceased completely after almost four weeks [5]. Locally available sand (Ghaggar River: 29°28'27"N 74°50'19"E) and clay (Morni hills: 30°42'N 77°05'E) were used for the study. Petrol (contaminant) obtained from local fuel outlets, were added to soil samples for contamination in the percentages ranging from 3-12%. The soil samples were soaked in petrol in air tight containers for seven days. The engineering properties of the contaminated soil samples were again determined and the properties thus compared.

Result

An extensive laboratory-testing programme was carried out to determine the effect of petrol contamination on engineering properties of soil and the subsequent changes in its behaviour with varying degree of contamination. The result of all the tests conducted on uncontaminated and contaminated soil samples are shown below in the Tables 2-4. From the results it is seen that soil properties are modified when they are contaminated with pollutants. The extent of modification of properties depends upon the type of soil itself and nature of pollutant. The cause of change in properties of clay contaminated with pollutant may be due to effect on its Base Exchange capacity, change in the thickness of diffuse double layer, and nature of pollutants. It is seen that the engineering properties of soil are affected significantly after contamination with petrol [6].

S.No	Tests on Uncontamined Soil Samples	Tests on Contamined Soil Samples
1.	Moisture Content Determination	Free Swell Test
2.	Free Swell Test	Atterberg's Limits test
3.	Grain-Size Analysis - Mechanical method	Specific Gravity Test
4.	Grain-Size Analysis - Sedimentation method	Permeability Test
5.	Atterberg's Limits test	Compaction Test
6.	Specific Gravity Test	Unconfined Compression Strength Test (UCS)
7.	Permeability Test	Direct Shear Test
8.	Compaction Test	California Bearing Ration
9.	Unconfined Compression Strength Test	
10.	Direct Shear Test	
11.	California Bearing Ration	

Table 1: Tests conducted on soil samples.

S.No	Property	Sand	Clay
1.	Moisture Content (%)	8	3.81
2.	Free Swell (%)	-	32.5
3.	Liquid Limit (%)	-	27
4.	Plastic Limit (%)	-	20.84
5.	Shrinkage Limit (%)	-	17.02
6.	Plasticity Index	-	6.16
7.	Specific Gravity	2.67	2.88
8.	OMC (%)	8	11.3
9.	Max. Dry Density (g/cc)	1.6	1.81
10.	Permeability (cm/s)	0.03	$2.15*10^{-4}$
11.	Cohesion (kg/cm^2)	0	0.7187
12.	Angle of Friction, ø (°)	29	-
13.	CBR (unsoaked) (%)	4.86	3.67
14.	CBR (soaked) (%)	12.86	1.78

Table 2: Results obtained on the uncontaminated soil samples.

Degree of Contamination (%)	0	3	6	9
Specific Gravity	2.675	2.86	2.815	3.0
OMC (%)	8	6.7	10.4	9.85
Max. Dry Density (g/cc)	1.6	1.499	1.536	1.503
Permeability (cm/s)	0.03	0.0105	0.00889	0.00691
Cohesion (kg/cm^2)	0	0.0265	0.033	0.022
Angle of Friction, ø (°)	29	27.5	25	23.5
CBR (unsoaked) (%)	4.86	3.238	10	6.286
CBR (soaked) (%)	12.86	15.43	21.05	18.143

Table 3: Soil - Sand (SP).

Degree of Contamination (%)	0	4	8	12
Free Swell (%)	32.5	40	36	34
Liquid Limit (%)	27	32.5	35.8	37.4
Plastic Limit (%)	20.84	27.07	30.85	33.02
Shrinkage Limit (%)	17.02	18.64	16.37	15.52
Plasticity Index	6.17	5.43	4.93	4.38
Specific Gravity	2.88	3.24	2.844	2.516
OMC (%)	11.3	12	11.05	11.3
Max.Dry Density (g/cc)	1.81	1.735	1.683	1.632
Permeability (cm/s)	0.000215	0.0041	0.0015	0.00014
Cohesion (kg/cm^2)	0.718	0.765	0.575	0.514
CBR (unsoaked) (%)	3.67	1.67	1.24	1.77
CBR (soaked) (%)	1.78	1.31	1.31	1.386

Table 4: Soil - Clay (CL-ML).

Conclusion

Following are the important conclusions drawn from the test results:-

Sand (SP)

1. Specific Gravity increases with the contamination.
2. More than 50% reduction is observed in the permeability of the soil due to contamination with petrol. The Permeability of sand decreases from 0.0296 cm/s to 0.0069 cm/s as the degree of contamination increases to 9%. This reduction can be attributed to the contaminant occupying the pores spaces and hence reducing the pore volume for the free movement of water.
3. Direct shear test indicates that the sand starts attaining some cohesion with the addition of petrol to it but the fall in angle of friction is indicative of lower bearing capacity. Since the bearing capacity factors reduce by almost 50% with the addition of 9% petrol, the bearing capacity of the contaminated sand becomes 50% of that of the uncontaminated sand.
4. In case of CBR values, the CBR value of soaked sand soil samples is higher than un-soaked samples. The CBR value of un-soaked sand samples decreases by 3% contamination but with further increase in contamination, the values increases. As the degree of pollutant increases from 0% to 9%, the soaked CBR values also increase. Both these values are found to be maximum at 6% contamination. Therefore, it can be concluded that there is not any negative impact on CBR value due to contamination with petrol [7].

Clay (CL-ML)

1. Percentage free swell of experimental clay increases with the

addition of petrol to it but with higher percentage of pollutant, this increase is reduced. The increases swell of soil is indicative of the fact that foundations resting over such soils will experience large swelling pressures and hence they are prone to differential settlement and hence cracks in the structure.

2. Liquid and plastic limit increase whereas plasticity index is found to be in decreasing order when the percentage of petrol in soil increases.
3. The value of shrinkage limit decreases with increase in concentration of petrol in the clay.
4. The value of specific gravity shows a decreasing trend with the increase in the percentage of petrol.
5. The OMC of the soil is increased to a maximum of 12% at 4% contamination. Though with further addition of petrol, the value is not much affected.
6. The max. dry density is found to be lower than that of uncontaminated soil at all contamination levels.
7. The value of permeability increases from 0.000215 to 0.00414 cm/s with 4% addition of petrol to it but with higher percentage of petrol, the permeability starts to fall again. This can be due to the excess of fuel blocking the pores and hence reducing the free flow of water.
8. The shear strength of clay increases from 0.718 to 0.765 kg/cm^3 with 4% contamination with petrol but with further addition of petrol, the shear strength decreases. It becomes only 0.513 kg/cm^3 with 12% contamination which is approximately 70% of that of the original soil.

The CBR value of un-soaked soil-sample is higher than the soaked soil samples. As the degree of concentration of the pollutant increases from 0 to 8% the values of both soaked and un-soaked clay decrease [8]. By taking the contamination level to 12% CBR shows an increase but it is still lower than that of the uncontaminated soil. Therefore, a higher thickness of pavement would be required over the clayey soils contaminated with petrol. Already constructed pavements will be in distress due to loss of CBR value and would require strengthening.

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