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Effect of Industrial waste water contamination on Geotechnical Properties of Soil

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Abstract: The present work is devoted for studying the geotechnical and chemical properties of intact and contaminated sandy soil samples. The soil samples were obtained from kapalsadi village that is located in the Gujarat region of India. The contaminant is a by-product industrial wastewater disposed from the refinery that supplies fuel for the thermal electricity power plant. The intact sandy soil samples were contaminated in the laboratory with four percentages of 10, 20, 40 and 100% of the weight of distilled water used in the soaking process and the soaking process continued for thirty days. The results of tests showed a slight increase in both liquid limit and particle size and a significant increase in the optimum moisture content with increasing the percentages of the contaminant. However, with increasing the percentages of the contaminant, there was a slight decrease in the specific gravity and maximum dry unit weight. In addition, there was a considerable decrease in the angle of internal friction and the coefficient of permeability. The angle of internal friction of contaminated soil samples decreased by 18 to 26% with increasing the contaminant percentage from 10 to 100%. The cohesion of soil samples decreased by 7 to 33% with increasing the contaminant percentage, this conclusion is limited to the soil samples contaminated with 10, 20 and 40%, but the cohesion of soil sample contaminated with 100 % of industrial wastewater increased by 7%.

Index Terms - **Industrial wastewater, Soil contamination, Sandy soil, Geotechnical properties.**

I. INTRODUCTION

In recent years, due to population growth, a progressive living standard, and industrial progress, much of the air, water and land have become polluted. Open dumps, chemical and industrial wastes cause these problems. as well as from many other sources.

All types of pollution have direct or indirect effects on ground soil properties. For example, rain falling on a garbage dump will pollute both surface and groundwater systems. The polluted water will attack foundation structures such as footings, caissons, piles and sheet piles. If the polluted water is used for mixing concrete, it will affect the workability and durability of the concrete. In embankment construction, the moisture-unit weight relationship of soil also will be affected.

Extensive literature is available on air and water pollution but little effort has been made to determine how the ground soil responds to these hazardous or toxic substances. At present, most geotechnical projects design and construction are based on the test results followed from ASTM and AASHTO standards. These standards are based on control conditions at room temperature with distilled water as the pore fluid. Since field conditions and the standard control condition are significantly different, many premature or progressive failures frequently occur. To understand soil behavior under in situ conditions, it is necessary to examine soil behavior as closely to the actual condition as possible. To accomplish this goal, we must understand the environmental conditions as they exist on the ground and their interactions over a long-term time period.

II. ROLES AND RESPONSIBILITIES OF GEOTECH ENGINEER:

Geotechnical engineering is the branch of engineering in which we study the performance of soils under the effect of loading forces and soil-water interactions. This information is useful for foundations design, retaining walls, stability of slope, earthen dams, clay liners, and geotextile for waste containment.

Geotechnical engineering is the science gives the information mechanics of soil and rock and their applications practically. It contains the analysis, design and construction of various foundations, slopes, retaining walls, embankments, roadways, tunnels, levees, wharves, landfills and other systems that are made of or are supported by soil or rock.

Transportation: Geotechnical engineers are responsible for construct that roads, highways and railroads, designed and maintained to ensure their long life.

Deep Foundation: All heavy constructions like high-rise buildings, bridges, tall towers, antennas, and essentially anything we see around us has a foundation that is properly designed by a geotechnical engineer to distribute the structure loads to the ground.

Landslides: Geotechnical engineers are also responsible for excavations so that they stay stable, as well as stable natural slopes for the public safety.

Underground Structures: Geotechnical engineers are also responsible for the design and construction of underground structures like tunnels, subways, and underground constructions used for subways, underground highways, railroads, flouting foundation water supply system and waste water storage .

Dams: Geotechnical engineers are also responsible for the design, construction, maintenance and monitoring for the various dams and specially earthen dams which are used for water storage.

Surface Characterization: Geotechnical engineers accomplish a different of tests on site or the laboratory to find out the subsurface conditions. They also responsible for characterize the properties of the various soils and different kind rocks, expensive soils, rocks properties can be recognized before construction.

Landfills: Geotechnical engineers are responsible for the landfills design for safeguard that solid waste not affect the environment and to protect the public health. Modern landfills are erudite engineered infrastructure systems that have very few similarities to waste dumps.

Offshore Structures: Geotechnical engineers are responsible for the stable foundation for off shore structure construction and also for the offshore platforms and various facilities which are used for oil and gas taking out.

Deep Excavations: Geotechnical engineers are also responsible for the stability of deep excavations, by Shoring. Such shoring systems allow the execution of deep excavations in urban areas which is vital for construction of underground metros, drainages, subways in the middle of a city adjacent to existing subways, structures, or infrastructures.

Ground Improvement & Soil Stabilization; Geotechnical engineers use various principles of physics as well as chemistry for modifying the properties of the soil so strength parameters of soils can increase and permeability can decrease and soil can support the structure properly.

Scour & Erosion: Geotech engineers are also responsible for protect the soil from scote and erosion under natural effects like rain, floods, snowfall, cyclones Geotechnical engineers develop policies to mitigate against scouring and erosion actions.

Contamination and Site Remediation: Geo-environment is a new branch which is work related to the environment effect on soil. Soil contamination is a big issue now a day in industrial zones, hence Geotechnical engineers engaged with clean-up the sites that have been contaminated and give a healthy and hygienic environment. Geo-environmental engineers use frequent techniques for removing the contaminants from the ground, many times, without excavating the ground surface.

Introduction Soil Engineering:

The term "soil" can have different meanings, depending upon the field in which it is considered. For geologist, it is a material in the thin zones of an earth surface. within which roots can occur, and which are formed as the products of past surface processes. The rest of the crust is grouped under the term "rock"

To a pedologist, it is the substance existing on the surface, which supports plant life.

To an engineer, it is a material that can be:

- built on: foundations of buildings, bridges
- built in: basements, culverts, tunnels
- built with: embankments, roads, dams
- supported: retaining walls

Soil Mechanics is a discipline of Civil Engineering involving the study of soil, its behaviour and application as an engineering material.

Soil Mechanics is the application of laws of mechanics and hydraulics to engineering problems dealing with sediments and other unconsolidated accumulations of solid particles, which are produced by the mechanical and chemical disintegration of rocks, regardless of whether or not they contain an admixture of organic constituents.

Soil consists of a multiphase aggregation of solid particles, water, and air. This fundamental composition gives rise to unique engineering properties, and the description of its mechanical behaviour requires some of the most classic principles of engineering mechanics.

Engineers are concerned with soil's mechanical properties: permeability, stiffness, and strength. These depend primarily on the nature of the soil grains, the current stress, the water content and unit weight.

III. Literature Review:

Soil contamination is a serious environmental problem and its occurrence is growing around the world. Human activities such as agriculture, mining, and heavy industry lead to the contamination of soil in many ways. In general, the most common contamination of soil occurs in the form of heavy soil in many ways. In general, the most common contamination of soil occurs in the form of heavy metals, petroleum hydrocarbon compounds, and agricultural pesticides. Petroleum hydrocarbon contamination of soil causes alterations of its geotechnical properties. Petroleum hydrocarbon contamination of soil causes alterations of its geotechnical properties. The degree of alteration depends on the soil type and the type and concentration of the contaminant [1]. Clay particles are chemically active and their behavior depends on their mineralogical composition [2]. Zulfahmi et al. [3] investigated the effect of hydrocarbon contamination on the geotechnical properties of artificially oil-contaminated soil. Thiyyakkandi and Annex [4] studied the influence of organic content on the engineering properties of Kuttanad clayey soil. The results of the study indicated that organic content significantly alters the engineering properties of this type of clay; an increase of organic content causes a decrease in both shear strength and compressibility. Zulfahmi et al. [5] studied the effects of oil contamination on granitic and met sedimentary soils by adding different percentages of hydrocarbon to the soil. The results showed a decrease in maximum dry density, optimum moisture content, and undrained shear strength (when increasing oil contents in the soil samples). Kermani and Ebadi [6] studied the effects of crude oil on the geotechnical properties of soil samples obtained from land near the site of the Tehran oil refinery. The results of this study indicated an increase in the angle of internal friction, maximum dry density, compression index, and Atterberg's limits, as well as a decrease in optimum water content and cohesion (when increasing the oil content). Elisha [7] studied the effects of crude oil contamination on the geotechnical properties of soft clay soil. The results of this study showed that contamination causes a decrease in porosity and swelling pressure (when both sorption time and crude oil content is increased). The increase in the strength of the crude oil-contaminated soft clays may be a result of the agglomeration of its particles. Karkush et al. [8] studied the effects of four types of contaminants on the geotechnical properties of clayey soil samples. The contaminants were kerosene, ammonium hydroxide, lead nitrate, and copper sulphate; each was added in two percentages to contaminate soil samples synthetically. The contaminants caused an increase in Atterberg's limits, maximum dry unit weight, the initial void ratio, the compression index, the swelling index, and collapse potential. The contaminants also decreased specific gravity, optimum moisture content, the coefficient of vertical consolidation, and cohesion between soil particles. Karkush and Resol [9] studied the geotechnical properties of sandy soil samples contaminated with different percentages of industrial wastewater. The results of their study showed an increase of the liquid limit and a decrease the particle size, specific gravity, and maximum dry density (when increasing the percentage of contamination). Karkush and Abdul Kareem [10] studied the geotechnical properties of clayey soil contaminated with different percentages of industrial wastewater. The results of the study showed a decrease in the the percentage of finer, Atterberg's limits, the coefficient of consolidation, and shear strength parameters when increasing the concentration of contaminant in the soil samples. Akinwumi et al. [11] studied the effects of different concentrations of crude oil on the physical properties of soil. Crude oil in soil resulted in an increase in the Atterberg's limits and a decrease in the specific gravity, optimum moisture content, and maximum dry unit weight. In this research, the effects of industrial wastewater on the chemical, physical, and mechanical properties of clayey soil samples were investigated. Industrial wastewater is a by-product of the Thi-Qar oil refinery which spills directly onto the soil and causes its contamination. This by-product will henceforth be referred to as total petroleum hydrocarbons (TPH) to avoid the complexity of discussing the effects of the individual components of industrial wastewater on the geotechnical properties of soil.

IV. SAMPLE COLLECTION

The soil samples used in this research were obtained from the Kapalsadi village of Gujarat region, Jhagadia GIDC. located in the Gujarat region of India with geo-referencing coordinates (21° 43' 10.1172" N and 73° 9' 3.6324" E). A part of this site is considered the disposal area many chemical and fertilizer waste. The groundwater table is located between 3 and 3.5 m above ground level. The soil samples were obtained from three locations in the study area; these locations represent the highly contaminated area, the slightly contaminated area and the intact area. The soil can be classified according to USCS as silty clay, and the consistency of the soil is medium to stiff (for Non contaminated soil) and soft to very soft (for contaminated soil. Disturb and Undisturbed both of the samples were collected. from three depths at each location (0.0, 1.5, and 3.0 m), measured from the existing ground level. The soil samples were placed in airtight plastic bags and labelled, and then transported to the soil mechanics laboratory to study the details of their contamination (the physical, chemical, and mechanical properties). The description and designation of soil samples are given in Table 1.

Table 1: Description of soil samples.

Location	Depth	Zone	Soil Description
1	0.0	Highly Contaminated	Light Yellowish silty clay with phosphorous content
	1.5		Light Yellowish soft silty clay
	3.0		Light Yellowish very soft silty clay
2	0.0	Less Contaminates	Yellow soft silty clay with alkalinity
	1.5		
	3.0		
3	0.0	Non-Contaminated	Dark Yellow clay with silt and salt
	1.5		
	3.0		

V. RESULTS AND DISCUSSION

Chemical properties of soil

A soil classification system emphasizes the importance of information about the quantitative composition of soil, which affects the geotechnical properties through chemical reactions between the particles forming the soil. Experimental work includes testing the chemical, physical, and mechanical properties of the intact and contaminated soil samples to measure the effects of soil contamination. The chemical properties of the samples play an important role in their chemical reactions, especially in the case of clayey contaminated soils. Chemical tests were conducted to determine the existence and quantity of various chemical compounds in the soil samples; for example SO3 (ASTM D516), CEC (ASTM D7503), organic matter (OM) (ASTM D2974), Gypsum, Cl-1 (ASTM D512 A), pH (ASTM D4972), TSS (ASTM D5907), and TPH (UV-160A), using nhexane as a blank. In this experiment, the industrial wastewater was measured in terms of total petroleum hydrocarbons (TPH). The physical properties of the samples were tested according to ASTM [12]. These tests include particle-size distribution (ASTM D422), field unit weight (ASTM D2937), moisture content (ASTM D2216), maximum dry density, optimum moisture content (ASTM D1557), specific gravity (ASTM D854), liquid and plastic limits (ASTM D4318), and the falling head permeability test (ASTM D2434). The moisture content of soil is normally calculated using Eq. (3.1), where pore fluid is water alone, but when a liquid contaminant is present and the pore fluid is no longer just water, this equation may not be used.

Table 2: **Chemical properties of soil**

Location	Depth	SO3 %	CEC meq/l	OM %	Gypsum %	CL^{-1}	pH	TSS %	Non-clay minerals		Clay minerals %
1	0.0	0.08	21.89	0.84	1.3	8267	8.63	7.43	50	43	10
	1.5	0.07	21.36	0.81	1.2	9974	8.05	6.24	52	45	11
	3.0	0.07	22.45	0.87	1.0	8256	8.15	6.12	54	41	11
2	0.0	0.1	20.48	0.92	3.8	7564	8.37	1.69	51	39	7
	1.5	0.1	22.36	0.91	4.0	3756	7.98	1.70	53	39	8
	3.0	0.05	19.61	0.97	4.3	7315	8.04	2.39	55	43	8
3	0.0	0.13	18.61	0.89	5.2	7612	8.08	0.0	46	38	13
	1.5	0.11	20.37	0.87	5.5	3765	8.00	0.0	46	40	16
	3.0	0.11	20.21	0.9	5.3	4213	7.76	0.0	47	36	14

Physical properties of soil

Following tests were conducted on both of the contaminated and non-contaminated soils for finding out physical properties of soil. as per IS. For Atterberg limits (L.L, P.L, S.L), grain size distribution, specific gravity, specific gravity, standard proctor test, direct shear test, free swell, soil pH. For determining Atterberg limits the soil sample have to first sieved through a 0.425 mm sieve (#40 mesh). It is advisable L.L test first.

Liquid Limit is a soil water content at which soil changes from a plastic to liquid state. Liquid limit is determined using the Casagrande cup. It contains finding a soil water content which corresponds to the 25 number of blows required to bring together a 13 mm slices of a groove cut into the soil sample. It is difficult to get accurate count so by plotting the graph [Fig-1] get the L.L at 25 blows.

Plastic Limit is a soil water content at the border amid the semi-solid and plastic state. It is obtained as the water content at which a soil should be rolled by palm in to the thread of around 3.2 mm diameter without failure.

Plasticity Index (Ip) is difference between the liquid limit and the plastic limit (Ip = L.L-P.L)

Grain size distribution test had been carried out for finding the percentage of clay and silt contents present in soil samples. Sieve analysis test was ne performed on both of the soil samples.

Specific gravity of a soil is an important parameter for finding the other parameters like compaction curve, void ratio, hydrometer.

Standard Proctor test is a test by which we can find out the Optimum Moisture Content and Maximum Dry Density of the soil samples. Soil compaction parameters can be determinate by this test. It is also required for the various strength and settlement criteria of the foundation.

Direct Shear test is useful for finding out the Shear strength, angle of friction and cohesive strength of the soil sample. Many researchers had concluded that if the cohesion content increasing the frictional angle decreasing.

Soil Permeability test had been carried out for finding the permeability of contaminated as well as non-contaminated soil. Constant head permeability test was used for both of the soil samples. Soil permeability is effect on the Bearing capacity of the soil it is an inverse relation between permeability and bearing capacity. If the permeability is more than less bearing capacity of the soil.

Free Swell test is useful for finding out the swelling potential for the soil which is useful for constructing the foundation.

Soil pH is the Concentration of Hydrogen ion and it is useful parameter for finding out the acidity of the soil. Due to the present of acid content steel which used in foundation goes to corrode and due to that strength of the structure goes to decrease.

Table 2: Index Properties of soil sample:

Location	Depth	G_s	Sand %	Silt %	Clay %	MDD g/cc	OMC %	LL %	PL %	K x 10^{-7} cm/sec
1		2.54	7	21	72	1.923	11	55	32	5.6
		2.61	5	21	74	1.891	13	53	29	3.7
		2.60	6	22	72	1.876	16	57	31	2.8
2		2.70	5	20	75	1.972	14	49	49	4.9
		2.72	4	22	74	1.851	14	46	47	3.4
		2.69	6	19	76	1.872	13	46	44	2.6
3		2.68	6	18	76	1.843	15	48	53	3.8
		2.70	5	20	75	1.841	16	45	50	2.9
		2.72	6	20	74	1.841	16	49	56	1.7

VI. CONCLUSIONS

TPH soil contamination has different effects on the physical, chemical, and mechanical properties of soil samples. The effects depend mainly on the concentration of contaminant in the soil as well as the type of soil, where the geotechnical properties of the contaminated soil samples were affected significantly with the increase of the concentration of the contaminant. In the study area, the concentration of TPH is variable with location and depth, and therefore several soil samples had undergone testing. The results showed that TPH affects the size of particles; the contaminated soil particles become coarser than the particles of intact soil. Also, TPH contamination causes a reduction in the hydraulic conductivity, specific gravity, liquid and plastic limits, natural and optimum moisture contents, and a slight decrease in field unit weight and maximum dry density of soil samples. The compression index and coefficient of consolidation of the contaminated soil samples increased with the increase of TPH concentration, while the void ratio, swelling index, pre consolidation pressure, and constrained modulus of elasticity of contaminated soil decreased with the increase of the TPH content. The cohesion between soil particles decreased significantly with the increase of TPH concentration in the soil samples. Finally, the angle of internal friction decreased with the increase of the TPH content in the samples.

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