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Changes in Engineering Properties of Heavy Metals Contaminated Soil

T Stuthikeerthana
Department of Civil Engineering,
VNR-Vignana Jyothi Institute of Engineering and Technology, Hyderabad
Dr P N Singh
Professor, Department of Civil Engineering,
VNR-Vignana Jyothi Institute of Engineering and Technology, Hyderabad
V ramya Krishna
Assistant professor, Department of Civil Engineering,
VNR-Vignana Jyothi Institute of Engineering and Technology, Hyderabad

ABSTRACT

In this rapidly developing world today, pollution is one of the main risk to the ecosystem and human life. Due to massive industries the soils are polluted by the heavy metals released from them. This contaminated soilsusually becomes useless for agriculture and construction activities. The contaminated soils also have impact on nature. Ground contamination leads to change in engineering properties of soil causing threat to the existing structures and ground water. The current study evaluates the effect of heavy metals like Lead, Zinc, Sodium Chloride, Potassium dichromate and flyash on engineering properties of the contaminated soil. For the experimental work the soil used is red soil, which is brought from a localnursery. The soil is artificially contaminated with lead, zinc, potassium dichromate, sodium dichromate and flyash. Each metal is added to the soil in the proportion of 100gm/kg. Flyash is added in the proportion of 50% to the weight of the soilto check the metals impact present in it on soil. The physical and engineering properties likewere performed on the virgin as well as the contaminated soil. It is observed thatthe liquid limit and plastic limit of the contaminated soil got decreased up to 13% and 36% as compared to the virgin soil. Similarly optimum moisture content decreased for zinc, lead and potassium dichromate up to 24.5%, 14%, 10% respectively and unconfined compressive test increase for lead and zinc up to 63% and 58.6% and for sodium chloride and fly it decreased up to 88% and 56% when compared with virgin soil. There was also an increase in specific gravity of lead contaminated soil up to 10.6%. No significant changes in the engineering properties of the contaminated soils is observed when compared with the virgin soil. Thus in most of the situations, contaminated soil may be reused with proper remediation.

INTRODUCTION

Soils are formed by the mixture of organic matter and minerals, they withhold gases, liquids and several organisms. Soil is an essential part of the natural environment. It is as essential as herbs, animals, rocks, landforms and waters. It plays a crucial role in influencing the plant growth and provides a domain for all inclusive organisms. From the geotechnical engineering aspect soil is one of the most fundamental and key source where the structures are laid or constructed. Due to rapid industrialization and urbanization the soils are directly or indirectly being contaminated. As soils exists in the nature since from the beginning, they are taken for granted by man in fulfilment of his own needs neglecting the contamination and damage caused to the soil. The contaminated soils tend to become futile for further use. The soils are mainly polluted by the wastes that are produced from industries, municipal waste landfills, mining areas, firing range, construction waste sites etc.

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industries and above mentioned sites produce Heavy metals directly into soil causing harm to soil and ground water. Metals like lead, zinc, cadmium, chromium, sodium chloride, cobalt, selenium etc. are hazardous to both ecosystem and human life. These contaminated soils become of no use as the change in their properties make the soil unfit for construction and agriculture. Heavy metal lead contaminated soil after washing with EDTA also exhibited differences in the properties of the soil (Ping Wang et al., 2013)[1]. Diesel oil contaminated soil exhibited a decrease in the results as the percentage of diesel increased from 0-16 percent (Dr.sollygeorge et al., 2014). Black cotton soil contaminated with barium, chromium, zinc, copper, nickel, cobalt and vanadium have showed variation in results like decrease in specific gravity, optimum moisture content and increase in liquid limit and maximum dry density. Soils do show dissimilarities in their results when they come in contact with heavy metals or other unsuitable materials (Arpithapatel 2014). This paper is a study on how soil's physical and engineering properties change when heavy metals and fly ash are added to it individuallyand combined.

EXPERIMENTAL SETUP

Soil used for conducting the tests is red soil, which was brought from a nearby nursery. The soil was crushed to make it free from lumps, oven dried and allowed to pass through 4.75 IS sieve. Physical and engineering tests on this virgin soil was conducted as per relevant IS codes. Five different samples of this virgin soil was prepared and each sample was then contaminated with individual metal contaminants. Heavy metals used for contamination were Lead, Zinc, Potassium dichromate, Sodium chloride and fly ash. Flyash is added as it is mixtures of all metals. Four metalcontaminants were added to the soil in a proportion of 100gm/kg to each individual sample separately. Fly ash was added in the proportion of 50% the weight of soil to the fifth soil sample.The sixth soil sample was prepared in which four metal contaminants and fly ash were added in the proportion 25 gm/Kg to the virgin soil. Physical and engineering properties of these contaminated soil for all these six sampleswere tested following standard IS codes. All the metals were added in powdered form.

METHODOLOGY

Representative soil samples were prepared for the experiments. Tests like Specific gravity, Consistency limits, OMC, MDD, Direct shear and unconfined compressive test were performed. Impact of metals on soil was checked by added them individually and combined. The tests like specific gravity, consistency limits, sieve analysis, standard proctor, direct shear and unconfined compressive test are performed on virgin soil. The same tests were also performed on contaminated soil except of sieve analysis. Thebrief description of tests performed are as follows:Specific gravity [4]: The soil sample was prepared with the contaminant and test on the specific gravity bottle and the values were note and calculated for result.

Consistency limits [6]: Soil sample for liquid limit and plastic limit was take as mentioned in the IS code, the samples are contaminated with heavy metals and the test procedure is carried out.

Standard proctor test [7]: 2.5kg of soil sample passing through 4.75 IS sieve is taken along with the metal contaminants and is compacted using light compaction. Little amount of soil sample for each water content it taken and kept in oven for 24 hours at 120^0 to find out the moisture content.

Direct shear [8]: The soil sample along with metals was prepared and extracted using compaction method. The specimen was place in the apparatus to test the shear. The angle of friction (Ø) and cohesion (C) are found through plotting the graph.

Unconfined compressive test [9]: the specimen is prepared using dynamic compaction and tested on the UCC apparatus for the unconfined compressive strength.

All the physical and engineering tests procedures performed on virgin soil, each metal contaminant and combined heavy metal contaminant are as per IS codes.

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RESULTS AND DISCUSSION

The basic physical and engineering properties of the virgin soil are given in Table-1, the same physical and engineering properties of the six contaminated soil samples are given in Table-2.

S NO	TESTS	RESULTS
1	Specific gravity	2.53
2	Liquid limit (%)	46
3	Plastic limit (%)	36
4	Plasticity index	9.5
5	Soil classification (sieve analysis)	Clayey sand
6	Wet sieve analysis	Percentage of silt and clay = 40.5%
7	Standard proctor test 1. OMC (%) 2.MDD (gm/cc)	 15.5 1.8
8	Direct shear	Ø=38^0 C=0.12kg/cm^2
9	Unconfined compression test q_u (kg/cm^2)	4.21

Table: 1 Basic physical and engineering properties of virgin soil.

HEAVY METALS ADDED TO THE SOIL IN PROPORTION OF 100GM/KG AND FLYASH 50% PER KG							
S No	Tests performed	Sample:1 Lead (Pb)	Sample:2 Zinc (Zc)	Sample:3 Sodium chloride (Nacl)	Sample:4 Potassium dichromate ($K_2Cr_2O_7$)	Sample: 5 Flyash	Sample: 6 All metals combined
1	Specific gravity	2.80	2.55	2.58	2.51	2.33	2.58
2	Liquid limit (%)	43	40	39	42	33	42
3	Plastic limit (%)	38.23	18.66	23.33	24.09	16.77	20.52
4	Plasticity index	4.77	21.34	15.67	17.91	16.23	21.48
5	OMC (%)	14.36	11.7	13.3	13.94	14.2	13.89
6	MDD (gm/cc)	1.930	1.86	1.87	1.83	1.71	1.86
7	Direct shear	Ø=10^0 C=0.45kg/cm^2	Ø=28^0 C=0.4kg/cm^2	Ø=8^0 C=0.45kg/cm^2	Ø=23^0 C=0.35kg/cm^2	Ø=25^0 C=0.65kg/cm^2	Ø=29^0, C=0.5kg/cm^2
8	Unconfined compressive test q_u (kg/cm^2)	6.90	6.68	0.48	3.18	1.85	3.18

Table: 2 changes in the engineering properties of contaminated soil.

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After conducting all the tests, the changes in physical and engineering properties of the contaminated soil are observed. From table2the Lead (pb) contaminated soil the is the sample1 have shown increase in specific gravity up to 10.6% and decrease in flyash contamination up to 7.9%. the Zinc (Zn) contaminated soil have decreased liquid limit, plastic limit and OMC up to 13%, 89% and 24.5% on an individual basis and increase in unconfined compressive strength up to 58.6%. In sample3 that is Sodium chloride (Nacl) contaminated soil the decreaseof 15.2%, 14% and 88% for liquid limit, OMC and unconfined compressive strength was observed. For Potassium dichromate ($K_2Cr_2O_7$) contaminated soil there was decrease in OMC and UCC up to 10% and 24.4% respectively. For Flyash contaminated soil the sample5 the specific gravity and liquid limit have decreased up to 7.4% and28.7% also a decrease in plastic limit and UCC was noticed up to 52.7% and 56% subsequently. For the sample6 which is the all metals contamination the change of decrease in plastic limit was up to 41.6% also the change of decrease in OMC and UCC up to 10.5% and 24.4% was observed. The angular frictional value (Ø) for was Lead (Pb) and Sodium chloride (Nacl) decrease up to 73.6% and 78.9% when compared with virgin soil.

CONCLUSIONS

The results show that different contaminants have different effect on the physical and engineering properties of the soil. The impact of heavy metals on the red soil exhibit several change, from the table2 it is observed that the specific gravity for unconfined compressive strength got increased. For Sodium chloride contaminated soil there was decrease in OMC and UCC. The plastic limit and liquid limit for decreased for Zinc and Flyash. The angle of friction (Ø) decrease for Lead, Sodium chloride and all metals contamination. The cohesion value (C) increased for Lead, Flyash and Potassium dichromate. Therefore no significant changes in the engineering properties of the contaminated soils is observed when compared with the virgin soil. Thus in most of the situations, contaminated soil may be reused with proper remediation.

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