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Change in Engineering Properties of Black Cotton Soil due to Acid Contamination

Sojil Jain
M. E. Students,
Department Of Civil Engineering
Jabalpur Engineering College
Jabalpur

Prof. Rajesh Jain
Associate Professor,
Department Of Civil Engineering
Jabalpur Engineering College
Jabalpur

Abstract: **Soil is an important element in construction of any civil engineering structure as almost every structure rests on soil and transfers its load to ground. Thus this makes it important for geotechnical engineer to have a good knowledge of behavior of soil before and after soil-pollutant interaction. With the increase in industrialization, discharge of anthropogenic pollutant has been increased, when this mixed with soil alters its property and this entire mechanism of polluting a soil is called soil contamination. Emphases are being made through this research to understand the variation in engineering properties of virgin soil and the acid contaminated soil. For this purposes high plastic black cotton soil passing from 4.75mm sieve is mixed with different acids of 0-15% concentration and observations were made on compaction characteristics, hydraulic conductivity, unconfined compressive strength, shear parameter and CBR value. The result indicates that the acid contamination of black cotton soil adversely affects its engineering properties.**

Keywords: Soil Contamination, Anthropogenic Pollutants, Engineering Properties of Soil.

INTRODUCTION

Soil is being contaminated by anthropogenic sources such as leakage from waste containment facilities, accidental spills and industrial operations. These pollutants have direct or indirect effects on soil properties. With increase in industrialization problems like landslide and settlement of foundation has increased because soil-pollutants interaction adversely affect the geotechnical properties of soil. Thus conventional knowledge of simple soil along with knowledge about variation in geotechnical properties due to pollutant is important for geotechnical engineer to construct a stable and durable structure. Acids are considered as pollutant in this work to determine the variation in properties of soil. Few works were done in past in this related field which give information as Masashi K (1997) suggest that the enhance rate of leaching of cation and absorption of hydrogen ion, sulphate ion and nitrate ion changes the engineering properties of soil. Sivapullaiah P.V (2000) has reported the addition of sulphate to soil adversely affect the strength parameter of black cotton soil. Ramesh et al (2008) investigate the effect of sulphuric acid on compaction and strength properties of black cotton soil and suggest gradual decrement in those properties. Sharma Pankaj (2012) investigates the effect of acid rain on soil and suggests that due to the reduction in attraction between soil particles due to leaching of cation reduces the overall strength of soil. Munehide Ishiguro (2010) has reported the reduction of permeability of soil with increase in acid concentration due to change in repulsive potential energy cause by soil-acid interaction. Ramesh H.N, Venkatarajan Mohan S.D and Abdul Bari (2008) have reported the adverse effect of phosphoric acid and sulphuric acid on engineering characteristics of black cotton soil. Thus it is known that the presence of acid in soil can change the behavior of soil though different acids shows different trend. In this research work, a detail experimental investigation is carried out to understand the effect of sulphuric acid, phosphoric acid and nitric acid on engineering properties of black cotton soil.

MATERIALS AND METHEDOLOGY

Black Cotton Soil

The effect of acid on soil is analyzed on black cotton soil collected from a village Archha, Jabalpur (M.P.). The particle size distribution of collected soil sample is shown in figure 1. Number of tests was performed on dried sample of black cotton soil and the observed geotechnical properties of uncontaminated soil are listed in table 1.

Characteristics	Result
Specific Gravity	2.32
Sand %	2
Silt %	67
Clay%	31
Liquid limit %	72.21
Plastic limit %	28.32
Soil Type	CH
Shrinkage limit %	2.98
Differential Free Swell %	60
Optimum Moisture Content %	19.34
Maximum Dry Density (g/cc)	1.617

Permeability (cm/sec)	$1.2x10^{-4}$
Unconfined Compression Strength (KN/m^2)	142.69
Cohesion (KN/m^2)	0.895
Angle of Internal Friction (^{o})	22.549
CBR %	1.115

Table 1: Geotechnical properties of black cotton soil

Figure 1 shows the particle size distribution curve of black cotton soil. And according to IS classification, this soil is classified as "Clay with high plasticity (CH)".

Contaminating Agents

Sulphuric Acid (H_2SO_4), Phosphoric Acid (H_3PO_4) and Nitric Acid (HNO_3) are used in varying concentration to synchronize with industrial pollutant.

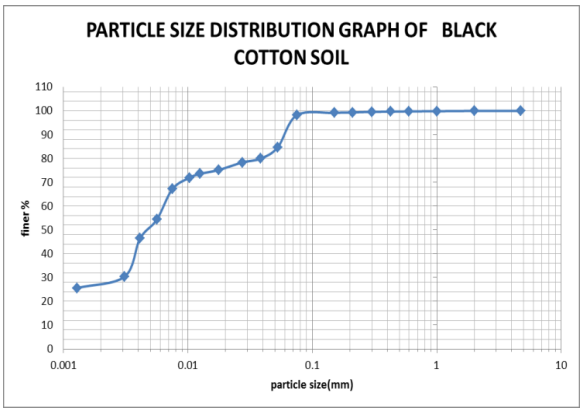

Fig .1 Particle Size Distribution Curve

Methodology

Collected black cotton soil is dried in oven to remove the moisture content, then acids in concentration of 2%, 4%, 6%, 8%, 12%, 15% with water is mixed with soil. This mixture of soil, acid and water is transferred to the polythene bags to allow acid to react with soil for short period of 3days. After 3days the prepared sample is oven dried and tests were performed. The nomenclature of contaminated soil sample is given in table 2.

Sample 1	Soil + 0% acid concentration
Sample 2	Soil+ 2% acid concentration
Sample 3	Soil + 4% acid concentration
Sample 4	Soil+ 6% acid concentration
Sample 5	Soil + 8% acid concentration
Sample 6	Soil+ 12% acid concentration
Sample 7	Soil + 15% acid concentration

Table 2: Sample Nomenclature

LABORATORY TESTS

The experiments were performed on prepared sample of simple and contaminated soil to determine compaction characteristics, permeability, unconfined compressive strength, shear parameters and CBR value.

Modified proctor compaction test of the soil specimen was determined as per IS: 2720 (part 8) - 1983.
Unconfined compressive strength test of the soil specimen was determined as per IS: 2720 (part10) – 1991.
Shear strength parameters of a soil specimen tested unconsolidated undrained triaxial compression without the measurement of pore water pressure was determined as per IS: 2720 (part 11) – 1993.
Permeability test of the soil specimen was determined as per IS: 2720 (part 17) – 1986.
Laboratory determination of CBR for the soil specimen was done as per IS: 2720 (part 16) -1987.

RESULTS AND DISSCUSION

COMPACTION CHARACTERISTICS

Figure 2 and 3 shows the variation in optimum moisture content and maximum dry density for different concentration of acid mixed with soil. [7] reports that with the increase in acid concentration OMC gets increased up to some particular percentage of acid concentration and then it starts to decrease. The similar results were observed, in case of phosphoric acid OMC gets increased till 6% acid concentration and then it declines while OMC gradually increases when nitric acid and sulphuric acid is mixed in increasing concentration. However, overall OMC has increased if compared with OMC of simple soil with all three acids.

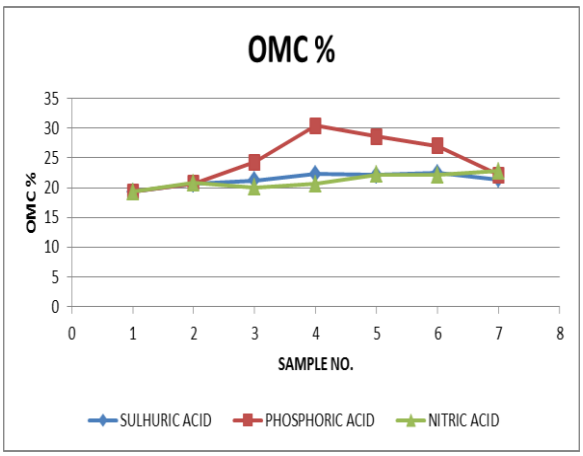

Fig .2 Effect of acid concentration on Optimum Moisture Content

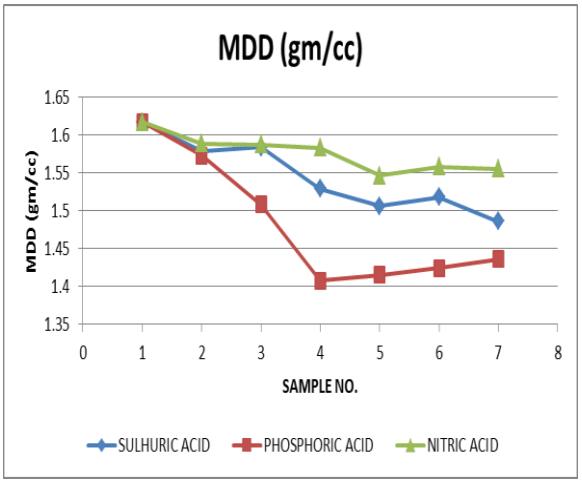

Fig .3 Effect of acid concentration on Maximum Dry Density

Maximum dry density for simple black soil was 1.617g/cc. [7] reports gradual decrement in MDD for increasing acid concentration and the similar variation was observed when soil is mixed with different concentration of sulphuric acid, phosphoric acid and nitric acid. In case of phosphoric acid, MDD decreased by high rate till 6% acid concentration and then it slightly increase. Overall MDD decreases with increasing acid concentration, the order variation in MDD is observed as $H_3PO_4 > H_2SO_4 > HNO_3$.

PERMEABILITY

Figure 4 shows variation of permeability for various acid concentrations of sulphuric acid, phosphoric acid and nitric acid in the pore fluid of black cotton soil.

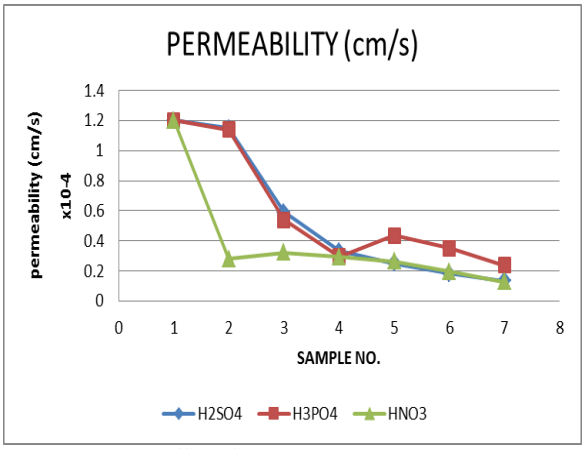

Fig .4 Effect of acid concentration on Permeability

[1] suggests the decrement in permeability of soil with increasing acid concentration due to structural change of soil and increase in negative charge. Similar variation has been observed as initially the permeability of simple black cotton soil was $1.2x10^{-4}$cm/sec which decreases with increasing acid concentration to order of 10^{-5} cm/sec in all three acids.

UNCONFINED COMPRESSIVE STRENGTH

[6] reports the decrease in unconfined compression strength of soil for increasing acid concentration and similar results were observed when soil is mixed with different concentration of sulphuric acid, phosphoric acid and nitric acid. Figure 5 shows the variation of unconfined compressive strength for various concentration of acid. It is observed that UCS with sulphuric acid and nitric acid decreases gradually with increase in acid concentration but in case of phosphoric acid UCS decreases till 12% acid concentration and shows some increment at 15% concentration.

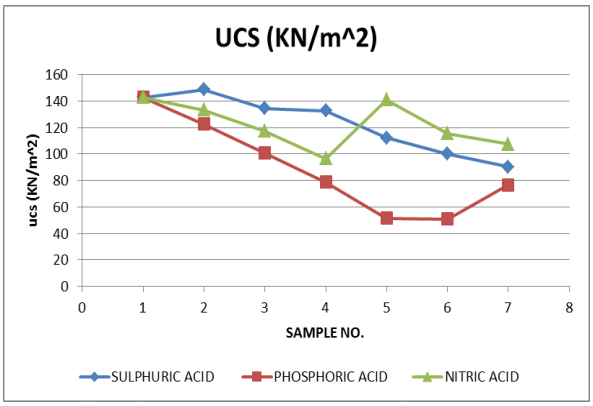

Fig .5 Effect of acid concentration on Unconfined Compressive Strength

SHEAR PARAMETER

Figure 6 and 7 shows the variation of cohesion and angle of internal friction for different acid concentration of sulphuric acid, phosphoric acid and nitric acid. In previous research work, [2] reports that shear parameter "c and Φ" decreases with increasing acid concentration due to reduction in the electric forces as concentration of exchangeable cations reduced on acid treatment. In this case, results are slightly different as "c" increases initially at 2% concentration of sulphuric acid and phosphoric acid and the gradual decrease is observed with increase in acid concentration for both acids. However, in case of nitric acid "c" increases at 2% concentration and then decreases till 6% concentration, it again shows a sudden increase at 8% concentration and then gradually decreases. Initially "c" for simple black cotton soil was $0.895KN/m^2$ which overall decreases to lower value for all three acids.

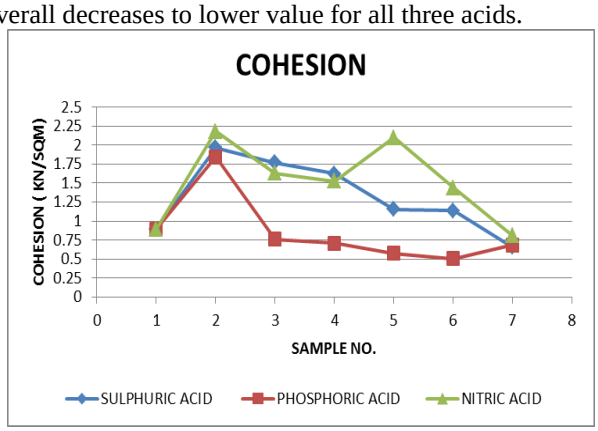

Fig .6 Effect of acid concentration on Cohesion

Figure 7 shows a overall decrement of "Φ" for increasing concentration of sulphuric acid in pore fluid of soil. "Φ" decreases from 22.549º for simple black cotton soil to 21.083º at 15% sulphuric acid concentration.

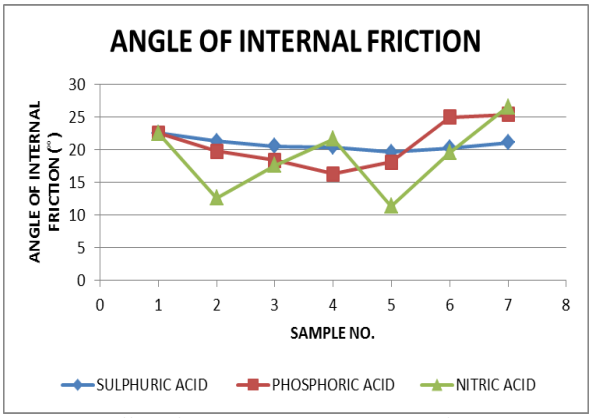

Fig .7 Effect of acid concentration on Angle of Internal Friction

While "Φ" decreases from 22.549º for simple soil to 16.304º for soil mixed with 6% phosphoric acid concentration and then it show increment for higher concentration of phosphoric acid to 25.384º at 15% acid concentration with soil. In case of soil mixed with different concentration of nitric acid, "Φ" decreases to 11.349º at 8% concentration and then increases at higher acid concentration to 26.584º at 15% nitric acid concentration.

CALIFORNIA BEARING RATIO

Figure 8 shows the variation of CBR value for various concentrations of sulphuric acid, phosphoric acid and nitric acid in the pore fluid of black cotton soil. An overall reduction in CBR % was observed for soil mixed with increasing concentration of sulphuric acid and nitric acid which reduces from 1.115% for simple black cotton soil to 0.677% at 8% sulphuric acid concentration recorded as lowest CBR for this acid which increases slightly to 0.916% at 15% acid concentration and gradual decrement for nitric acid from 1.115% at 0% acid concentration to 0.677% at 15% nitric acid concentration. While in case of soil mixed with different concentration of phosphoric acid CBR% decreases at 2% acid concentration to 1.036% and then increased to 2.112% at 15% acid concentration.

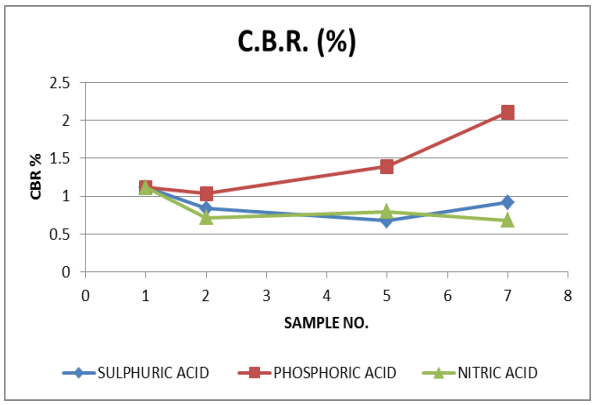

Fig .8 Effect of acid concentration on C.B.R.

CONCLUSION

A study has been conducted to investigate the probable effect of acid contamination on black cotton soil. H_2SO_4, H_3PO_4 and HNO_3 were used as contaminating agent which results in change in physic-chemical characteristics of soil due cation exchange. Following conclusion based on the test results in this study are drawn:

1. OMC increases with increasing concentration of acid while MDD for black cotton soil decreases with increasing amount of acid.
2. Permeability of black cotton soil reduces with addition of acids of increasing concentration. This decrement is due to structural change of soil and increase in negative charge.
3. The UCS and shear parameter reduces with increase in acid concentration, which indicates the overall reduction in strength of soil due to acid contamination.
4. CBR for sulphuric and nitric acid decreases with addition of acid of increasing concentration, on the other hand it slightly increases with adding phosphoric acid.

Data obtained suggests the deterioration of soil when it comes in contact with acidic pollutant; however magnitude of damage depends on the concentration and type of acid.

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