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Effects of Acid and Base Contamination on Geotechnical Properties of Clay

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Abstract: ***Industrial advancements have led to discharge of variety of pollutants in the form of effluent into the soil. Such effluents consist of acid and base wastes. The pollutants and wastes tend to contaminate soil. The geotechnical property of polluted soil gets altered. The study is carried out to determine the effects of acid and base contamination on the geotechnical properties of clay. Clay of high compressibility (CH) is taken up for study in this work. The effects of contamination in soil are studied by adding the contaminants in the laboratory. The properties such as particle size analysis, plasticity, differential free swell, compaction, unconfined compressive strength are studied. The acid contaminants used are hydrochloric acid, nitric acid and sulphuric acid. The base contaminants used are sodium hydroxide, potassium hydroxide and calcium hydroxide. Clay sample is collected from Mullai nagar, Coimbatore. The geotechnical properties are evaluated. The clay samples are then contaminated by adding acids and bases in varying percentages such as 5%, 10%, 15%, 20%, 25% and 30%. The geotechnical properties of acid contaminated and base contaminated clay are studied.***

Keywords: compressibility, contaminants, compaction, unconfined compressive strength

1. Introduction

Industrial activity is necessary for socio-economic progress of a country but at the same time it generates large amounts of solid and liquid waste. But increased industrialization, high population growth and uncontrolled exploration of natural resources have resulted in environmental degradation, bringing in unanticipated changes in engineering behaviour of soils. Pollution of soil has challenged current soil mechanics concepts. A geotechnical engineer is concerned about the impact on soil as most of the effects of soil contamination are mainly due to changes in the geotechnical behaviour of foundation soil.

The task of geotechnical engineer has become complicated, as conventional geotechnical principles cannot be extended to contaminated soil behaviour. Accordingly it seems imperative that handling of potential pollution problems in soil must be based on the prediction of likely or possible impairment of the functioning of soil. In practice this implies in the first place knowledge of composition of influx as well as the soil. Next the influence of interactions of the compounds of interest with the solid phase on soil behaviour is to be explored. Planning suitable preventive and remedial measures to safe utilization of the site is another challenging task. The main types of contaminants include various substances such as inorganic acids, alkalis, sulphates, organic contaminants, toxic or phytotoxic metals and combustible substances.

All types of pollutants can change the behaviour of soils to some or large extent. Soil acidity and alkalinity are common in all regions where precipitation is high enough to appreciable quantities of exchangeable base forming cations (Ca2+, Mg2+, K+ and Na+) from the surface layers of soil. When certain minerals present in soil are disturbed or exposed to atmosphere, it gets oxidized to form acids or gets reduced to form bases. Many types of acid and base wastes are released in soil from mining operations, industries, drainage leakages, underground reservoirs and waste disposal sites. The unintended modification of soil properties due to interaction with pollutants can lead to various geotechnical problems. The effect of pollutants can be very similar to the effect of weathering. The nature of soil pollutant interactions depends on the mineralogy of soil and type and concentration of the pollutant. There is a need to understand the geotechnical behavior of acid and base contaminated soils.

In Tamil nadu, factories like soap industries, iron and steel industries, tanneries, textile industries etc., pollute both water and soil. Polluted water changes the properties of soil. In this thesis work the effects of acid and base contamination on some of the geotechnical properties of clay was analyzed by artificial contamination of acids and bases in varying percentages such as 5%,10%, 15%, 20%, 25% and 30%.

2. Material

2.1 Soil

Soil sample was collected from the location 11.0267°N 76.9165°E (Mullai nagar, Coimbatore. The soil sample is analyzed for its various physical, engineering and strength properties. The property of soil is shown in the following table 1.

2.2 Acid Contamination

Hydrochloric acid (HCL), Nitric acid (HNO_3) and Sulphuric acid (H_2SO_4) were prepared with one normality (1N). The soils minus gravel fraction were oven dried. Acid contaminants were added in different percentage namely 5%, 10%, 15%, 20%, 25% and 30% by weight. The contaminated samples were put in dessicator for about four days.

Table 1: Properties of soil

S.No	Properties	Results
1.	Initial Moisture Content	13%
2.	Specific Gravity	2.62
3.	Percentage of Gravel	2.7%
	Percentage of Sand	39.7%
	Percentage of Silt	26.7%
	Percentage of Clay	30.9%
4.	Liquid limit	57.5%
	Plastic limit	16.7%
	Shrinkage limit	14.6%
	Plasticity Index	40.8%
5.	Differential free swell	40.8%
6.	Soil Classification	CH
7.	Optimum Moisture Content	24.3%
	Maximum Dry Density	1.669 g/cc
8.	Unconfined Compressive Strength	0.223N/mm^2
	Cohesion	0.112N/mm^2

2.3 Base Contamination

Sodium hydroxide (NaOH), Potassium hydroxide (KOH) and Calcium hydroxide ($Ca(OH)_2$) were prepared with one normality(1N). The soils minus gravel fraction were oven dried. Base contaminants were added in different percentage namely 5%, 10%, 15%, 20%, 25% and 30% by weight. The contaminated samples were put in dessicator for about seven days.

3. Experimental Program

General

The experimental study involves Consistency test, Free Swell test, Specific Gravity test, Standard Proctor's Compaction test, pH test and Unconfined Compressive Strength test on natural and contaminated soil sample with varying percentage of acids and bases contaminated samples namely 5%, 10%, 15%, 20%, 25% and 30%.

3.1 Atterberg's Limits Test

Consistency test was performed on the clay sample contaminated with different amount of acids and bases such as 5%, 10%, 15%, 20%, 25% and 30%. From this test the consistency characteristics of the contaminated samples were studied.

The consistency test was conducted as per IS: 2720 (Part 5) – 1985 and IS: 2720 (Part 6) – 1972 on acid contaminated and base contaminated samples and results are shown in figure 1, figure2, figure 3and figure 4.

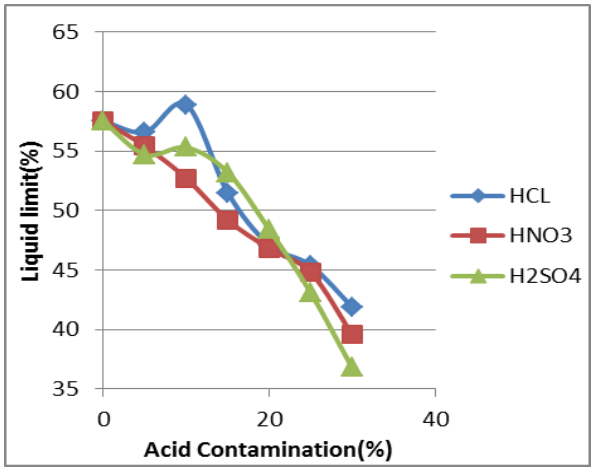

Figure 1: Liquid limit (LL) results for acid contaminated clay

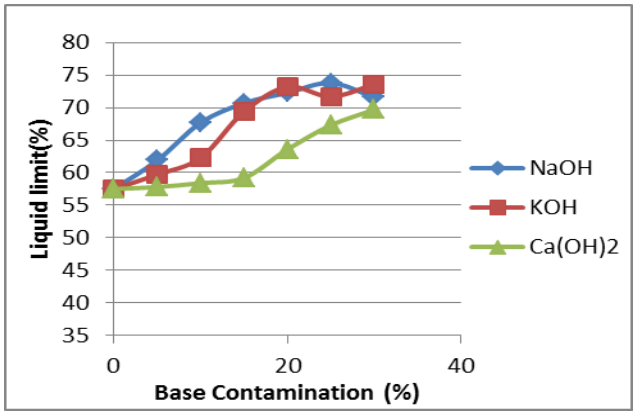

Figure 2: Liquid limit (LL) results for base contaminated clay

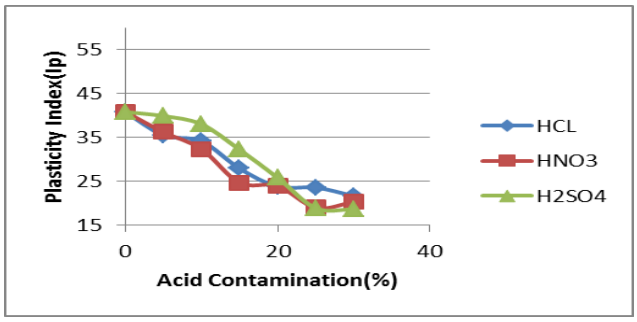

Figure 3: Plasticity Index (Ip) results for acid contaminated clay

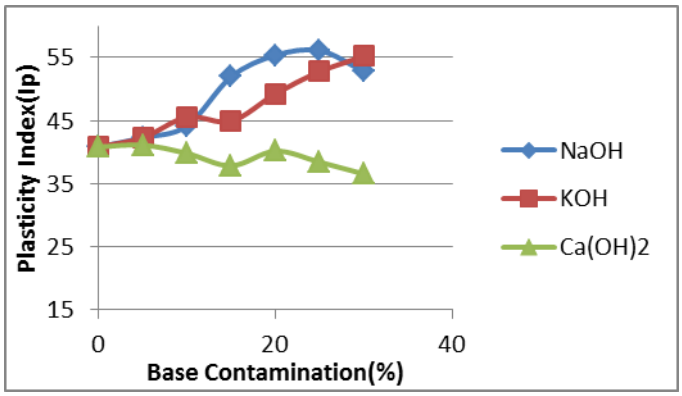

Figure 4: Plasticity Index (Ip) results for base contaminated clay

3.2 Free Swell Test

Free swell test was performed on the acid contaminated and base contaminated clay with varying percentages such as 5%, 10%, 15%, 20%, 25% and 30%. On contaminated clay, the free swell results of acid contaminated clay are charted as shown in the figure 5 and the free swell results of base contaminated clay are charted as shown in figure 6.

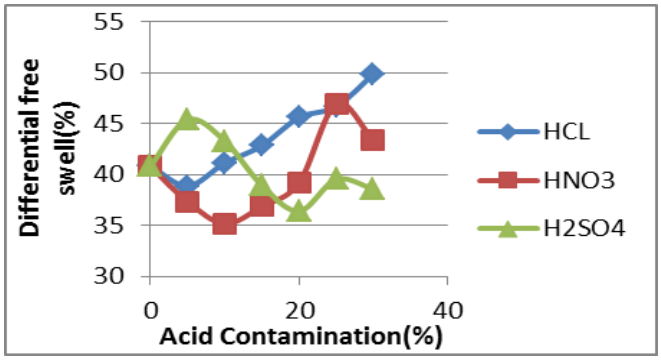

Figure 5: Differential free swell results for acid contaminated clay

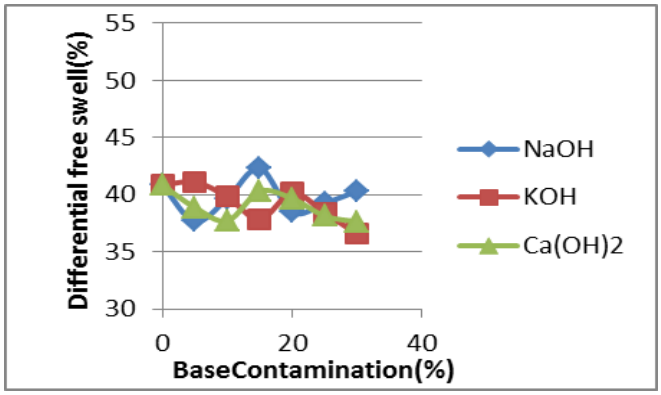

Figure 6: Differential free swell results for base contaminated clay

3.3 Specific Gravity Test

Specific gravity (density bottle) test was performed on the acid contaminated and base contaminated clay with different amount of acids and bases such as 5%, 10%, 15%, 20%, 25% and 30%.

Specific gravity test was conducted as per IS 2720 (Part III/sec 1) – 1980 on acid contaminated and base contaminated clay and readings are obtained.

3.4 Standard Proctor's Compaction Test

Standard proctor compaction test was performed on the acid contaminated and base contaminated clay sample contaminated with varying amount of acids and bases such as 5%, 10%, 15%, 20%, 25% and 30%. From this test the compaction characteristics of the contaminated samples were studied by determining OMC and MDD respectively. the optimum moisture content and maximum dry density of the acid contaminated and base contaminated samples and readings are charted as shown in the figure 7 and figure 8.

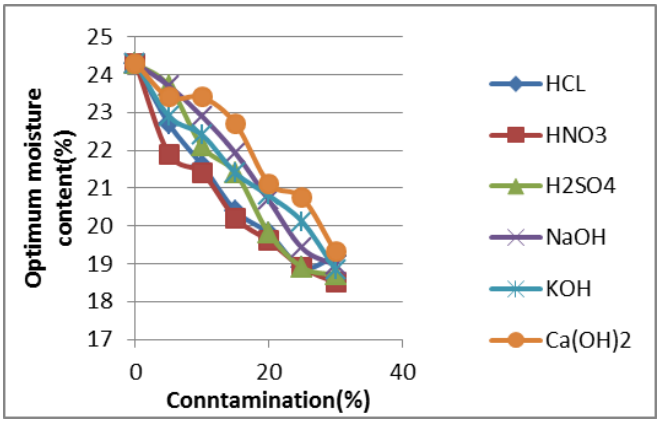

Figure 7: Optimum moisture content for acids and bases contaminated clay

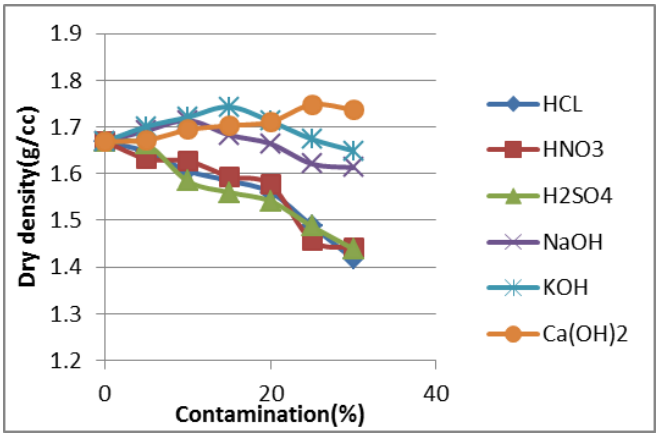

Figure 8: Dry density results for acids and bases contaminated clay

3.5 Unconfined Compression Test

Unconfined compression test was performed on the acid contaminated and base contaminated sample contaminated with varying amount of acids and bases such as 5%, 10%, 15%, 20%, 25% and 30%. From this test the shear strength characteristics of the contaminated samples were studied by determining unconfined compression strength and undrained cohesion.

Unconfined Compression Strength and Undrained Cohesion

The unconfined compression strength and undrained cohesion was determined in the laboratory by conducting unconfined compression test. The test was carried out as per IS 2720 (Part 10) – 1991 in the contaminated samples and the unconfined compression strength and undrained cohesion of the acid contaminated and base contaminated samples are charted in the Figure 9.

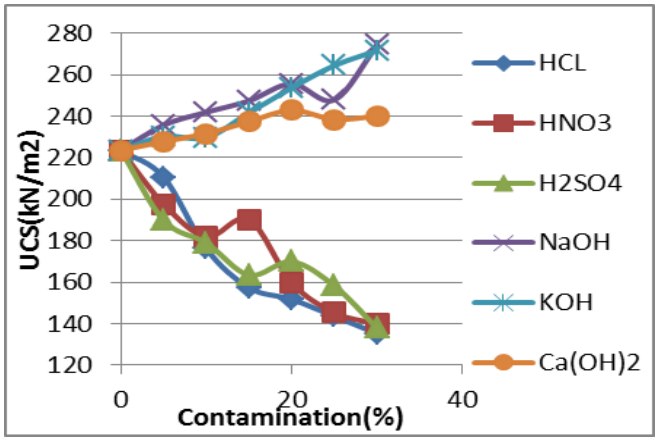

Figure 9: Unconfined compressive strength for acids and bases contaminated clay.

3.6 pH TEST

The soil pH is a measure of the acidity or basicity in soils. pH is defined as the negative logarithm (base 10) of the activity of hydrogen ions. It ranges from 0 to 14, with 7 being neutral. A pH below 7 is acidic and above 7 is basic. The pH test was conducted using pH meter as per IS 2720 (Part 26) – 1987 in order to determine the pH value.

The pH of the clay sample is found as 9.78. Thus the natural sample taken is basic in nature. The pH values of contaminated samples are charted in Figure 10.

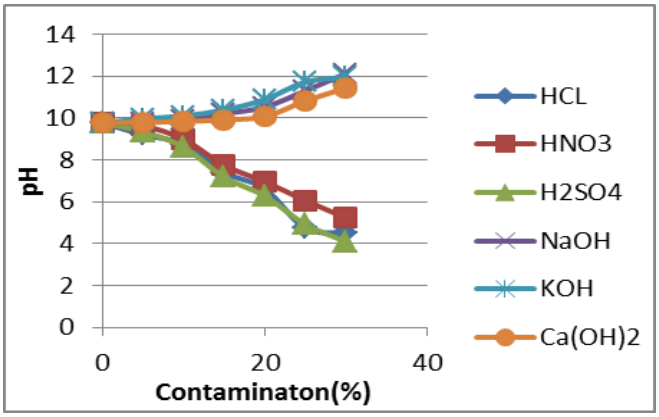

Figure 10: pH results for acids and bases contaminated clay

4. Results And Discussion

4.1 Acid Contamination

From the results it is observed that the liquid limit of the sample contaminated with acid decreases with increase in the percentage of acid content. The plastic limit of contaminated clay increases up to 10% contamination and then gradually decreases. The shrinkage limit values have no significant variation. The plasticity index decreases with increase in the percentage of acid content which indicates the problematic nature of the soil.

From this it is clearly understood that the contaminant decreases the liquid limit of acid contaminated clay by 27%, the plastic limit decrease by 21%. Therefore the plasticity characteristics of acid contaminated clay decrease by 46.87% with contamination.

The free swell of the acid contaminated samples increases by 28.27% with increase in acid content whereas the specific gravity decreases by 15.56% with increase in acid content.

The contaminant acid decreases optimum moisture content of sample by 21% and dry density of the sample decreased by 12.7%. The shear strength of clay contaminated with acid decreases by 39.5% with increase in acid content.

4.2 Base Contamination

From the results it is observed that the liquid limit of the sample contaminated with base increases with increase in the percentage of base content. The plastic limit and shrinkage limit values have no significant variation. The plasticity index increases with increase in the percentage of base content which indicates the problematic nature of the soil.

From this it is clearly understood that the contaminant increases the liquid limit of base contaminated clay by 24.5%, the plastic limit increases by 12.6%. Therefore the plasticity characteristics of base contaminated clay increase by 29.4% with contamination.

The free swell of the base contaminated samples increases by 8.35% with increase in base content whereas the specific gravity increases by 4.2% with increase in base content.

The contaminant base decreases optimum moisture content of sample by 22% and dry density of the sample decreased by 3.47%. The shear strength of clay contaminated with base decreases by 22.7% with increase in base content.

5. Conclusions

An extensive laboratory testing program was carried out to study the effects of acid and base contamination on clay sample. The acid and base was added at an increment of 5% by weight of dry samples to make the soil artificially contaminated. The following conclusions are drawn from the experimental study carried out.

5.1 Acid Contamination

1. The liquid limit of clay sample decreases with acid contamination.
2. The plasticity index decreases, thus the soil changes from highly plastic (natural sample)to medium plastic (for 30% acid contamination)
3. The differentials free swell values show gradual increase with increase in acid contamination.
2. The specific gravity of acid contaminated clay decreases with contamination.
3. The optimum moisture content and maximum dry density decreases with increase in acid content
4. The shear strength decreases with increase in acid contamination

5.2 Base Contamination

1. The liquid limit of clay sample decreases with base contamination.
2. The plasticity index increases with increase in base content
3. The differentials free swell values show gradual decrease with increase in base contamination.
2. The specific gravity of base contaminated clay increases with contamination.
3. The optimum moisture content decreases with increase in base contamination. The maximum dry density increases upto 10% contamination
4. The shear strength increases with increase in base contamination.

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