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Effect of pH Variation of Pore Fluid on The Geotechnical Properties of Fly Ash Stabilized Clay

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Abstract: ***Industrial advancement has merits and demerits. One of the demerits is discharge of various waste materials in the form of effluents. This effluent sweeps in to the soil and thus pore fluid properties get altered. The changes in the properties of pore fluid have a great effect in the soil behavior. When this soil is used for infill or foundation for the structures it is necessary for a geotechnical engineer to understand changes in engineering properties of soil and taking necessary precautions according to the variations in the soil behavior. This paper presents a study on the topic, effect of pH variation of pore fluid on the geotechnical properties of fly ash stabilized clay. Fly ash stabilized Kuttanad clay, distilled water, NaOH and Acetic acid (25% & 50%) were used. According to the test results there is an increase in the liquid limit and plasticity index properties of the Acetic acid and NaOH contaminated sample. Acetic acid contaminated sample shows a reduction in swelling and compression index.***

Keywords: liquid limit, plastic limit, compression index, swelling index and pore fluid.

1. Introduction

1.1 General

Kuttanad clay is well known in its properties such as very low shear strength and high compressibility. Clay has high strength in its dry state, but characteristics changes with presence of water. Pore fluid property is an important factor which affects the properties of clayey soil. Industrialization results in contamination of various sites. Large storage units, mines, industrial buildings were disposing their waste materials in the form of effluents in to the soil. When this effluent dissolves with pore fluid in the soil, characteristics of pore fluid get altered and thus the properties of the soil highly affected. When this soil is used for infill or foundation for the structures it is necessary for a geotechnical engineer to understand changes in engineering properties of soil and taking necessary precautions according to the variations in the soil behavior. This paper presents the study on the effects of the pH variations of pore fluids on the geotechnical properties of fly ash stabilized clayey soil. Fly ash stabilized Kuttanad clay, distilled water, NaOH and Acetic acid (25% & 50%) were used. According to the test results there is an increase in the liquid limit and plasticity index properties of the soil. Acetic acid contaminated sample shows a reduction in swelling and compression index.

Characteristics of clayey soil is depends upon compositional and environmental factors. Type and amount of soil minerals, pore water composition, size and shape of soil particles and absorbed cations are the main compositional factors. Environmental factors are confining pressure, temperature, fabric, water content and density. Two main soil minerals are montmorillonite and kaolinite. The basic structural unit of Kaolinite mineral consists of an alumina sheet combined with a silica sheet. The kaolinite material is electrically neutral. However, in the presence of water, some hydroxyl ions dissociate and lose hydrogen and leave crystal with a small residual negative charge. The flat surface of the mineral attracts positive ions and water. A thick layer of adsorbed water is formed on the surface. In the case of kaolinite mineral diffuse double layer theory is insignificant.

The behavior of kaolinite minerals depends on the vander waals force of attraction between the particles. In the presence of organic solute such as acetic acid vander waals force of attraction between the particles is high so it transforms into clusters through flocculation process and provide high resistance. This makes an increase in the value of unconfined compressive strength and cohesion. But in the case of montmorillonite mineral the basic structural unit consists of an alumina sheet sandwiched between two silica sheets. Oxygen ions of silica sheets form a link which connects two successive silica sheets. Diffuse double layer is highly significant in montmorillonite mineral in the presence of organic solutes. In Kuttanad clay Kaolinite mineral is more predominant. In this study Atterberg limit test, consolidation test, swell index test, unconfined compression test and pH tests were conducted on the soil samples to arrive at the results. SEM test were conducted on the soil samples before and after adding acids and bases. Swelling and compression index of the acid contaminated samples showed a decrease in their values.

1.2. Objectives of the Study

Based on the introduction the main objectives of the study are:

- Analyze the variations in the geotechnical properties of fly ash stabilized clay under the presence of different pore fluids.
- To check the unconfined compression strength and cohesion for various samples
- Determine compression and swelling index for various samples.
- Conduct SEM test on the samples before and after adding acids and bases.

2. Literature Review

1) ***Mohammed fadhil obaid, Dr. V. C. Agarwal, and Prabhat kumar sinha*** (2014) studied variations involving the geotechnical properties of a highly plastic clayey soil in the presence of various organic solutes. Geotechnical properties of plastic clayey soil with pure water, acetic acid, isopropyl alcohol, ethanol and methanol (40% and 80%) were investigated through a series of soil tests such as Atterberg limit tests and consolidation tests. Depending on the collapse of the diffuse double layer under the effect of the organic fluids, less liquid was held in the pores between the particles. There is a significant decrease in the swelling and compression index soil samples.
2) ***Fa-xing Huang and Hai-jun Lu*** (2014) done a study on the Atterberg Limits of Clay Contaminated by Oil. The study showed that oil played a significant role in changing the value of Atterberg limits of oil-contaminated soil. Up to 3% oil contamination the change in Atterberg limits is less, but when the oil concentration is higher than 3%, the plastic limits of crude oil contaminated sample get reduced and liquid limit increase. The reduction in the plastic limit was comparatively low.
3) ***Umadevi.S and Hashifa Hassan*** *(2014)* conducted a Study on the Effect of Rice Husk Ash & Lime on the Properties of Soft Clay. Kuttanad clay is very soft in its character so it is necessary to adopt a suitable method to improve the bearing capacity of clay. In this study, rice husk ash (RHA) and lime are mixed with the soil to improve its load bearing capacity. The studies showed that 15 %RHA and 6% lime gave the optimum CBR values.
4) ***Prof. J.M. Raut, Dr. S.P. Bajad and Dr. S.R. Khadeshwar (2014)*** conducted study on Stabilization of Expansive Soils Using Flyash and Murrum. Important findings from the study are when the percentage of Murrum additive increases there is a reduction in the plasticity of the clay murrum mixture, but MDD values increases and the corresponding OMC values decreases. Similarly when the quantity of fly ash increases the plasticity of the clay fly ash mixture shows an increase, the optimum moisture content value increases and corresponding maximum dry density value MDD values.
5) ***M. H. Ghobadi ,Y. Abdilor and R. Babazadeh*** (2013) were studied the results of geotechnical and mineralogical investigations on lime treated clay soils and effects of pH variations on their shear strength parameters. Various samples of lime treated and untreated clay mixed with pore fluid having pH(9,7,5,3) subjected to different laboratory tests to arrive at the results. The tests results indicated that the for lime untreated clays undrained shear strength parameter increased significantly when pH of pore fluid is high (pH=9)or a low pH (pH = 3).
6) ***S. Prakash, Dr.P.D.Arumairaj*** (2013) were carried out study on the Effects of Acid and Base Contamination on Geotechnical Properties of Clay. Liquid limit, plasticity index, shear strength, optimum moisture content and specific gravity decreased with increase in acid content.
7) ***Ivan Gratchev and Ikuo Towhata*** (2013) studied Stress–strain characteristics of two natural soils subjected to long-term acidic contamination. Result from the study indicated that strength characteristics of soil were influenced by the acid contamination. The stress strain behavior of the soil is significantly influenced by acid concentration in the pore fluid and mineralogy of clay fraction.
8) ***M. Olgun and M. Yildis*** (2012) studied shear strength test results and structural changes in clay soils with acetic acid. Test results indicated that the peak shear strength and shear strength parameter increases with increase in the concentration of acetic acid. Liquid limit values of kaolinite mineral sample increased with an increase in the acetic acid concentration. From the scanning electron microscopy jellification in kaolinite sample is clearly visible.
9) ***N. Z. Mohd Yunus, D. Wanatowski, and L. R. Stace*** (2011) studied Effect of Humic Acid on Physical and Engineering Properties of Lime-Treated Organic Clay. Results from the study indicated that in the case of organic clay efficiency of lime stabilization in the organic clay is significantly reduced if the humic acid content is more than 1.5%.
10) ***P. Sentenac, R. J. Lynch, M. D. Bolton and R. N. Taylor*** (2007) studied Alcohol's effect on the hydraulic conductivity of consolidated clay. Centrifuge tests were carried out to determine the effect of different alcohols and one glycol on a thin consolidated disc of clay. Dielectric constants and polarity of alcohols significantly influenced the hydraulic conductivity of samples.

3. Materials and Methodology

3.1 Materials

Fly ash collected from Hindustan News Print Ltd. Velloor. Soil was collected from Thayamkari Kuttanad region. Using manual operated auger sample collected from a 4m depth. Initial tests were carried out on fly ash and soil for finding specific gravity optimum moisture content, maximum dry density, liquid limit and plastic limit. Acetic acid with pH3 and NaOH with pH 13 will use to change the pH of pore fluid.

3.2 Methods

Particle size distribution test were done to determine the particle size distribution of soil as per IS: 2720 (Part 4) – 1985. Atterberg limit test such as liquid limit test and plastic limit test were performed on fly ash and soil samples according to IS: 2720 (Part 5) – 1985. Standard Proctor compaction test were performed for determining OMC and Maximum dry density of soil samples before and after stabilization with fly ash by applying IS 2720 (Part 7) 1980. The consolidation test was carried out as per IS 2720 (Part 15) – 1965 in the contaminated samples to find out compression index. Sample is filled in the mould at its maximum dry density and optimum moisture content. Before conducting the test, the sample is soaked in acid and base solution for 7 days. Along with these test swell index test as per IS 2720 (Part 40) 1970, pH test as per IS 2720 (Part 26) 1987 and UCC test as per IS 2720 (Part 10) 1991 were done for soil samples with varying percentage (25%, 50%) of Acetic acid and NaOH. Properties of soil sample before and after stabilization are shown in Table 3.1 and Table 3.2 respectively.

Table 3.1: Properties of soil before stabilization

Serial No:	Properties	Results
1	Water content	145.2%
2	Specific gravity	2.42
3	Liquid limit	190%
4	Plasticity index	127%
5	Clay content	52.4%
6	Sand	11.8%
7	Silt content	35.8%
8	OMC	23.08%
9	Maximum dry density	1.12 g/cc

Table 3.2: Properties of soil after stabilization

Serial No:	Properties	Results
1	Specific gravity	2.25
2	Liquid limit	72%
3	Plasticity index	21.6%
4	OMC	27.39%
5	Maximum dry density	1.24g/cc

4. Results and Discussion

4.1 General

The experimental study involves Atterberg limit test, Free Swell test, pH test and Unconfined Compressive Strength test and consolidation test on Fly ash stabilized clay with distilled water and contaminated soil sample with varying percentage of Acetic acid and NaOH base (25% and 50%). From the Atterberg limit test it is obtained that the liquid limit and plasticity index of the samples increased with increase in the concentration of Acetic acid NaOH. Sample with Acetic acid showed higher increase in LL and PI values than that in NaOH contaminated samples. Behavior of clayey soil depends to a large extent on the nature and characteristics of minerals present in it. Type of minerals in clay is most significant factor which influences the properties of clay. Here the tests were conducted on clay sample with kaolinite mineral. Figure 4.1 represents behavior of sample in 100% distilled water. In kaolinite mineral vander waals force is more significant than diffuse double layer force. At high concentration of Acetic acid samples having very low dielectric constant, vander waals force of attraction between particles increases and thus particles come closer and flocculation takes place As a result particles transforms in to new character which is similar to the characteristics of silt or fine grained soils and which offers more resistance external forces. Figure 4.2 and Figure 4.3 shows the SEM images of sample in 50 % Acetic acid concentration and 50 % NaOH concentration respectively.

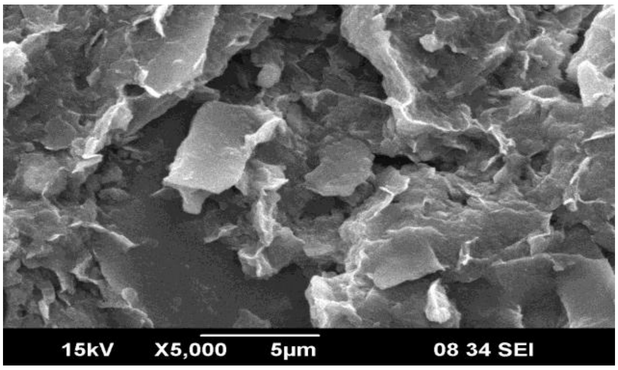

Figure 4.1: SEM image of sample in 100% Distilled water

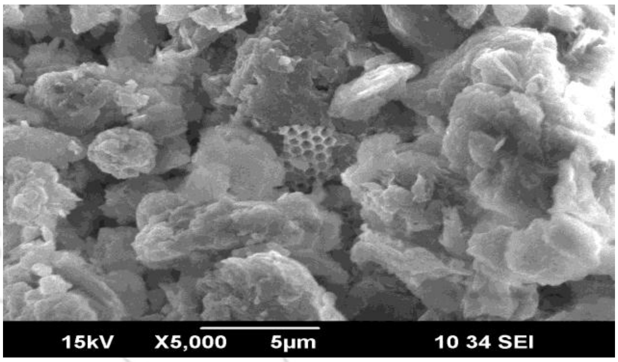

Figure 4.2: SEM image of sample in 50% Acetic acid

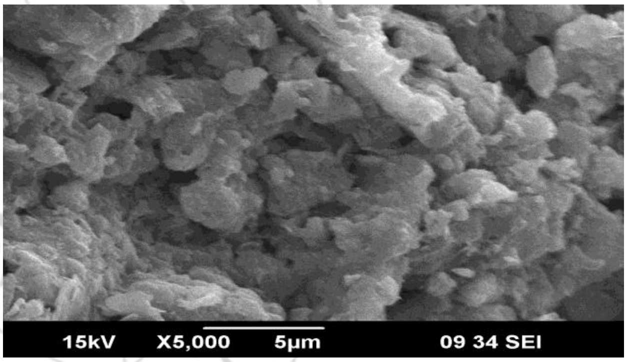

Figure 4.3: SEM image of sample in 50% NaOH

4.2 Atterberg Limit Test

Atterberg limit test was performed on the clay sample contaminated with different amount of Acetic acid and NaOH such as 25% and 50%. From this test the Atterberg limit characteristics of the contaminated samples were studied. The Atterberg limit test was conducted as per IS: 2720 (Part 5) – 1985 on acid contaminated and base contaminated samples and results are shown in Figure 4.4 and Figure 4.5.

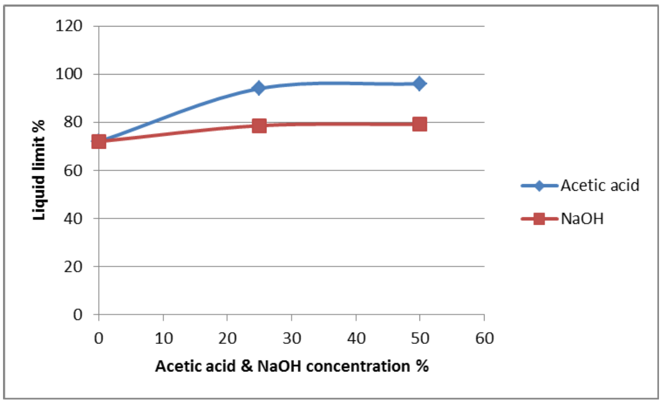

Figure 4.4: Liquid limit results for Acetic acid and NaOH contaminated soil.

Figure 4.4 shows that with the increase in the concentrations of Acetic acid and NaOH the liquid limit of the sample get increased. The tests were performed only up to 50 % concentrations. After 50% concentrations there is some difficulty to conduct test. Percentage increases in liquid limit of Acetic acid and NaOH sample at 50% concentration is 33.3 % and 10% respectively.

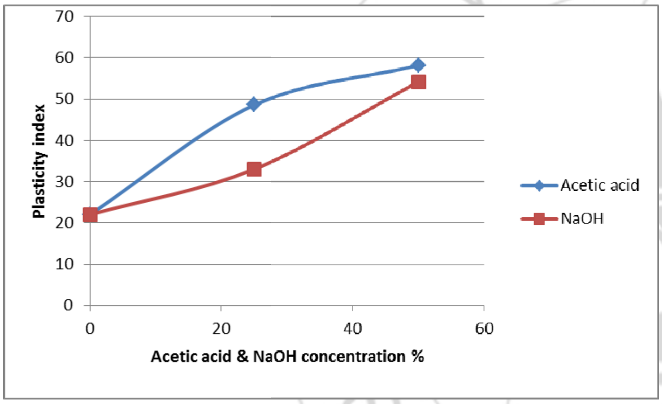

Figure 4.5: Plasticity index results for Acetic acid and NaOH contaminated soil.

The effects of contaminated fluids on clays have been investigated by many researchers it was reported that the behavior of montmorillonite was dependent on changes in diffuse double layer repulsive forces, whereas the behavior of kaolinite was less affected by these forces. The behavior of kaolinite under the influence of acid and base fluids is controlled by vander Waals attractive forces. Clays tend to flocculate and behave almost as if they were silt soil in the presence of these fluids, which have a lower dielectric constant than water, in accordance with the change in van der Waals attractive force and diffuse double layer repulsive force between clay particles. The experiments performed on kaolinite by the former researchers showed that the LL values increased with increasing Acetic acid and NaOH contents and the decreasing dielectric constant of the pore fluid.

4.3 Unconfined Compression Test

The unconfined compression strength and undrained cohesion were 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 4.6 and Figure 4.7.

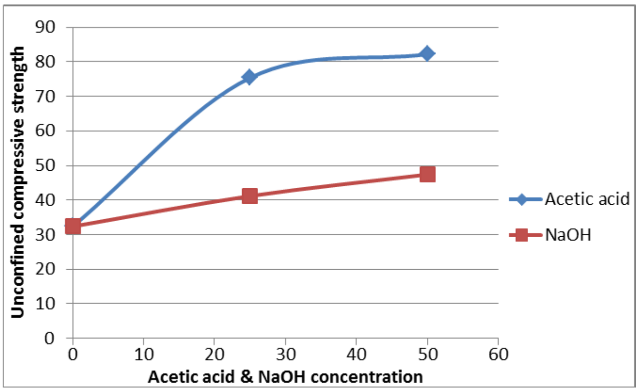

Figure 4.6: Unconfined compressive strength for acids and bases contaminated clay.

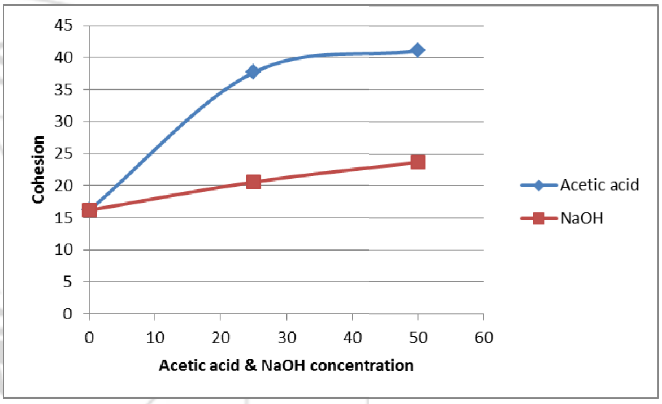

Figure 4.7: Cohesion for acids and bases contaminated clay

UCC strength and Cohesion values increased slightly due to van der Waals attractive forces and shown in Figure 4.6 and Figure 4.7 respectively. In other words, the cohesion changed in direct proportion to the increasing LL values. If the dielectric constant of a pore fluid decreases, the net force between the clay particles will be an attractive force. In this study, the dielectric constants of pore fluids decreased with increasing Acetic acid and NaOH contents. So the net attractive force between the clay particles increases due to the decreasing dielectric constant of the pore fluid. Thus, the particles formed clusters through a flocculation process and began to demonstrate increased resistance. The strength values obtained in the unconfined compression tests were in concordance with this change.

4.4 Compression Index

The variation in the compression index with different solute is shown in Figure 4.8. The consolidation test was carried out as per IS 2720 (Part 15) – 1965 in the contaminated samples.

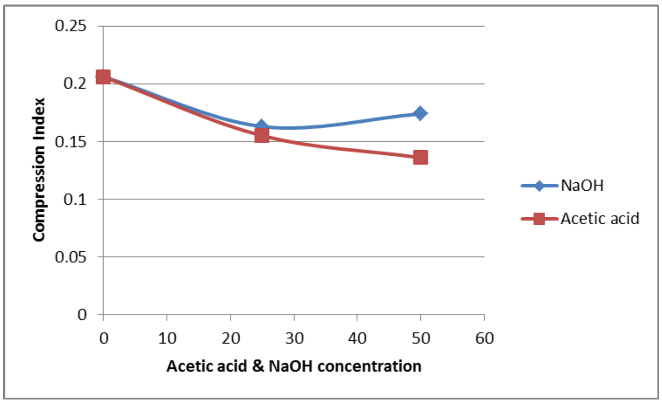

Figure 4.8: Compression Index for Acid and base contaminated clay.

As the percentage of the acetic acid increases, the compression index was found to be decreasing. In the case of NaOH contaminated clay up to 25% variation is similar as that of acetic acid after that there is a slight increase in the compression index. The acid and base fluids improved both the strength and compression properties of the clay sample. Percentage reduction in compression index of Acetic acid sample and NaOH sample at 50% was 33.9% and 15.53 % respectively. A structure which was more resistant to external forces is created in fluids with low dielectric constant than in the presence water. In acid contaminated fluids the net attractive force between the particles was higher than that observed in distilled water. Thus in Acetic acid a process of pronounced coagulation occurred. As a result, the fly ash stabilized clay in acetic acid solution showed a greater unconfined compression strength, and lower compression and swelling index values.

4.5 Swell Index

Free swell test was performed as per IS 2720 (Part 40) – 1977 on the acid contaminated and base contaminated clay with varying percentages such as 25% and 50%. On contaminated clay, the free swell results of acid contaminated clay & base contaminated clay are charted in Figure 4.9.

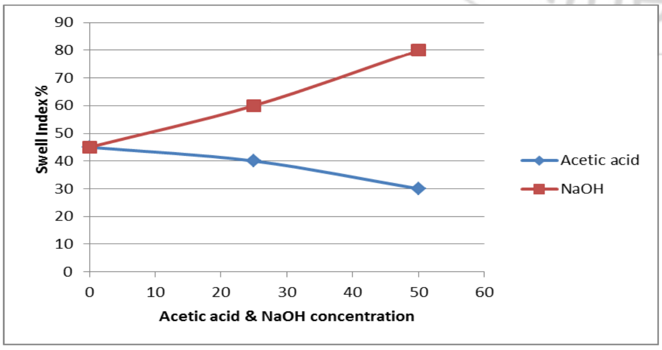

Figure 4.9: Free swell results of acid & base contaminated clay

Swell index decreases with increase in concentration of acetic acid but it increases with increase in NaOH concentration. Percentage increase in swell index of NaOH sample at 50 % concentration is 77.7% and percentage reduction in swell index of Acetic acid sample at 50% concentration is 33 %.

4.6. 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. pH of the flyash stabilized clay sample is 4.47. Variation in pH value is given in Figure 4.10.

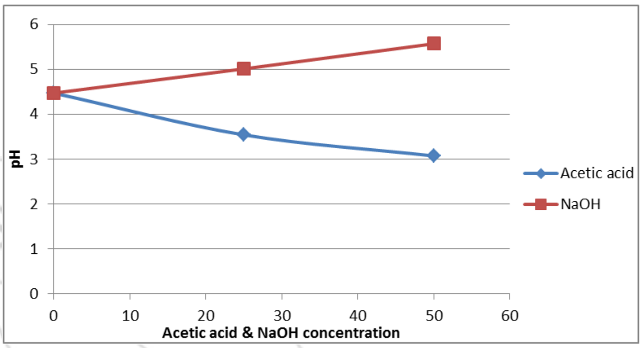

Figure 4.10: Variation in pH

5. Conclusions

The contributions of this project work are summarized below:

- Liquid limit and plasticity index of samples increases with decrease in the dielectric constant of pore fluid.
- Unconfined compressive strength and cohesion of the sample increases with increase in the concentrations of acids and base.
- Compression index decreases with increase in concentration of acid and base.
- Swell index decreases with increase in concentration of acetic acid.

References

[1] Mohammed fadhil obaid1, Dr. V. C. Agarwal2, Prabhat kumar sinha3, "*The influence of organic solutes on the geotechnical properties of extremely plastic clayey soils*", ijciet, pp. 83-91, 2014. (journal style).

[2] Prof.J.M. Raut, Dr. S.P.Bajad Dr. S.R.Khadeshwar, "*Stabilization of Expansive Soils Using Flyash and Murrum,*" **,** IJIRSET,Vol. 3, Issue 7, July 2014

[3] Fa-xing Huang, Hai-jun Lu, *"Experiment Study on the Atterberg Limits of Clay Contaminated by Oil"*, EJGE, Vol. 19 2014.

[4] Umadevi.S, Hashifa Hassan, "*A Study on the Effect of Rice Husk Ash & Lime on the Properties of Soft Clay*", ijeate, Volume 4, Issue 11, November 2014.

[5] M. H. Ghobadi, Y. Abdilor and R. Babazadeh, "*Stabilization of clay soils using lime and effect of pH variations on shear strength parameters*" Springer - Verlag Berlin Heidelberg, 10 December 2013.

[6] Ivan Gratchev, IkuoTowhata, "*Stress–strain characteristics of two natural soils subjected to long-term acidic contamination",* Science direct Soils andFoundations2013;53(3):469–476, May 2013.
[7] S. Prakash, Dr. P. D. Arumairaj, "*Effects of Acid and Base Contamination on Geotechnical Properties of Clay*", IJSR, 2013,
[8] M. olgun and m. yildiz, "*Influence of acetic acid on structural change and shear strength of clays"*, Transactions of Civil Engineering, IJST Vol. 36, pp 25-38,2012.
[9] N. Z. Mohd Yunus, D. Wanatowski, and L. R. Stace, "*Effect of Humic Acid on Physical and Engineering Properties of Lime-Treated Organic Clay"*, IJBBAFBE,Vol:5, No:11, 2011,
[10] P. Sentenac, R. J. Lynch, M. D. Bolton, "*Alcohol's effect on the hydraulic conductivity of consolidated clay"*, Springer-Verlag, 24 January 2007