International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 09, September-2016

A Study on the Effect of Chemicals on the Geotechnical Properties of Bentonite and Bentonite-Sand Mixtures as Clay Liners

Soumya M Das
Post Graduate Student,
Geotechnical Engineering
St.Thomas Institute for Science and Technology
Trivandrum,Kerala,India

Mrs. Sudha A R
Asst.Professor,
Geotechnical Engineering
St.Thomas Institute for Science and Technology
Trivandrum, Kerala, India

***Abstract*— One of the main problems in the geoenvironmental field is the intrusion of toxic contaminants from waste disposal and other sources into the underlying ground water supply. The liners are affected by the leachate from decomposition of waste materials. Due to high swelling and adsorption capability, bentonite is commonly used material for liners. Sand is the basic material used with bentonite to improve its properties. This paper embraces the results of a study on the effect of organic and inorganic chemical components on the geotechnical properties of bentonite and bentonite-sand mixture. The organic components selected is acetic acid and inorganic components selected are sodium chloride and calcium chloride. A series of laboratory experiments were conducted to evaluate the changes in soil properties such as consistency limits, hydraulic conductivity and shear strength with different concentrations (0.25M, 0.5M, 1M, and 2M) in bentonite and bentonite-sand mixtures. The experimental results shows that due to the chemical interaction, the geotechnical properties of bentonite and bentonite- sand mixture were changed which affects the clay liner performance.**

***Keywords*— Bentonite,bentonite-sand mixtures,liners,UCC**

I. INTRODUCTION

Clays are commonly used as barriers in landfills, slurry walls, and similar structures to slowdown the movement of contaminants because of their higher water absorption capacity. Hydraulic containments such as reservoirs and waste containment such as landfill are requires to have appropriate liners in order to prevent leaks. Compacted clays are usually used as the liners because they are very impervious. To build the liners with sand is difficult because, naturally, sand is a pervious material. But the hydraulic conductivity of sand can be reduced if sand is mixed with a very impervious material such as bentonite. To build the liners with sand is difficult because, naturally, sand is a pervious material. The hydraulic conductivity of sand can be reduced if sand is mixed with a very impervious material such as bentonite. The liners are exposed there to various chemical, biological and physical events, and they are affected by the resulting leachate. To assess the durability of the liner material, it is important to study the chemical compatibility of the liner material with different pore fluids, or the leachate that the liner may be subject to. One material that can meet the hydraulic conductivity criteria without suffering from shrinkage cracking is a sand-bentonite mixture. The sand particles providing mechanical stability and preventing shrinkage. Bentonite gets contaminated upon reaction with chemical constituents of leachate resulting from waste products. So the geotechnical properties of bentonite get altered when interacted with organic and inorganic chemicals of leachate. This study is about the effect of organic and inorganic leachate components on geotechnical properties of bentonite and bentonite-sand mixture. For that three chemicals are selected including acetic acid (CH_3COOH), sodium chloride (NaCl), calcium chloride ($CaCl_2$). Sand is the basic material used in this study along with bentonite. A series of laboratory experiments were conducted to evaluate the changes in soil properties such as consistency limits, hydraulic conductivity and shear strength with different concentrations (0.25M, 0.5M, 1M, and 2M) in bentonite and sand-bentonite mixture the proportion of sand is 50%. In this study for each concentration of the chemicals , its effect on the geotechnical properties on bentonite and bentonite-sand mixtures are studied.

II. LITERATURE REVIEW

The behavior of soil water systems is primarily controlled by (i) the type and amount of clay mineral, (ii) the nature of pore fluid, (iii) associated cations and anions, (iv) organic matter. So one of the important environmental factors that affect soil behavior is pore fluid. Bentonite gets contaminated upon reaction with chemical constituents of leachate resulting from waste products. So the geotechnical properties of bentonite get altered when interacted with organic and inorganic chemicals of leachate. Engineering properties of bentonite soils get modified upon contamination with different chemicals from industrial waste. The interaction of minerals in bentonite soil with organic materials may result in changes of their surface properties and microstructures.The following are the literature regarding this subject.

Seracettin Arasan (2010) presented a paper on the topic "Effect of Chemicals on Geotechnical Properties of Clay Liners: A Review". The paper presented a review of recent research on the geotechnical properties (consistency limits, hydraulic conductivity, shear strength, swelling, and compressibility) of clay liners conducted with organic and inorganic chemicals. Finally he concluded that the chemicals significantly affect the properties of clay and clay liners. There has not been a general consensus regarding the effect of chemicals on the geotechnical properties of clay and clay liners. The behavior of the low plasticity clays (CL and kaolinite clay) is different from the high plasticity clay (CH and bentonite clay). The chemical solutions tended to increase the thickness of the DDL and disperse the clay particles, resulting in increasing of liquid limit, increasing of swelling and reduction of hydraulic conductivity of low plasticity clays.

Evangeline, Y.Sheela ,Raji Ann (2010) presented a paper on the topic “Effect of Leachate on the Engineering Properties of Different Bentonites”. They studied the effect of leachate on calcium bentonite and four types of sodium activated bentonites. Acetic acid and calcium chloride were used to represent the components of leachate. The variations of properties like Atterberg’s limits, swell index, percentage of swell and hydraulic conductivity with various concentrations of the chemicals were studied. Finally they concluded that the index properties and hydraulic conductivity get altered due to the reaction with acetic acid and calcium chloride. Also the result indicated that calcium bentonite would be more resistant than sodium bentonite to chemical constituents in the permeating fluids. From there study percentage swell is seemed to be the most suitable independent variable for the better prediction of hydraulic conductivity for most of the bentonite types.

Nader Shariatmadari and Marzieh Salami (2011) presented a paper on the topic “Effect of inorganic salt solutions on some geotechnical properties of soil-bentonite mixtures as barriers.” The paper embraces the results of a recent study on the effect of three inorganic salts, NaCl, $CaCl_2$ and $MgCl_2$ on some geotechnical properties of a common used clay soil in impermeable bottom barrier in Kahrizak landfill, the main waste disposal center of the Tehran Metropolitan. Also the effect of bentonite content by adding different percentage of this special clay mineral, 10 and 20 percent, on these properties was investigated. They concluded that Salt solution increases the maximum dry density and decrease the optimum water content of mixtures. Higher cation valance leads to higher increase in the maximum dry density and higher decrease in optimum water content as well. The decrease of the diffuse double layer's thickness is the source of this trend. By increasing the salt concentration and cation valance the swelling volume decreases, decrease in liquid limit, compression index (Cc) decreases, increases the hydraulic conductivity.

Dhanya Sree, A.R. Ajitha et al (2011) presented a paper on the topic “Study on the shrinkage, swelling and strength characteristics of clay soils under different environmental conditions”. The paper presented an attempt made to study the effect of pore fluids like sodium hydroxide, calcium chloride and acetic acid of different concentration on swelling, shrinkage and shear strength behavior of clay minerals like bentonite and kaolinite. She concluded that with increase in concentration NaOH, shrinkage limit and free swell increases, but shear strength decreses for bentonite. In kaolinite, with increase in concentration of NaOH, shrinkage limit and shear strength increases, but free swell decreases. With $CaCl_2$ as pore fluid, as the concentration increases, shrinkage limit and shear strength increases, but free swell get decreases. Shrinkage limit of kaolinite decreases from 30% to 12% when molarities of $CaCl_2$ increases from 0 to 2M. But free swell decreases with increases in concentration of $CaCl_2$. With increase in concentration of CH_3COOH free swell decreses for both kaolinite and bentonite.

Francesco Mazzieri (2010) presented a paper on the topic “Diffusion of calcium chloride in a modified bentonite : Impact on osmotic efficiency and hydraulic conductivity”. In his study a combined chemico/osmotic diffusion test was carried out in order to investigate solute diffusion and to evaluate the potential for membrane behavior of a chemically modified bentonite (MSB), obtained by treating base sodium bentonite with propylene carbonate. The chemico-osmotic/diffusion stage of the test was performed using a 5 mM $CaCl_2$ solution. The diffusion stage was preceded by permeation with distilled water and followed by permeation with the 5 mM $CaCl_2$ solution. The increase in hydraulic conductivity was also attributed to the invasion of pore space by Ca^{2+} cations. The final properties of the free swell, hydraulic conductivity were consistent with those of an untreated and calcium-exchanged bentonite.

Jae-Myung Lee et al (2005) presented a paper on the topic “Correlating Index Properties and Hydraulic Conductivity of Geosynthetic Clay Liners”. The study includes three index properties (liquid limit, sedimentation volume, and swell index) of two sodium bentonites from geosynthetic clay liners (GCLs) are correlated with the hydraulic conductivity (*k*) of the same GCLs to evaluate the suitability of index properties for evaluating chemical compatibility. Deionized water (DIW) and calcium chloride ($CaCl_2$) solutions were used for hydration (index tests) and permeation (hydraulic conductivity tests). In general, increasing the $CaCl_2$ concentration caused each index property to decrease and the hydraulic conductivity to increase relative to values obtained with DIW, with the strongest correlations obtained with the liquid limit. The correspondence between index properties and hydraulic conductivity differed by index property, the quality of the bentonite, and the effective stress applied during the hydraulic conductivity test.

M. Heeralal, V. Ramana Murty and S. Shankar (2012) presented a paper on the topic “Influence of Calcium Chloride and Sodium Silicate on Index and Engineering Properties of Bentonite”. In the study an attempt has been made to study the influence of $CaCl_2$ and Na_2SiO_3 on Atterberg limits, swell, strength and consolidation properties of bentonite and the effect of individual and combined influence of chemical additives on the above properties of bentonite is investigated. They concluded that the plasticity properties of bentonite are significantly modified by the addition of $CaCl_2$ and Na_2SiO_3. The liquid limit of bentonite is decreased to one-third of its original value due to the addition of about 1% $CaCl_2$ or Na_2SiO_3. The shrinkage limit is increased by45-80% with the addition of $CaCl_2$ and

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 09, September-2016

Na_2SiO_3 indicating the fabric changes and reduced potential for volume change. The addition of $CaCl_2$ and Na_2SiO_3 reduced the unconfined compressive strength with period for different bentonite-additive mixes. This study revealed that the plasticity and swell properties of bentonite can be substantially modified with $CaCl_2$ and the combined influence of $CaCl_2$ and Na_2SiO_3 is not impressive. However, micro-scale studies are required to understand the exact behavior changes with respect to strength, swell and consolidation properties. A marginal variation is observed in consolidation parameters with $CaCl_2$ but the Cc of bentonite - Na_2SiO_3 mixes are about twice that for other mixes.

III.OBJECTIVES OF STUDY

- To study the effect of organic and inorganic chemicals on geotechnical properties of bentonite and bentonite-sand mixture.
- To investigate how engineering properties of bentonite get altered on interaction with chemical contaminants in leachate produced from the waste.
- To check whether bentonite or bentonite-sand mixture meets the basic requirement of landfill liner.
- To check whether organic or inorganic chemicals cause more adverse effect on clay liner performance.

IV SCOPE OF STUDY

One of the main problems in the geoenvironmental field is the intrusion of toxic contaminants from waste disposal and other sources into the underlying ground water supply. Clays are commonly used as barriers in landfills, slurry walls, and similar structures to slowdown the movement of contaminants because of their higher water absorption capacity. Bentonite clay, when used in the field as a hydraulic barrier, comes in contact with various organic and inorganic chemicals which eventually cause the performance of bentonite clay to diminish in terms of permeability and chemical outflux . The net electrical charge on bentonite is negative, which causes dissolved cations in the surrounding pore water to be attracted to the surface of the clay. As the bentonite lining system would be laid underneath the leachate collection system in a landfill, the effects of hydraulic gradient and temperature would be minimal on the degradation of the hydraulic conductivity of bentonite layer. Inorganic contaminants, while transported through the bentonite layer, are chemically adsorbed on to the particle surfaces and experience a delay in solute breakthrough in hydraulic barriers. During the process of chemical solute transport through a low permeability bentonite layer, cation exchange takes place on the clay particle surfaces due to the high cation exchange capacity (CEC) of montmorillonite minerals.. This study is intended to find out the effect of organic and inorganic leachate components on geotechnical properties of bentonite and bentonite-sand mixture.

V. MATERIALS USED

A.Bentonite

Bentonite is a naturally occurring clay mineral derived from in situ chemical alteration of volcanic ash. It is very highly plastic swelling clay of the smectite mineral group, and is mineralogically known as “montmorillonite”. It is a clay with extra ordinary properties such as very high expansion capability by absorbing water (swelling capacity), high ion exchange capacity and very low water permeability. Commercially available calcium bentonite is chosen for the study. The basic properties of bentonite are presented in the Table 1.

Table 1 : Basic properties of bentonite

ENGINEERING PROPERTIES	VALUES
Liquid limit (%)	185
Plastic limit (%)	55
Plasticity index (%)	130
Shrinkage limit (%)	10
Specific gravity	2.6
Free swell (ml/2g)	24
Percentage of clay	73
Percentage of silt	27
Maximum dry density (g/cc)	1.56
Optimum moisture content (%)	23
Coefficient of consolidation , Cv	2.1×10^{-7}
Coefficient of permeability, k (m/sec)	1.6×10^{-9}
Unconfined compressive strength (kN/m²)	32.37

B. Sand

Sand is the basic material added to the bentonite to improve its mechanical properties like hydraulic flow and shrinkage. Sand is added to determine bentonite-sand mixture can be used as a liner material. Sand is a permeable material but its hydraulic conductivity decreases significantly when mixed with bentonite. Sand used in this study is river sand. The basic properties of bentonite are presented in the Table 2.

Table 2 : Basic properties of sand

ENGINEERING PROPERTIES	VALUES
Specific gravity	2.51
GRAIN SIZE DISTRIBUTION	
Effective size, D10 (mm)	0.17
Uniformity coefficient, Cu	2.94
Coefficient of curvature, Cc	0.858
Percent of Gravel (%)	0.02
Percent of Coarse sand (%)	1.35
Percent of medium sand (%)	35.8
Percent of Fine sand(%)	62.85
Relative density (g/cc)	1.67

C.Porefluids

Bentonite gets contaminated up on reaction with chemical constituents of leachate resulting from waste products. So the geotechnical properties of bentonite get altered when interacted with organic and inorganic chemicals of leachate.

The organic and inorganic fluids used in this investigation are acetic acid, sodium chloride and calcium chloride of molarity 0.25M, 0.5M, 1M and 2M. The physical and chemical properties of fluids are shown in Table.3.

Table 3 : Physical and chemical properties of pore fluids

Type of liquid	Molecular formula	Molecular weight (g/mol)	Dielectric constant 20ºC
Acetic acid	CH_3COOH	60.05	6.2
Sodium chloride	NaCl	58.44	23
Calcium chloride	$CaCl_2$	100.99	11.8

D. Bentonite-sand mixture

The incorporation of bentonite fines into a naturally occurring soil, e.g. sand, will significantly alter the physical and chemical properties of the soil. However, leakage can result from shrinkage cracking if the clay content of the soil is too high. One material that can meet the hydraulic conductivity criteria without suffering from shrinkage cracking is a sand-bentonite mixture. The sand is added at equal amount by weight of bentonite (50:50) for comparing results with bentonite-sand mixtures. The basic properties of bentonite-sand mixtureare presented in the Table 4.

Table 4 : Basic properties of Bentonite-sand mixture

ENGINEERING PROPERTIES	VALUES
Liquid limit(%)	95
Plastic limit(%)	30
Plasticity index (%)	65
Maximum dry density, (g/cc)	1.24
Optimum moisture content (%)	19
Coefficient of consolidation , Cv	3.66×10^{-7}
Coefficient of permeability, k (m/sec)	3.558×10^{-9}
Unconfined compressive strength (kN/m²)	23.544

VI.*EXPERIMENTAL* SETUP AND METHODOLOGY

A series of laboratory experiments were conducted to evaluate the changes in soil properties such as consistency limits, hydraulic conductivity and shear strength with different concentrations (0.25M, 0.5M, 1M, and 2M) of organic (acetic acid) and inorganic porefluids($CaCl_2$ and NaCl) in bentonite and bentonite-sand mixtures. In bentonite-sand mixture the proportion of sand is 50%. Then results obtained were analysed and concluded. The various laboratory studies carried out are listed below.

1. Atterbergs limits

Atterbergs limits were found out according to IS (2720: Part 5- 1985). Liquid limits shown to be useful indicators of clay behavior. For the liquid limit tests, the specimens were prepared by mixing bentonite and bentonite-sand mixture with each organic and inorganic fluids at different molarities (0.25M, 0.5M, 1M, and 2M).

2. Unconfined compression test

Unconfined compression test was conducted as per IS 2720(Part 10) - 1973 and strength behavior of bentonite and bentonite-sand mixture for the varying concentrations of chemicals (0.25M, 0.5M, 1M, 2M) were studied.

3. Hydraulic conductivity test

The experiments were carried out in a standard consolidation apparatus as per IS: 2720 (Part 15) - 1986 specifications. The samples were carefully filled in the consolidation mould and they were fully saturated, applied a seating load of 0.05kg/cm². The coefficient of consolidation (Cv), and coefficient of permeability (k) of bentonite and bentonite-sand mixture for different concentrations of chemical components(0.25M, 0.5M, 1M, and 2M) were studied. Coefficient of permeability (k) is determined from the coefficients of consolidation (Cv) and volume change (m_v).

VII.RESULTS AND DISCUSSION

Effect of various chemicals on liquid limits of bentonite

It can be observed from Fig 1, that the liquid limit of bentonite is decreased from its original value of 185% to 130% by the addition of 0.25M acetic acid. As the concentration of acetic acid increases, the liquid limit decreases and obtained a liquid limit value of 65% by the addition of 2M acetic acid.

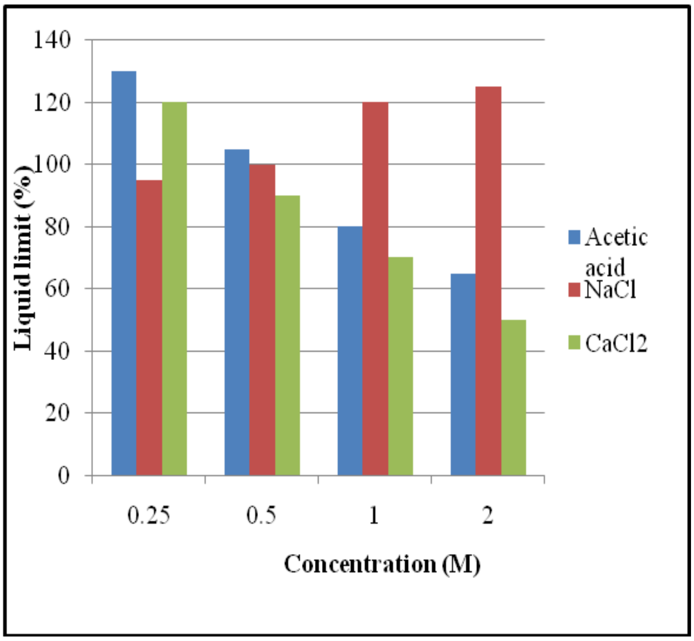

Fig 1 : Variation of liquid limit on bentonite with different concentrations

By adding NaCl , the liquid limit of bentonite is decreased from its original value of 185% to 95% by the addition of 0.25M NaCl. But as the concentration of NaCl increases, the liquid limit also increases. It can be observed that the liquid limit is increased to 130% by the addition of 2M sodium chloride solution. In case of Calcium chloride solution , it can be observed from Fig 1, that the liquid limit of bentonite is decreased from its original value of 185% to 120% by the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 09, September-2016

addition of 0.25M $CaCl_2$. As concentration of $CaCl_2$ increases, there may be further decrease in the liquid limit value and obtained a liquid limit of 50% by the addition of 2M Calcium chloride solution.
The reduction in liquid limit of bentonite by the addition of acetic acid, NaCl and $CaCl_2$ solutions at different concentrations is due to the reduction in the thickness of diffuse double layer by various cations and anions present in the chemicals.

Effect of various chemicals on liquid limits of bentonite-sand mixtures
It can be observed from Fig 2, that the liquid limit of bentonite is decreased from its original value of 95% to 80% by the addition of 0.25M acetic acid. As the concentration of acetic acid increases, the liquid limit decreases and obtained a liquid limit value of 40% by the addition of 2M acetic acid. The decrease in liquid limit is due to the reduction in the thickness of diffuse double layer of bentonite clay by the presence of hydroxide ions in acetic acid. By adding NaCl , the liquid limit of bentonite is decreased from its original value of 95% to 35% by the addition of 0.25M NaCl. But as the concentration of NaCl increases, the liquid limit also increases. It can be observed that the liquid limit is increased to 60% by the addition of 2M sodium chloride solution.From the result it is observed that there may occur a great reduction in the liquid limiit of bentonite. It is due to the reduction in diffuse double layer thickness by Na^+ ions.

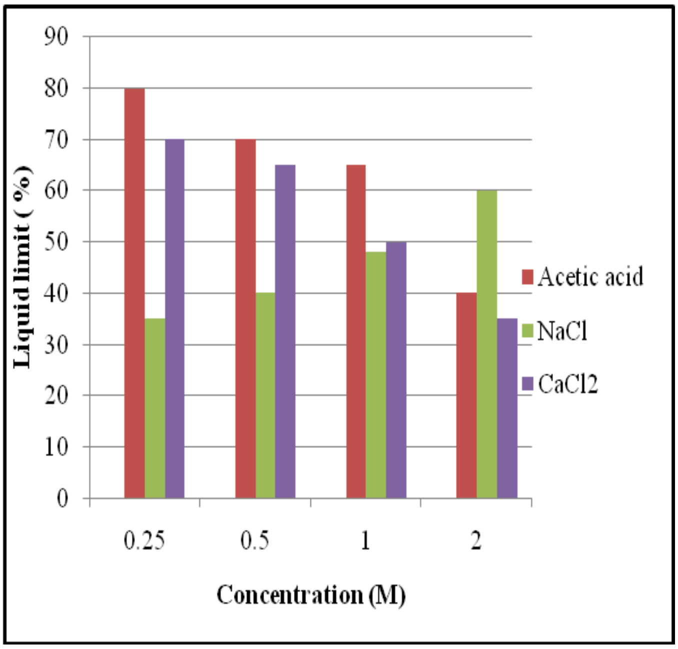

Fig 2 : Variation of liquid limit on bentonite-sand mixtures with different concentrations

In case of Calcium chloride solution , it can be observed from Fig 2, that the liquid limit of bentonite is decreased from its original value of 95% to 70% by addition of 0.25M $CaCl_2$. As concentration of CaCl2 increases, there may be further decrease in the liquid limit value and obtained a liquid limit of 35% by the addition of 2M Calcium chloride solution. The reduction in liquid limit of bentonite by the addition of $CaCl_2$ solutions at different concentrations is due to the reduction in the thickness of diffuse double layer by the presence of calcium ions.

Thus it could be concluded that in both bentonite and bentonite-sand mixtures the presence of chemicals decreases the liquid limit. Increasing the salt concentration and the cation valence decreases the inter-particle repulsion which results in particles moving more freely in lower water contents, thus the liquid limit of the mixtures decreases.

Effect of various chemicals on unconfined compressive strength of of bentonite and bentonite-sand mixture
The variation of unconfined compresssive strength of bentonite and bentonite-sand mixtures with different concentration of acetic acid is shown in figure 3. For bentonite, as the concentration of acetic acid increases unconfined compresssive strength increases up to .25M and then decreases.

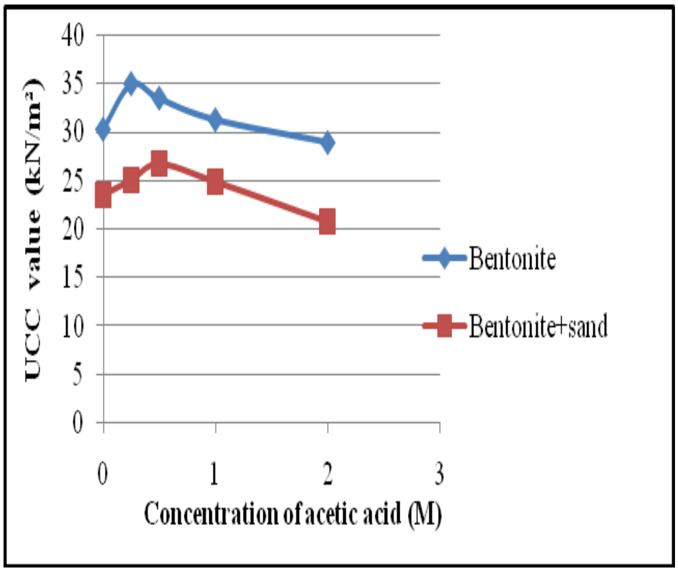

Fig 3 : Effect of acetic acid on unconfined compresssive strength of bentonite and bentonite-sand mixture

For bentonite-sand mixture, as the concentration of acetic acid increases unconfined compresssive strength increases up to .5M and then decreases.
The initial increase in strength and then reduction in strength as concentration of acetic acid increases is due to the changing in the thickness of diffuse double layer of clay. The large increase in interparticle attraction made possible by the reduction of the diffuse double layer was responsible for the flocculation of the clay mixture on mechanical remolding. This effect resulted in strength change of of bentonite and bentonite-sand mixture by the addition of acetic acid.
The variation of unconfined compresssive strength of bentonite and bentonite-sand mixtures with different concentration of sodium chloride is shown in figure 4. For bentonite, as the concentration of NaCl increases unconfined compresssive strength increases up to 1M and then decreases.

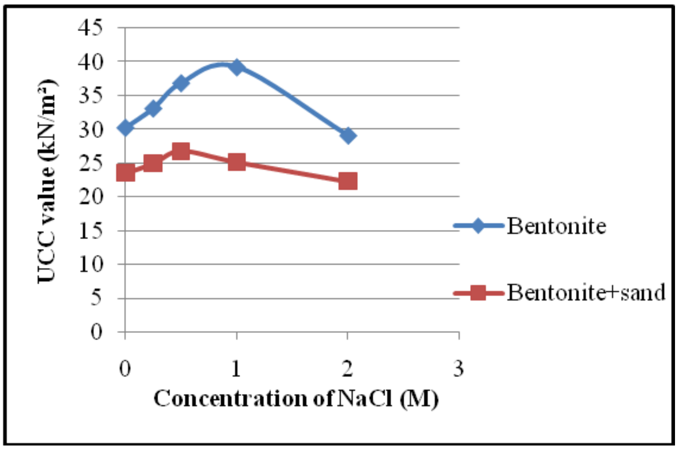

Fig 4: Effect of NaCl on unconfined compresssive strength of bentonite and bentonite-sand mixture

For bentonite-sand mixture, as the concentration of sodium chloride increases unconfined compresssive strength increases up to .5M and then decreases.

An increase in salt concentration according to colloidal theory reduces the thickness of the diffuse double layer, there by decreasing the repulsive force between the particles. This should result in more flocculated clay structure and hence a higher initial shear strength.

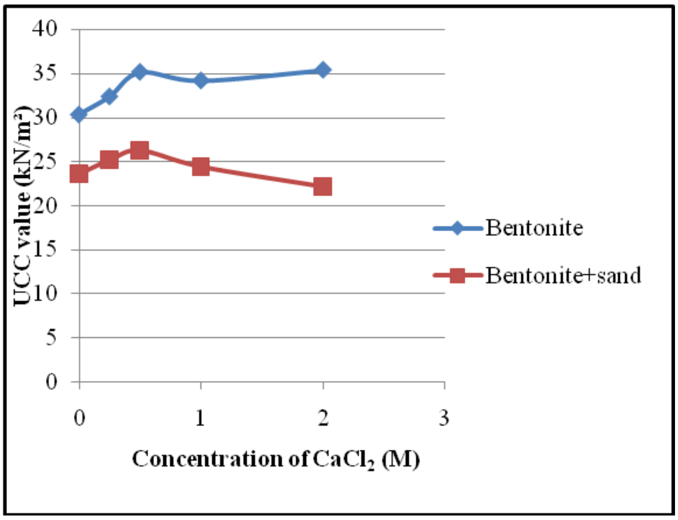

Fig 5 : Effect of calcium chloride on unconfined compresssive strength of bentonite and bentonite-sand mixture

The variation of unconfined compresssive strength of bentonite and bentonite-sand mixtures with different concentration of calcium chloride is shown in figure 5. For bentonite, as the concentration of $CaCl_2$ increases unconfined compresssive strength increases up to .5M , then decreases slighty and then increases. For bentonite-sand mixture, as the concentration of calcium chloride increases unconfined compresssive strength increases up to .5M and then decreases.

The reason for the increase in compressive strength is due to the increase in salt concentration which reduces the thickness of the diffuse double layer, there by decreasing the repulsive force between the particles. This should result in more flocculated clay structure and hence a higher shear strength.

Hydraulic Conductivity characteristics of bentonite and bentonite-sand mixture added with different chemicals

The coefficient of consolidation (Cv), and coefficient of permeability (k) of bentonite and bentonite-sand mixture for different concentrations of acetic acid, sodiumchloride and calcium chloride (0.25M, 0.5M, 1M, and 2M) were studied. Coefficient of permeability (k) is determined from the coefficients of consolidation and volume change (m_v).

The variation of hydraulic conductivity of bentonite and bentonite-sand mixture with different concentrations of acetic acid, sodium chloride and calcium chloride is shown in figures 6 and 7.

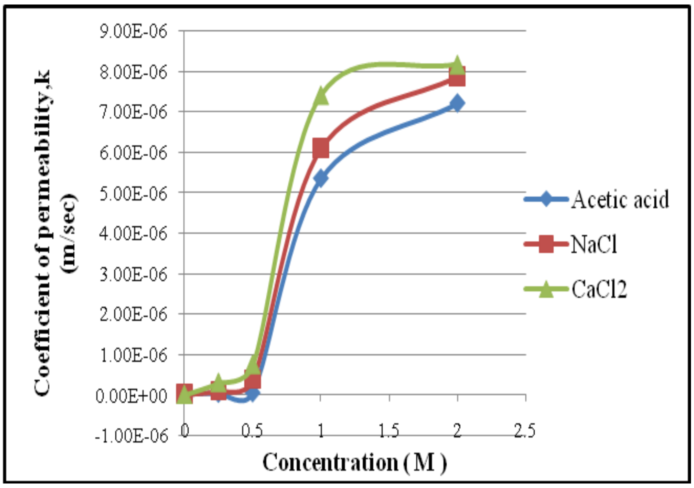

Fig 6 : Variation of hydraulic conductivity on bentonite with different concentrations of chemicals

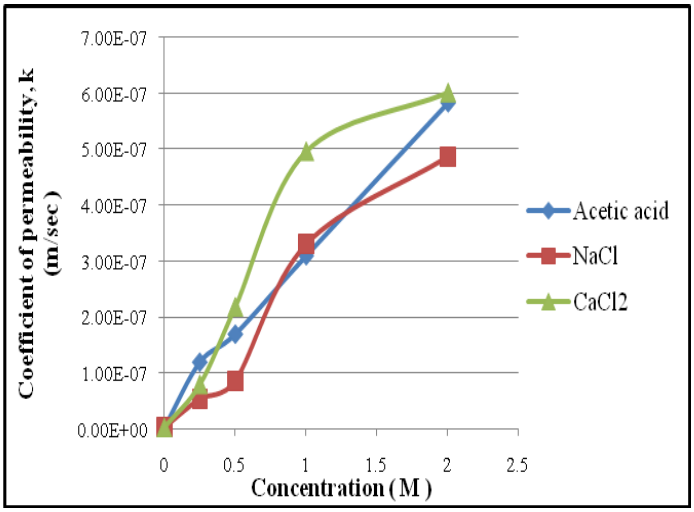

Fig 7 : Variation of hydraulic conductivity on bentonite-sand mixture with different concentrations of chemicals

It is observed that the hydraulic conductivity of bentonite and bentonite-sand mixture is increased by the addition of chemicals with diiferent concentrations. The increase in the hydraulic conductivity is related to the diffuse double layer. When the chemicals mixed with soil the diffuse double layer shrink or suppressed. This shrinkage leads to the formation of cracks which results in increase in the hydraulic conductivity of the soil. Increasing the cation valance also increases the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 09, September-2016

hydraulic conductivity. From the figures 6 and 7 , it is observed that the increase in hydraulic conductivity with chemical concentration is more in bentonite as compared with bentonite-sand mixture. Also it is observed that the increase in hydraulic conductivity caused by $CaCl_2$ salt solution is higher in comparison to the hydraulic conductivity caused by acetic acid and NaCl.

VIII.CONCLUSIONS

From this study, conclusion can be drawn that the geotechnical properties of bentonite and bentonite-sand mixture get altered when in contact with the organic and inorganic chemicals. Also it is observed that the effect of chemicals on bentonite-sand mixture is less than that of bentonite.

- As the concentration of acetic acid and $CaCl_2$ increases, the liquid limit decreases for bentonite and for bentonite-sand mixture. By the addition of NaCl, liquid limit first decreases and as the concentration of NaCl increases, liquid limit increases for both bentonite and bentonite-sand mixture.
- Increasing the salt concentration and the cation valence decreases the inter-particle repulsion which results in particles moving more freely in lower water contents, thus the liquid limit of the mixtures decreases.
- From unconfined compressive strength tests it is concluded that the strength of bentonite get reduced by about 14% by acetic acid, sodium chloride decreases strength by 10% and calcium chloride increases strength by 9%.
- For bentonite-sand mixture, acetic acid decreases the unconfined compressive strength by 11%, sodium chloride decreases strength by 6% and calcium chloride decreases strength by 5%.
- Organic chemical (acetic acid) and inorganic chemicals (NaCl and $CaCl_2$) increases the hydraulic conductivity of bentonite by about 90% . For bentonite-sand mixture, Organic chemical and inorganic chemicals increases the hydraulic conductivity by about 80%.
- The increase in the hydraulic conductivity is due to the reduction in the thickness of diffuse double layer.Increasing the cation valance also increases the hydraulic conductivity.
- Thus it is observed from the present study that the geotechnical properties of bentonite and bentonite-sand mixture get altered when interacted with organic and inorganic chemicals of leachate.
- It is observed that the effect of organic and inorganic chemicals on bentonite-sand mixture is less than that of bentonite and also the inorganic salt solutions cause more effect on the geotechnical properties of bentonite and bentonite-sand mixture.
- Thus the effect of chemicals should be considered as a serious issue and so routine check should be necessary to determine if the chemically contaminated leachate can affect the clay liner performance.
- Chemical contaminants affected on the clay liner performance are not limited to this three chemicals so future work is possible.

REFERENCES

[1] Alther, G., J.C. Evans, H.Y. Fang, and K. Witmer.(1985). “Influence of inorganic permeants upon the permeability of bentonite”. Pages 64–73 in Hydraulic Barriers in Soil and Rock. ASTM STP 874.
[2] B.B. Neethu, Y.E. Sheela (2015), “ Effect of acetic acid on amended clay liner designed using Thonnakal clay” 15th Indian Geotechnical conference.
[3] Bowders, J.J. and D.E. Daniel, (1987). Hydraulic conductivity of compacted clay to dilute organic chemicals. ASCE J. Geotech. Eng., 113(12): 1432-1448.
[4] Chalermyanont. T and Arrykul.S (2005) “Compacted sand-bentonite mixtures for hydraulic containment liners” Songklanakarin J. Sci. Technol., 27(2) : 313-323.
[5] Charles D. Shackelford et al (2005), “Correlating Index Properties and Hydraulic Conductivity of Geosynthetic Clay Liners”, Journal of Geotechnical and Geoenvironmental Engineering, Vol. 131 , 1320-1329.
[6] Dhanya Sree, A.R. Ajitha et al ,(2011), “Study on the shrinkage, swelling and strength characteristics of clay soils under different environmental conditions” Proceedings of IGC., Paper No.L-237.
[7] Evangeline, Y.Sheela ,Raji Ann (2010) , “ Effect of Leachate on the Engineering properties of different bentonites”,Indian Geotechnical Conference, pp:16-18.
[8] Francesco Massieri et al (2010), “Diffusion of calcium chloride in a modified bentonite : Impact on osmotic efficiency and hydraulic conductivity”, Clays and Clay Minerals, Vol. 58, No. 3, 351–363.
[9] Gleason, M., Daniel, D., and Eykholt, G. (1997). ”Calcium and Sodium Bentonite for Hydraulic Containment Applications.” J. Geotech. Geoenviron. Eng., 123(5), 438–445.
[10] Jae-Myung Lee et al (2005), “Correlating Index Properties and Hydraulic Conductivity of Geosynthetic Clay Liners”, ASCE 1090-0241.
[11] M. Heeralal et al (2012), “Influence of Calcium Chloride and Sodium Silicate on Index and Engineering Properties of Bentonite”, International Conference on Chemical, Environmental Science and Engineering, Pattaya (Thailand), pp : 52-56.
[12] Nader Shariatmadari et al (2011) , “Effect of inorganic salt solutions on some geotechnical properties of soil-bentonite mixtures as barriers”, International Journal of Civil Engineering,Vol. 9,pp:103-110
[13] Seracettin Arasan (2010),“Effect of Chemicals on Geotechnical Properties of Clay Liners: A Review”, Reserch Journal of Applied Sciences, Engineering and Technology 2(8): 765-775.