Effect of Sea water intrusion on Geotechnical behavior of soil- A review

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***Abstract*—Due to seawater intrusion there is a change in behavior of geotechnical properties of soil. Sea water intrusion changes soil behavior and also leads to geotechnical problems, the alkalinity and TDS value is increased in groundwater due to rate of intrusion. There is a discrepancy in seawater effect on compressibility and consistency properties of clay having low and high plasticity, the results indicates that the seawater intrusion is negligible on tested consistency limits of compressible characteristics of clay when liquid limit is up to 110%. The main reason for the changes in decreased Atterbergs limit and increase in shear strength parameter are due to increase in soil salinity , this is due to increasing attractive force between soil particles , establishing a bonding between them , and forming salt crystals in pore soils. Unexpected heave can occur in swelling and non-swelling soil due to contamination in water, thus free swelling index decrease by increasing the salt concentration and the reason is decrement in attraction between the soil particles and fineness increment. The Unconfined Compressive strength gradually increase from lower to higher value (4.3kg/cm^2 to 6.24kg/cm^2) as the soil salinity increased.**

Keywords - Seawater intrusion, Atterbergs limit, Swelling index, UCC strength.

I. Introduction

Soil is an essential constituent for construction activity, therefore due to sea water intrusion in seashore areas the soil gets affected and causing disturbances in construction of superstructure and forming soil salinization. Soil salinization is the accumulation of free salts in soil that leads to the degradation of soil and vegetation. The extent of modification not only depends on nature of contaminant but also the type of soil such as the chemical composition, physical nature and mineralogical properties. The Soil - Salinity interactions changes the soil behavior and also leads to various geotechnical problems. The change in geotechnical behavior of soil is mainly due to types of cations in saline water and types of clay mineral in soil layers. Thus the effects of pollutants on soil are complex, they are studied by understanding the factors such as ion exchange (cation exchange and anion exchange) or nature of pore fluid (electrolyte concentration, dielectric constant, acidity and alkalinity). The studies in the literature papers have reported that seawater had a strong impact on the engineering behavior of different clayey soil samples, especially on the montmorillonite clay type. In fine grained soil the geotechnical behavior of soil depends on chemistry of pore fluid. Due to excessive pumping of ground water, saline water intrusion takes place in coastal regions causing remarkable alterations in geotechnical properties of soils. Expansive soils shows high swell and shrink behavior which causes heave and uplift of building during high moisture variations. In this review paper the effect of seawater on geotechnical behavior of soil samples is studied.

II. Effect on Geotechnical Behavior of Soil

A. *Effects on Atterbergs limit*

[1]Atterbergs limit was studied to determine the seawater effect on clays, test including Liquid limit, Shrinkage limit and Plastic limit was conducted according to the ASTMD4318 standards on natural seawater and distilled water collected from Aegean Sea. The test results were analysed and found that seawater effect is negligible on tested consistency limits and compressibility characteristics of soils when they have liquid limits up to 110%. The seawater effect is most noticed on the consistency limits and compressibility of Na-bentonites. The results of previous research were compiled and compared with those obtained in this study. All reported data were normalized by dividing the index values obtained using seawater by those obtained using distilled water. The comparison of data indicate that the compiled data and present study data are in good agreement, i.e. when the normalized values are plotted as function of liquid limit, all index properties plot along the unity line until the liquid limit of soils is about 110%; then, the normalized index values decrease almost linearly with liquid limit.

[2] The author studied the Atterbergs limit and observed that Low influence of salinity on plastic limit can arise little moisture of soil in this condition that lead to decrease the interaction between soil and solute in water. But in liquid limit, in which soil moisture is higher, the effect of salinity will be more. The liquid limit has decreased 5 and 17 percent with half saline and saline water respectively. The lower part of changes of atterberg limits are attributed to decrease in the double layer thickness and most of the changes can be attributed to sediment salt in the soil pores. Due to reduce of liquid limit with increase in salinity water, plastic index also has decreased and it is not certainly indication of decrease in soil activity. The effect of salinity is low in the soils with LL lower than 120 percent. But liquid limit in contact saline water decreases more than 60% in the very active soils. So it seems that influence of salinity on the liquid limit increases as the percentage of active clay minerals in the soil increases. The time of exposure is not an effective factor for changes in Atterbergs limit.

TABLE I. EFFECT ON LL, PL AND PI WITH TIME

	Saline water		
Time	**0**	**24hrs**	**48hrs**
Plastic limit	20.12	20.87	19.39
Liquid limit	24.89	25.3	26.47
Plastic index	4.77	4.43	7.08

[3]The author studied the clay types that falls under CH type in IS classification , and the variation of Liquid limit, Plastic limit and Plasticity index was studied with tap water and seawater and the observations revealed that testes limits of the contaminated soils increases when the results observed from tap water is compared with that of sea water.

TABLE II. EFFECT ON SEAWATER ON ATTERBERGS LIMIT

Atterbergs Limit	Increases by
Liquid limit	9.32%
Plastic limit	8%
Plasticity index	10.91%

[4] The author studied the effect of Atterbergs limit and results discussed that Low influence of salinity on plastic limit can arise little moisture of soil, at this condition that lead to decrease the interaction between soil and solute in water. But in the liquid limit, in which soil moisture is higher, the effect of salinity will be more. The Plastic Limit is observed in the sense when the soaking soil is tested for plastic limit; the plasticity gradually decreases with the increase in the salt concentrations. The Plasticity is decreased due to the salt content increment. The plasticity is decreased due to the effect of salt solution on particle adhesive strength.

[5] The author studied the seawater influence on the behavior ofthe expansive clays. In this study the rate of change in liquid limit of clayey soils when exposed to natural seawater with respect to distilled water. The four clayey soil samples were gathered with different mineralogy and plasticity characteristics and tested to determine liquid limit in the presence of distilled water, tap water and seawater. The results showed that the liquid limit decrease in presence of seawater; values of all liquid limits in seawater are lower than those in tap water and the difference is seen more clearly in Bentonite sample.

[6] The author studied the samples which were exposed to the higher salinity shows less sensitivity to increasing the moisture content. As it can been seen the plastic limit will increase slightly by increasing the salt content. RSM model was used to predict the amount of the plastic limit. The liquid limit will increase in decrease of salt content. Results significantly shows that there is a reduction in the liquid limit and consequently in the plastic index due to presence of clayey material in the samples while the plastic limit is nearly constant. It can be said that whatever the concentration and percent of salt be higher, the repulsive forces between particles and consequently the dual layer thickness and also decreases, and thus the liquid limit is down.In general, any increase in the fluid cavity concentration will lead to decrease in the liquid level, little change or gradual increasing in plastic limit and consequently decrease in plastic index.

[14]The author studied the effect of Atterbergs limit on expansive clayey sample, where the sample is passed through Distilled water, tap water, treated waste water and seawater. The results show a clear change in theliquid and plastic limits after using different watertypes in mixing with expansive clay soils. It has been observed that there is a significant change in plastic and liquid limit due to use of different water samples. Liquid limit decreasesfrom 70% by using distilled water to 68%, 61% and55% when using tap water, treated waste water andsea water, respectively. Also, plastic limit decreasesfrom 43.36% when using distilled water to 41.8%,39.3% and 35.78% when using tap water, treatedwaste water and sea water, respectively. The reduction in plastic limit is due to the ions present in seawater is replaced by the cations present in the hydrous layer surrounding the clay layer and thus reducing the net electrical charge forming flocs. The floc behaves as silt particles which is less plastic in nature particles, establishment of bonding between them and formation of salt crystals in pores of soil.

[28]The author studied the effect of saline water on minerals such as kaolinite and bentonite to evaluate the liquid and plastic limits. The effect of time after mixing clays with water was also investigated for the consistency limits of clays. The test was conducted immediately, 1 day, or 7 days after mixing soils. For liquid limit tests two different test methods were used, the percussion cup method by Cassagrandes apparatus and the fall cone method. When sea water is used the liquid limit of kaolinite decreased by 6-15% and that of bentonite further decreased up to 37-53%. The liquid limit obtained from the fall cone method was approximately 10% for bentonite and 20% for kaolinite, which are higher than those from the percussion cup method.

[29]The author studied the Atterbergs limit on various kaolinite, bentonite and sand mixtures using salt water, the results inferred was the liquid limit of kaolinte clay decreases by both water salinity. For pure kaolinite an increase in water salinity from 0 to 200gm/litre NaCl, results in 6% decrease in Liquid limit. Similarly the bentonite showed same as of kaolinite clay. Nearly 50% and 70% of decrease in liquid limit occurs with 20% and 5% salt concentration increase for kaolinte and bentonite.

[30]The author studied the high salinity and pH may lead to change of geotechnical properties of soil. The liquid limit and the unit weight increase with salinity and decrease with pH. It can be seen that liquid limit increase with the increase in the value of salinity and the behavior of liquid limit with pH decrease in with increasing pH. The salinity directly affects the consistency as well as the strength properties of soil.

[31]The author studied that the effect of common salt on engineering properties of black cotton soil. The soil was mixed common salt water NaCl of 0% , 2%, 4%, 6%, 8% concentrations and the result UCC strength with increase in NaCl concentration. On addition of 1.5% NaCl to the soil, the maximum reduction percentage of 60.42% was observed (131-51.85% on liquid limit), 42.86% (50-28.57% on plastic limit).

[33]The author studied that the test were performed using distilled water and natural brine and saline solution with different salt concentration and the results indicates that the liquid limit and plastic limit decreases with pore fluid salinity. The difference between the liquid limit values obtained with the conventional water content and fluid content method is equal to 4% of salinity of 3.5% (seawater salinity) but increase to 33% for a salinity of 25%. The liquid limit obtained with both the methods display good correlation with the plasticity index.

[36]The author studied the Atterbergs limit on two sets of clay samples. One was mixed with pure water (pure water clay soil) and the other was mixed with salty water added to in the ratio ranging from 20 -80%(clay soil mixed with salt). Plasticity index decreases from 26 for pure water clay soil to 24.96 for clay soil mixed with 80% salt. The result of testing value drops as liquid limit, plastic limit, shrinkage limit are 34.5%, 26-2.125%, 10.75-1.4% for the soil mixed with 80% salt content. From this salty water causes a reduction in liquid limit plastic limit and plasticity index of clay minerals. In general Salty water increases the particle size of clay minerals.

[38]The author studied the Atterbergs limit using eighteen samples collected from nine sites and the sample property consists of clay fraction varying from 36-94%, plasticity indices of 8-42% which is an indication of illitic clay type. The tests results shows differences in geotechnical index properties of soils which are mostly due to variation in the relative proportion of minerals, texture and also due to salt leaching.

[42]The author studied the swell index of Vermin clay which are performed according to ASTM D698 with 0, 10 and 20 % percent of Bentonite content, DI water and fluids which includes NaCl, $CaCl_2$, $MgCl_2$ were used 1N is used, the observation was due to increase in salt concentration and cation valance the swelling volume increases.

B. Effect of Swelling potential

[2]Change in fine grain soil behavior due to contaminants in the absence of strong interaction leading to mineralogical changes can be explained based changes to mineralogical changes can be explained based changes in the diffuse double layer theory and fabric changes. The amount of swell depends up on the type of mineral present in the soil and concentration of acid solution.

[3]The author studied the effect of sea water on some geo technical properties of clayey soil that falls under CH group as per I.S classification. The geotechnical properties were discussed and the free swell index was observed with tap water and sea water It is observed that the free swell index increased 6.67% in sea water.

[5] The author studied the seawater influence on the behavior of the expansive clays. In this study the rate of change in swelling behavior of four clayey soils of different mineralogy and plasticity characteristics are tested with natural seawater with respect to distilled water and swelling characteristics are determined. It was observed that the differential free swell per cent is lower in tap water and distilled water for swelling soils (LL > 150...200 %), indicating reduction in swelling potential in seawater, The difference in free swell per cent between distilled water and seawater is remarkable, between 0% to 200%; zero is for non-swelling soils and 200% is for bentonite.

[6]The author studied that swelling by conducting Infiltrometer test (Swelling Infiltrometer) was conducted on clay samples the results shows that effect of seawater has

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significant infiltration thereby decreasing the swelling potential of clays containing high percentage of montromorillonite clays. The reduced swelling potential is due to submergence (Infiltration) of seawater.The swelling characteristics of the clay soil sample were also determined using free swell index test. Here sea water results in a marked decrease in the free swell index from 650% with distilled water to less than 95%. So it is concluded that the swelling characteristics of the soil that exhibit high liquid limit are more significantly reduced when mixed with seawater. The results indicate that as the seawater of the mixing water increases, the free swell index decreases.

[22] The Differential free swell index was carries and the result obtained shows that DFS has reduced from 41% to 19% in Black cotton soil.

[24] The author studies the swelling characterstics of five types of bentonite soil (a, b, c, d & e) by conducting swelling deformation experiment and swelling pressure experiment and the test results shows that the maximum swell pressure for bentonit A is same in case of distilled water and seawater, whereas there is some small difference (24% - 14%) is seen from bentonite (b-e) type

C. Effect of UCC strength

[4]The author studied the Unconfined Compressive Strength of the Black cotton soil of various concentration (0.001 M, 0.01M & 0.05M) of seawater. The UCC value is observed as increment from the normal black cotton soil treated with distilled water. The UCC value was obtained as 4.82 kg/cm2 to 6.24 kg/cm2.

[7]The author studied the UCC strength on seawater sample test which was conducted as per IS 2720 (Part 10): 1991 with both tap water and seawater. The observation was that the unconfined compressive strength remained almost same for both control sample and sea water treated sample with a reaction time of two days for the sea water treated sample which is due to absence of pozzolonic reactions. Sea water contains very meager amount of Ca^{2+} which is insufficient for the pozzolonic reaction to take place.

TABLE III. EFFECT ON SEAWATER ON UCC STRENGTH

Parameter	UCC strength (T/M^2)
Tap water	31.61
Sea water	21.48
Normal water after 2days reaction time	95.92
Seawater after 2days reaction time	97.45

[9]The author studied the UCC strength of Black cotton soil using different concentrations of NaCl with different Pore Fluid Content Ratio. It is observed that the strength of the contaminated soil decreases when the pore fluid content passes from dry side of optimum to wet side of optimum irrespective of the % concentration of sodium chloride. It is also observed that the strength of the soil decreases with increase in concentration of sodium chloride irrespective of the Pore Fluid Content Ratio.

[14] The author studied the UCC strength on four different water types (distilled water, tap water, treated waste water and seawater) on expansive soils. The observation was that the unconfined compressive strength remained almost same for all the soil samples which is due to time is not enough for reaction of water withexpansive clay soil, where all samples were left only one day to allow uniform distribution of moisture in specimen.

[39]The author studied the unconfined compressive strength in dead sea region the fresh water is compared with brine water where the fresh water shows higher UCC strength, lower MDD and higher OMC compared with brine water.

[40]The author studied the unconfined compressive strength on three soil type namely clay soil, clayey sand, base course where tap water and salty water where used for comparison of results, the inference observed was the clay soil and clayey sand have higher UC strength using salty water than using tap water respectively it is because the clay soil has multilayers of gibbsite and silica sheets with hydrogen bonding linked with sheets(Dunn 1980)

III. CONCLUSION

The purpose of this review paper is to study theeffects on geotechnical behavior of various soil types due to sea water intrusion. The following conclusions can be drawn from this review. Higher cation valance and increasing salt concentration causes decreases in Atterbergs limit. The free swell index get increased with presence of seawater intrusion compared to normal water for construction purpose. The strength behavior is influenced by nature of pore fluid, Unconfined Compressive strength gets increased considerably due to seawater which causes problem in construction of superstructure. Therefore some precautions have to be taken before the construction process in areas that are subjected to seawater intrusion.

REFERENCES

[1] YelizYukselen-Aksoy, Abidin Kaya, Ali Hakan Ören.,2008. "Seawater effect on consistency limits and compressibility characteristics of clays". Engineering Geology 102 (2008) 54 – 61.

[2] RassoulAjalloeian, HadisehMansouri, "Effect of Saline Water on Geotechnical Properties of Fine-grained Soil" EJGE.

[3] M. Chittaranjan, T. Srikanth, B. Yamini Lakshmi & D. Pavani “Effect of sea water on some geo technical properties of clayey soil” International Journal of Earth Sciences and Engineering 1ISSN 0974- 5904, Volume 04, No 06 SPL, October 2011.

[4] Bale Nikhil Kumar, JeevanaSmitha, Dr. K V Uday. "Effect of Salinity on Geotechnical Properties of Expansive Soils” International Journal of Innovative Research in Science, Engineering and Technology.

[5] Tatiana ivasuc” Seawater influence on the behavior of the expansive clays” Vol. I, 2012.

[6] Mohammad Ajam, Mohammad Reza Sabour, Gorban Ali Dezvareh. "Study of water salinity effect on geotechnical behavior of soil structure using response surface method (RSM), (Case study:Gotvand Dam). CienciaeNatur, Santa Maria, v.36 n. 2jun 2014, p. 360-369.

[7] Dr. P. D. Arumairaj and A. Sivajothi, Bund. J, “Effect of Sea Water on Expansive Soils’’. EJGE Vol. 15 [2011],

[8] Natalie Campbell, Burt Look and Andreas NataAtmadja."An Investigation Into The Effect Of Salt Water On The Geotechnical Properties Of A Residual Clay". Australian Geomechanics Vol 44 No 1 March 2009.

[9] T Srikanth and K L A V Harnadh. "Effect of sodium chloride on some geo-technical properties of an expansive clay ". International Journal of Conceptions on Mechanical and Civil Engineering Vol. 1, Issue. 1, Dec’ 2013; ISSN: 2357 – 2760.

[10] Sivapullaiah, P.V. and Sridharan, A. (1987). “ Effect of Polluted Water on the Physico Chemical Properties of Clayey Soils”, Proc. Sym. On.

[11] Arasan, S., and T. Yetimoglu (2008) “Effect of Inorganic Salt Solutions on the Consistency Limits of Two Clays,” Turkish J. Eng. Env. Sci, 32, 107-115.

[12] P.V.Sivapullaiah.,2009. Effect of soil pollution on geotechnical behaviour of soils. IGC 2009, 933 - 940.

[13] Mohie Eldin Elmashad, Alaa A. Ata(2015). "Effect of seawater on consistency, infiltration rate and swelling characteristics of montmorillonite clay" HBRC Journal.

[14] Mohamed Mahmoud A. Hussein. “Effect of Different Water Types on Expansive Soil Behaviour”, Life Science Journal 2016;13(5).

[15] Bag,R.(2011)"Effect of Saline Water on Geotechnical Properties of Low Plastic Soil and High Plastic Soil".

[16] Hideo Komine, Kazuya Yasuhara, and Satoshi Murakami. Swelling characteristics of bentonites in artificial seawater. Canadian Geotechnical Journal , 46(2):177–189, 2009.

[17] Adrian D. Werner , Mark Bakker , Vincent E.A. Post. "Seawater intrusion processes, investigation and management: Recent advances and future challenges ". Advances in water resources.

[18] Murugaiyan. V, Anandhanarayanan. G."Effects Of Salt Solutions and Sea Water on the Geotechnical Properties of Soil –A Review". International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181.

[19] Janzen, H. H. (1993). Soluble salts. In M. R. Carter (Ed.), “Soil sampling and methods of analysis (pp. 161–166)”. Boca Raton: Canadian Society of Soil Science. Lewis Publ.

ISSN 2229-5518
[20] Sreepada Rao, A. (1982).“ Physico Chemical Properties and Engineering Behaviour of Anion Adsorbed Clay ”,Ph.D. Thesis , Indian Institute of Science, Bangalore.

[21] S .A. Naeini and M. A. Jahanfar,“Effect of Salt Solution and Plasticity Index on undrained Shear Strength of Clays”, World Academy of Science, Engineering and Technology. Vol 49, 2011, ppr 1.

[22] Prakhar Dubey," Effect of Common Salt (NaCl) on Index Properties of Black Cotton Soil",IJIRST –International Journal for Innovative Research in Science & Technology| Volume 2 | ISSN (online): 2349-6010.

[23] Kashyap, Rudrendra & Bag, R.,"Effect of Saline Water on Geotechnical Properties of Low Plastic Soil and High Plastic Soil", B.Tech Thesis, National Institute ozf Technology, Rourkela, 2015.

[24] Hideo Komine, Kazuya Yasuhara, and Satoshi Murakami, . "Swelling characteristics of bentonites in artificial seawater". Canadian Geotechnical Journal, 46(2):177–189, 2009.

[25] Hadiseh Mansouri, Rassoul Ajalloeian, Amir Hossein Sadeghpour, "The Investigation of Salinity Effects on Behavioral Parameters of Fine-Grained Soils".International Conference on Case Histories in Geotechnical Engineering (2013).

[26] B.L. Kirov1, N.N. Truc1, "A study on the relationship between geotechnical properties and clay mineral composition of Hanoi soft soils in saline media". International Journal of Civil Engineering, Vol. 10, No. 2, June 2012.

[27] Toan, D.T., Truc, N.N.: 2010,"The impact of seawater on soil properties in the RRD. Journal of Science and Technology of Vietnam, ISSN 0866 708x, pp. 215-223, (in Vietnamese).

[28] Park, Sung-Sik; Nong, Zhenzhen; Jeong, Sueng-Won," Effect of Sea Water and Microorganism on Liquid and Plastic Limits of Soils". Journal of the Korean Geotechnical Society, Volume 28, Issue 10, 2012, pp.79-88.

[29] Behzad Fatahi , Hadi Khabbaz and Sudip Basack , "Effects Of Salinity And Sand Content On Liquid Limit And Hydraulic Conductivity". Australian Geomechanics Vol 46 68 No 1 March 2011.

[30] Rahanuma Tajnin, Tabassum Abdullah, Md. Rokonuzzaman, "Study On The Salinity And Ph And Its Effect On Geotechnical Properties Of Soil In South-West Region Of Bangladesh". International Journal Of Advanced Structures And Geotechnical Engineering Issn 2319-5347, Vol. 03, No. 02, April 2014

[31] Durotoui, T.O, Akinmusuru, J.O, Ogbiye, A.S, Bamigboye, G.O,"Effect Of Common Salt On The Engineering Properties Of Expansive Soil Durotoye" .International Journal Of Engineering And Technology Volume 6 No.7, July, 2016.

[32] Nikos J. Warrence, Dr. James W. Bauder, And Krista E, "Basics Of Salinity And Sodicity Effects On Soil Physical Properties". Pearson Land Resources And Environmental Sciences Department Montana State University - Bozeman.

[33] A. Messad B. Moussai , "Effect Of Water Salinity On Atterberg Limits Of El-Hodna Sabkha Soil". Bull Eng Geol Environ Doi 10.1007/S10064-015-0733.

[34] K. J . D. Ridley ,J K. Bewtraa, Nd J. A. Mccorquodale, "Behaviour Of Compacted Fine-Grained Soil In A Brine Environment".

[35] Yogesh Pathak, Ashutosh Pathak, "Effect Of Saline Water On Geotechnical Properties Of Soil" . International Journal Of Innovative Research In Science, Engineering And Technology, Vol. 5, Issue 9, September 2016.

[36] Mahmoud M. Abu Zeid A, Ahmed K. Abd El-Aal, "Effect Of Salinity Of Groundwater On The Geotechnical Properties Of Some Egyptian Clay". 1110-0621 Production And Hosting By Elsevier B.V. On Behalf Of Egyptian Petroleum Research Institute.

[37] S. Basack1 And R. D. Purkayastha2, “Engineering Properties Of Marine Clays From The Eastern Coast Of India**”,** Journal Of Engineering And Technology Research Vol.1 (6), Pp.109-114, September, 2009.

[38] Jacque locat And Guyl Efebvre And Gérarbdal Livy, “Mineralogy, Chemistry, And Physical Properties Interrelationships Of Some Sensitive Claysfrom Eastern Canada”.

[39] Z.M. Mansour, M.R. Taha And Z. Chik, “Fresh Brine Water Effect –On The Basic Engineering Properties Of Lisan Mari-Dead Sea-Jordan”, Journal Of Applied Sciences 8 (20): 3603-3611, 2008.

[40] G. R. Otoko, “The Effect Of Salt Water On The Physical Properties, Compaction Characteristics And Unconfined Compressive Strength Of A Clay, Clayey Sand And Base Course”. European International Journal Of Science And Technology Vol. 3 No. 2.

[41] Rageena S.S, Rani V, “Effect Of Various Pore Fluids On Free Swell And Shrinkage Cracking Of Clays”. International Journal Of Innovative Research In Science, Engineering And Technology. ISSN(Online) : 2319-8753.

[42] Nader Shariatmadari, Marzieh Salami, Mehran Karimpour Fard, “Effect Of Inorganic Salt Solutions On Some Geotechnical Properties Of Soil-Bentonite Mixtures As Barriers”. International Journal Of Civil Engineering, Vol. 9, No. 2, June 2011.

[43] Soumya M Das, Mrs. Sudha A R, “A Study On The Effect Of Chemicals On TheGeotechnical Properties Of Bentonite And Bentonite-Sand Mixtures As Clay Liners”. International Journal Of Engineering Research & Technology (IJERT), ISSN: 2278-0181Vol. 5 Issue 09, September-2016.

[44] Purabi Das, Jagori Dutta, Anil Kumar Mishra, “A Study On The Combined Effect Of Salt Solutions OnThe Swelling And Hydraulic Behaviour Of Bentonites”. Indian Geotechnical Conference Igc 2016 15-17 December 2016, IIT Madras, Chennai, India.