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The Effect of Lining Material on the Permeability of Clayey Soil

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Abstract

The main objectives of current work are to reduce the permeability of clayey soil for different fluid (water and crude oil) and to predict its efficiency for petroleum storage. Current research uses a sodium bentonite (B) with percentage (1.5, 3 and 6%) by the dry weight of soil and coal tar extended epoxy resin coating as the lining material. The soil sample was brought from AL -Nahrawan region. Soil's permeability for petrol was studied through using compacted soil model and making a central hole (core) in it with changing its dimensions (diameter, thickness of wall and base), type of fluid and number of filling cycles. After filling the core with these fluids, the volume losses of fluids were measured per day. When two cycles were finished, a sample was taken from the base of the core to be examined in a consolidation test. Number of laboratory tests have been conducted such as (Atterberg limits, compaction test, consolidation, sieve analysis and specific gravity).The results showed that the increase in bentonite percentage causes an increase in (optimum moisture content, Atterberg limit and specific gravity) and also decreasing in (max dry unit weight and permeability) as the fluid was water. However, an increase in permeability was obtained using the crude oil. A reduction in volume losses was observed when using the lining material, coal tar extended epoxy resin coating.

Keywords: Permeability; Compacted Clay Liner; Crude Oil; Bentonite; Lining Material (Coal Tar Extended Epoxy Resin Coating (Nitocote ET-402)).

1. Introduction

Environmental damage is usually the result of accidental spills and sometimes deliberate disposal of oil or oily wastes into water or land, through bursts of pipes and pumps, erosion of pipelines and spillage during transport [1]. Soil and groundwater contamination with petroleum components can result from small leaks to large ruptures in underground storage tanks (USTs), which represent broad public environmental and health concerns [2, 3].

Crude oil contains a complex mixture of compounds, mainly hydrocarbons. The constituents of crude oil are grouped into four major categories, the saturated compounds, the aromatics, the resins, and the asphaltenes [4]. The main environmental concern associated with crude oil is that it can pose serious risks to human health and the earth's ecology during all stages of production, processing and consumption, if not handled carefully [3, 5].

Soil permeability is considered a key parameter in many hydrological and geotechnical problems so, environmental concerns have led researchers to focus their attention on the hydraulic conductivity of clays, due to their important role in waste containment [6].

The compact clay liner is one of the most important components of municipal landfills used to prevent the infiltration of pollutants into groundwater resources. Compressed clay soil is generally considered impervious. Even with the

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emergence of hazardous waste disposal and associated problems of groundwater pollution through leachate, clays are being accepted as barriers [7].

Most of the soil at the site is used to build clay barriers as long as they can be compressed according to standard specifications, including hydraulic conductivity. Wherever the soil available at the site is not sufficient to be used for construction clay barriers, the soil mixing with bentonite is the most widely used [8].

Sodium bentonite has a hydraulic conductivity in the range of 10^{-11} to 10^{-12} m/s. High swell capacity associated with a very low hydraulic conductivity and high surface area makes this clay suitable as liner material to reduce leakage due to crack or any other reason [9].

At the present time a new way for compacted clay liner is being used through coating it by using Nitocote ET 402 material which has a corrosion resistance making it an economic material. The coating possesses a high-build capability, excellent bond and chemical resistance properties. Rasheed, (1999) [10], investigated that any film or impervious layer placed on the section of a channel can serve as a lining.

The successful construction and design of soil liners and covers require considering multiple factors e.g., assessment of chemical compatibility, selection of materials, determination of construction methodology, bearing capacity, evaluation of settlement, and analysis of slope stability [11].

Kavya et al. (2016) [11] examined the potential of modified soil barrier by mixing locally available soil with sodium bentonite with percentage (3, 6, 9, 12, 15%) by weight to contain municipal solid waste .They observed an increasing in un confined compression strength and a decreasing in hydraulic conductivity with increasing percentage of bentonite. Also, they found that 12% of the group met the liner standards and found it to be the optimum percentage.

Goodarzi et al. (2016) [12] investigated the effects of different concentrations of various organic chemicals including methanol, acetone, acetic acid and citric acid on macro and microscopic responses of Na + -Bent. They reported that contaminants produced small structural units and total structures that may be significantly different from natural soil. This is due to the breakdown of the diffused double layer and the decreasing of the surface charge density of the particles. In addition, aggregation and development of aggregated structure have been reported in the presence of organic chemicals. This change in tissue has reduced the plasticity and soil swelling index as well as increased Na + -Bentonite permeability [22].

Krishna et al. (2016) [13] tried to evaluate the effect of municipal leachate on soil properties. The results showed that the values of natural moisture content in non-contaminated soils are generally lower than those found in polluted soil samples. Also, they reported that the concentration of chloride in contaminated soil was higher than that of non-contaminated soil. This shows that due to the disposal of solid waste the soil quality is reduced. Finally, the study concludes by drawing on the results obtained from, the solid waste disposed, the soil quality is reduced compared with the non-contaminated soil.

Youssef and et al. (2016) [14] Investigated the impact of iron ore taillings (IOT) on the hydraulic conductivity of the compressed laterite using deionized water and municipal solid waste residues such as combustible liquids, respectively. The hydraulic conductivity decreased with an increase in IOT content due to improved mechanical properties of the soil. The decrease of IOT soil mixtures reduced the hydraulic conductivity to less than 1×10^{-9} m / s, particularly in higher compactive efforts. Also, biotic clogging of soil pores due to accumulation of biomass from yeast and bacteria found in leachate tends to greatly reduce hydraulic conductivity.

Chinade et al. (2017) [15] Discussed the impact of municipal solid waste (MSW) leachate on the strength of compressed tropical soil to slow landfills. Unconfined compressive strength (UCS) samples are compressed at water content from -2, 0 and + 2% relative to the optimum moisture content of three compactive efforts: British standard low(BSL), West African Standard (WAS) and British Standard Heavy (BSH) were permeated with MSW leachate for 7, 21, 42, 84 and 120 days respectively. They concluded that UCS for compressed samples decreased overall with increased BSH, WAS and BSL permeating intervals respectively, due to the increase in clay particles that reduced friction resistance between solid particles at their contact points.

Javadi et al. (2017) [16] estimated the swelling, hydraulic conductivity and pollutant retention of compacted clay modified with (hexadecyltrimethylammonium (HDTMA) bentonite) against both gasoline and organic solution. They found the addition of 10% of the HDTMA to the compressed clay is slightly increased the hydraulic conductivity of the mixture to water. However, a higher tendency for swelling and lower hydraulic conductivity of gasoline were observed with 5% of the HDTMA bentonite, and the embedded clayey soil had a much stronger retardation capacity for naphthalene.

Sobti et al. [2017] [17] investigated a relative cost analysis of the use of a compacted clay liner(CCL) consisting of a fine soil layer with low permeability overlapped by a geomembrane, fabricated soil liner(FSL), which was manufactured by locally available mixtures of sandy/silty soils with bentonite varies from 0 to 40% for sand and 0 to

15% for silt and geosynthetic clay liner (GCL) is a clay lining manufactured in the factory consisting of a thin layer of bentonite, which is encased between two earth cladding or adhered to a terrestrial membrane as a barrier material in landfills / waste containment facilities in order to judge the economic feasibility of different materials. They found that FSL is more economical contrast to other types. In addition, GCL can be used when both bentonite and appropriate clay are not attendance nearby and must be brought over long distances.

Naini et al. (2017) [18] Studied the influence of four kinds of inorganic leachate components at concentrations of 2, 5 and 10%, leachate .Also the effect of deionized water on shear strength factors for three compacted clay liner (CCLs) with different plasticity index conducted by a series of direct shear and vane shear tests. They found that the increase in pollutant's content to 2%, cause an increase in the undraind shear strength of the bentonite clay slabs in both direct and vane shear tests.

In this study, the effect of bentonite on the geotechnical properties of clayey soil and volume loss of clayey soil subjected to water flow as soluble polarity solvents and crude oil as insoluble solids in polarization are investigated. Also, the impact of the lining material (Nitocote ET 402) is examined. The new manner of coating the clay liner by Nitocote ET 402 yields the most effective results that minimizes the volume loss of crude oil than bentonite additive.

2. Sample Preparation

In order to compare between the modified and unmodified soil samples, the initial water content and dry density were fixed.

At first the unmodified soil passed from sieve No.4 then oven- dried with 105c. The dried soil mixed homogenously with bentonite then amount of water previously determined from compaction test was added to it and it was left to cure .Finally it was subjected to physical tests.

The consolidation and shear strength tests were conducted on samples (50mm in diameter and 20mm in height) and (38 mm in diameter and 75 mm in height) respectively were extruded from compacted mould by compaction test through using a hydraulic jack.

The model sample was prepared through using the split mould which has dimensions (15.1 cm in diameter and 17.5 cm in height) as shown in Figure 1. The weight of bentonite and soil were determined using the dry unit weight of soil and used mould volume. The soil has been mixed homogeneously with percentage of bentonite after determination its weight. Amount of water which is previously determined from the standard compaction test was added to soil, then it was compacted in three layers. Each layer has a determined number of blows to give the same energy of the standard proctor. The number of blows was (85 blows/layer) using a hammer dropping from height of 300 mm. The surface of the compacted soil has been scarified lightly with a spatula, then the second and the third layer are handled with the same way. The extension collar which is found at the top of the mould was removed carefully and the surface of top soil is leveled off. A compression machine is used to make a core inside the compacted soil by inserting different diameter cylinders (70, 80 and 90 mm) as shown in Figure 2.The procedure is repeated for origin soil by coating internal walls of the core with Nitocote material.

Figure 1. The split mould

Figure 2. The used cylinders

3. Materials

3.1. Soil

The soil that was used in this study was brought from Al- Nahrawan region which represents a soil that rich with clay content .The physical properties and chemical tests are illustrated in Tables 1 and 2 respectively. The chemical tests were achieved in ministry of science and technology.

3.2. Bentonite

To decrease the permeability of soil, sodium bentonite (B) was used which was brought from the middle oil company. The bentonite properties represented by high swell capacity associated with a very low diffusion coefficient, low hydraulic conductivity in the range of 10^{-11} to 10^{-12} m/s and high surface area makes bentonite-soil mixture suitable as liner material for underground storage tanks [18]. The chemical composition is illustrated in Table 3. The chemical tests of bentonite were achieved in ministry of science and technology.

Table 1. The physical properties of the soil

Property	Value	Specification
liquid limit%	49	
Plastic limit%	21	ASTM D4318
Plastic index%	28	
Max dry density gm/cm^3	1.78	ASTM D698
Optimum Moisture Content, %	17.5	
Specific gravity	2.7	ASTM D854-00
Clay%	60	
silt%	26	ASTM D422-63
sand%	14	
Classification soil unified classification system (USCS)	Clay with low plasticity (CL)	ASTM D 2487

Table 2. Composition of soil oxides

Compound	Weight%
SiO_2	53.15
SO_3	0.63
CaO	15.23
L.O.I	13.49
MgO	3.13
pH	7.2

Table 3. Chemical composition of bentonite

Compound	Weight%
Al_2O_3	16.65
CaO	3.49
SiO_2	54.45
MgO	3.73
Fe_2O_3	15.58

3.3. Coal Tar Extended Epoxy Resin Coating (Nitocote ET402)

Nitocote ET 402 is a coal tar extended, 100% solids, epoxy resin coating which has a corrosion resistance making it an economic material so, it was used in this study as lining material for coating clayey soil although it is used for coating concert surface. It is brought from local Fosroc Company. The coating possesses a high-build capability, excellent bond and chemical resistance properties according to BS 7542 & ASTM C30 .Rasheed, (1999) [10] investigated that any film or impervious layer placed on the section of a channel can serve as a lining.

NitocoteET 402 is used to prevent corrosion of concrete surfaces for applications such as:

- Chemical processing;
- Seawater tanks, channels and intakes;
- Foundation waterproofing;
- Manhole linings;
- Jetties, piers and docks;
- Sewage works and effluent plants.

It includes two cans (hardener can, and resin can). The entire contents of these cans are mixed mechanically using slow speed electric drill for 3-5 minutes till the homogeneous consistency is obtained. The application applied in this research involves two coats. The first coat is applied with a wet film thickness not less than 200 microns, and left for drying before the application of second coat for at least three hours at 45c.The second coat was applied after finishing the first one and left for drying. The chemical resistance and properties are shown in Tables 4 and 5 respectively.

Table 4. Chemical Resistance

Acids (m/v)	
Hydrochloric acid 10%	Excellent
Sulphuric acid 10%	Very good
Nitric acid 10%	Very good
Phosphoric acid 10%	Very good
Alkalis (m/v)	
Ammonia 15%	Excellent
Sodium Hydroxide 25%	Good
Solvents & organics	
Oils, vegetable and minerals	Excellent
Ferric Chloride 15%	Very good
Aqueous solutions	
Water	Excellent
Sea water	Excellent
Raw sewage	Very good

Table 5. The properties of lining material

Property	Value
Color	black
Flash point	25c
Film thickness	Dry:100-250microns/coat wet:161-403microns/coat

3.4. Crude Oil

The crude oil used in this work was brought from The Middle Oil Company. The properties are shown in Table 6.

Table 6. The properties of crude oil

Property	Quantity
Specific gravity (at 25ºC)	0.89
Viscosity (cp)	41.3
Density (g/cc)	0.88
Flash point (c)	43.1

4. Laboratory Work

4.1 Consolidation Test

Satisfactory to (ASTM,D2435_96) the test was achieved.

4.2. Shear Strength Test

The test was accomplished according to (ASTM, D 2166) and all tests were conducted in soil laboratory, civil engineer department, University of Baghdad.

4.3. Small Scale Model Test

The check of model is considered as a test to study the behavior of long time of stored fluids.

At first the core was filled with petroleum products. Through using Vernier the reading which represents the drop-in head per day was recorded till the central hole percolates all the fluid. The test is repeated for two cycles with different percentages of bentonite and also with coating the internal wall of the core by coal tar extended epoxy resin coating material. Figures 3 to 5 represented the stages of performing the model.

Figure 3. Coring the compacted clay

Figure 4. Extrude the core performing cylinder

Figure 5. Putting the model samples in container filled with sand

5. Results and Discussion

5.1. Atterberg Limit Test

From the results that is shown in Figures 6 to 8 and Table 7, there is an increase in liquid limit and plastic limit and plastic index. This is due to increase in clay content, which in turn causes an increase in the plasticity characteristics by taking more water to deform and filling up the voids make the mix impervious, which is the same result that was obtains by [20]. Also, may be due to the high activity of bentonite accordance to [19].

Perhaps the increase of dielectric constant and the decrease in cation valence of the pore fluid lead to an increasing in swelling and water retention which caused an increasing in Diffuse Double Layer thickness (DDL) and made an increasing in Atterberg limits .Similar to [21]. Water has approximately high dielectric constant which reveal the increasing in the Atterberg limits.

Odell et al. 1960 [22] and Pandian et al. (1995) [23] showed that increasing the bentonite content will linearly increase the liquid limit of soil-bentonite mix up to approximately 20%. However, they showed that the relationship is nonlinear at higher bentonite contents for clay-bentonite mixtures.

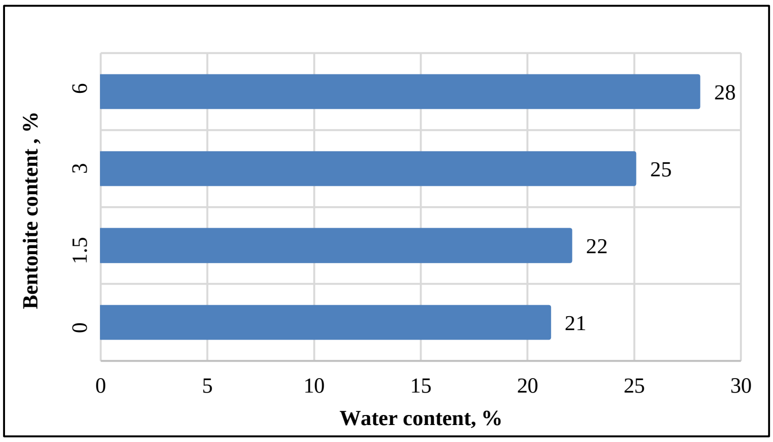


Figure 6. Effect of bentonite on plastic limit

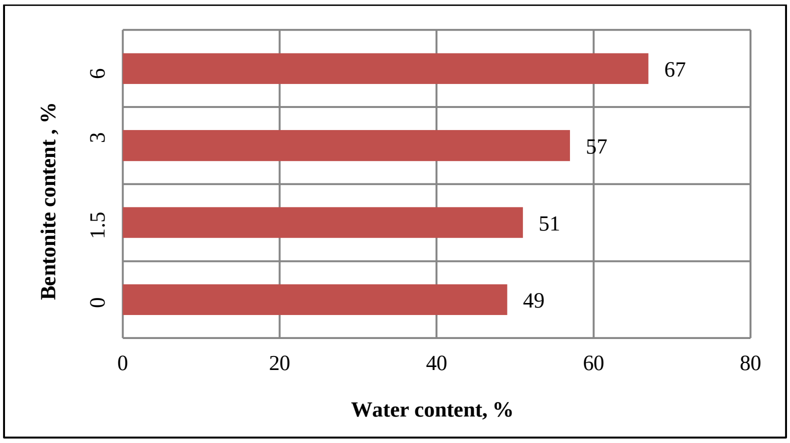


Figure 7. Effect of bentonite on liquid limit

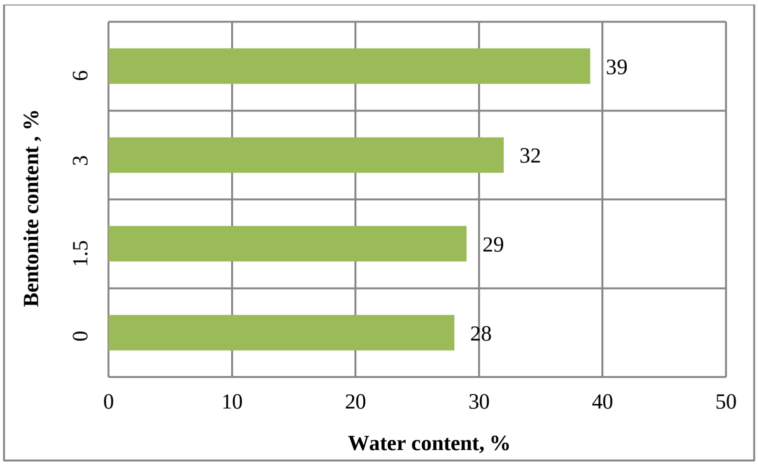


Figure 8. Effect of bentonite on plastic index

Table 7. Summery of Atterberg limit test

Additive percentage	Liquid limit value	Plastic limit value	Plastic index value
0%	49	21	28
1.5%	51	22	29
3%	57	25	32
6%	67	28	39

5.2. Grain Size Distribution Curve

The result are shown in Figure 9.

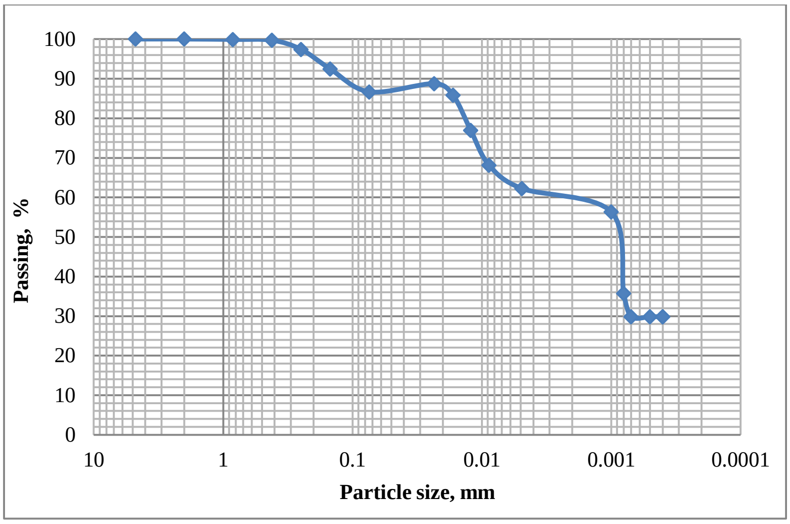


Figure 9. Grain size distribution curve for unmodified soil

5.3. Specific Gravity

The increasing in specific gravity was observed with increasing the bentonite content due to high specific gravity of bentonite. similar with [10]. Also increasing the clay content in the given soil led to a high specific gravity. These results are compatible with [24] as shown in Figure 10.

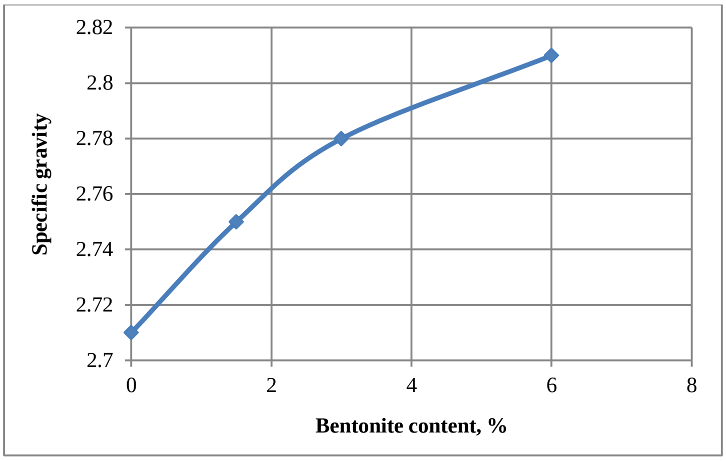


Figure 10. Effect of bentonite on specific gravity of soil

5.4. Compaction Test

From the result that is shown in Figure 11 below and Table 8, we observed a reduction in dry unit weight and an increase in moisture content has occurred when bentonite content incresed. When the given soil was mixed with bentonite material which has low weight and swelling characteristic caused an increase in clay content of soil and plasticity, thus the ability of possessing water in soil structure also increased .The water starts to occupy space which could be filled with soil mineral particles , which in turn reduces the weight of soil in compaction mold and leads to reduction in the maximum dry density and an increase in water content due to hydrophilic property of bentonite with water. The increase in clay content required more water to coat the soil particles to slide one over the other and to form the flocculent structure by occupying less solids in a given soil volume. This corresponds with the study of [8, 10, 20, 25].

In other words, due to larger specific surface area, high cation exchange and high activity of bentonite, the absorbed water surrounding the clay particles which has considerable volume, leads to an increase in the water content and a decrease in the dry unit weight. The results are similar to [10, 26-29].

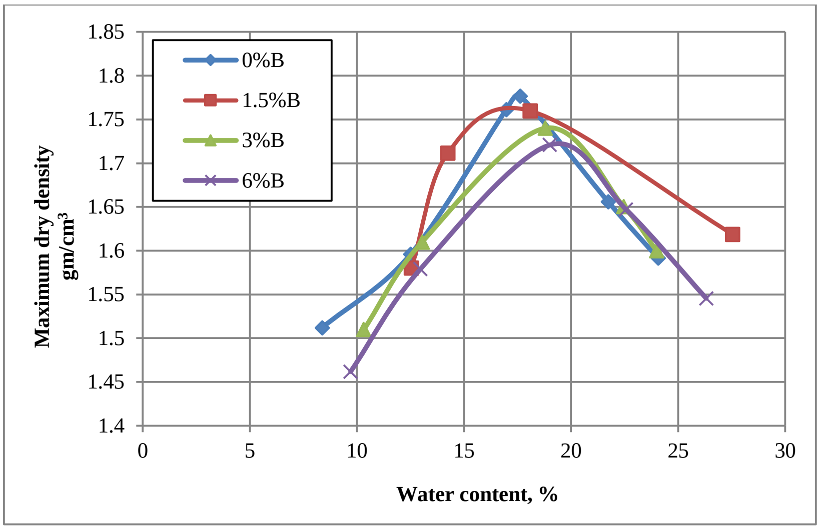


Figure 11. Compaction test result

Table 8. Summery of compaction test

Additive percentage	Maximum dry density	Optimum moisture content
0%	1.776	17.5
1.5%	1.759	18.1
3%	1.74	18.9
6%	1.72	19.3

5.5. Consolidation Test

It's obvious from the results shown in Figure 12 and Table 9, there is a decrease in hydraulic conductivity when increasing bentonite as fluid was water. This is due to the increase in fine content and in the swelling capacity of bentonite which may be possible as a result of the mineral galleries of the bentonite occurring due to the hydrophilic nature (hydrogen bonds) of bentonite and the time interval of 24 hrs. left for it to absorb water. Therefore, expansion occurs as water molecules penetrate beyond the external surface to the interstice of the bentonite layers [30]. So the saturated bentonite can perform as a gel whose volume is up to 15 times from its dry volume which fills most of the voids that cause a reduction in permeability. Similar result have been obtained by a number of researchers [25, 31]. Also as bentonite causes an increase in plasticity which, in turn causes an increase in double layer thickness and a reduction in congregation making the soil less permeability. Similar results were obtained by [11, 17, 32, 33, 34]. On the contrary the coefficient of consolidation is decrease due to filling the voids by fine particles. This is similar to the finding of [20, 32].

The test result indicates that as the bentonite content increases, the compression index and the coefficient of volume compressibility increase as a result of the increasing the plasticity of soil that will make it possess more water in its structure, so it increases the diffuse double layer thickness, making the particles to slide one over another with more a compressibility. The same results were found by [29].

While in contact with petroleum solvents, an increase in hydraulic conductivity was observed when bentonite content was increased as shown in Figure 12 and Table 10. This may be due to the density of viscosity oil and its viscosity correspond with [35]. Also, there was no swelling due to lack of association with organic solvent. This observation is based on the behavior of oversized bentonite on the chemical composition in line with the similar degree of substitution, and the quantity and nature of the cations associated with it. Similar with [30]. The decreasing in swelling makes an increase in permeability of soil by changing soil fabric, more flocculated structure will be formed. Similar result was observed by [3, 32, 36].

According to Goury Chapman's equation 1, the thickness of the double layer depends on the dielectric constant (D).

$$T = \sqrt{\frac{D}{n_0 * v^2}} \tag{1}$$

In which n_0= electrolyte concentration, v = cation valance. and T = Thickness of double layer.

Crude oil is a mixture of hydrocarbons that have very low dielectric constants; therefore, the D value of crude oil is low, so the value for T will decrease accordingly, causing the double layer to shrink and open flow paths. In addition to opening flow paths, low-dielectric-constant liquids cause clay particles to flocculate and shrink, thus causing the soil to crack. These cracks are the so-called syneresis cracks, which are similar to those associated with desiccation caused by drying. Similar results were found by [32, 37, 38].

It can be observed that the flocculation of clay particles and changes in Atterberg limits influence the distribution of void size and shape, there by changing the soil structure. Actually, the increases in hydraulic conductivity and alterations in soil structure cannot be solely attributed to the density and viscosity of pore fluid. In fact, both the viscosity and the dielectric constant of the fluid are responsible for the failure of the liner materials. In addition, the nature of the water or water-loving liquid (as measured by the constant insulation factor or the octanol-water division) is more important than the density or viscosity in assessing its permeability through the soil. This corresponds to. [32, 39].

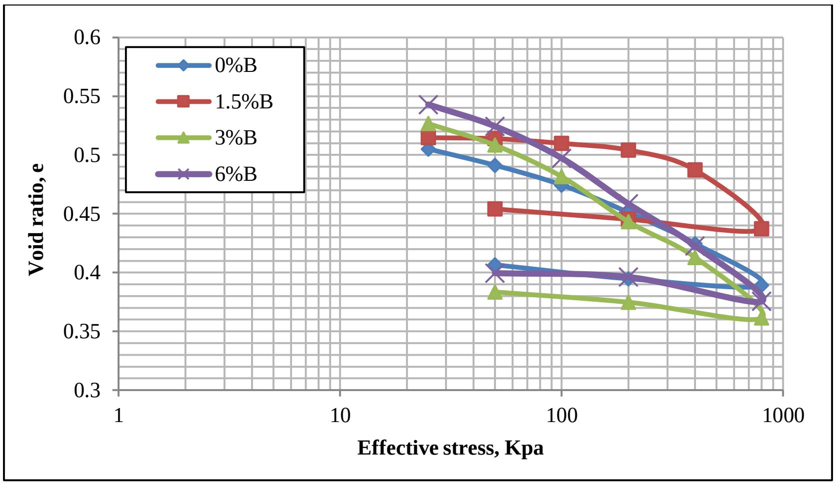


Figure 12. Consolidation test results

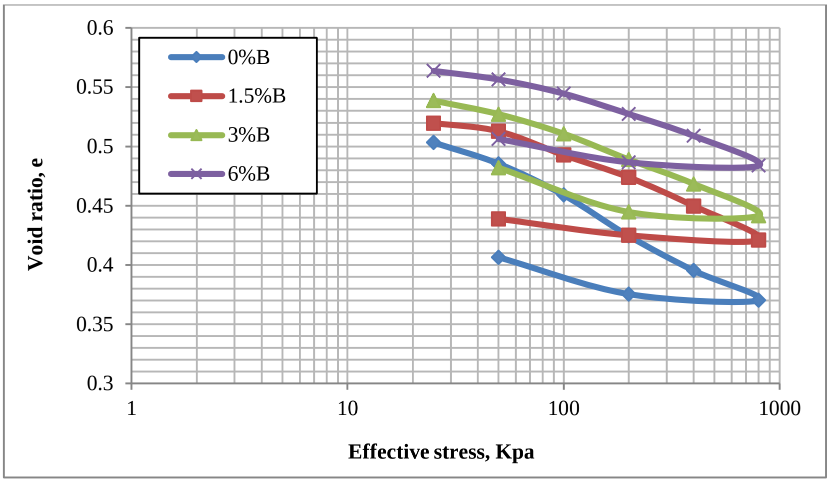


Figure 13. Consolidation test results with the effect of crude oil

Table 9. Consolidation test results as the fluid was water

Additive percentage	Cc value	Cr value	K value
0%	0.102	0.009	4.46E-9
1.5%	0.113	0.013	1.81E-9
3%	0.135	0.022	2.31E-10
6%	0.146	0.034	6.83E-11

Table 10. Consolidation test results as the fluid was crude oil

Additive percentage	Cc value	Cr value	K value
0%	0.092	0.008	7.2E-9
1.5%	0.100	0.009	9.3E-9
3%	0.116	0.019	8.21E-9
6%	0.119	0.020	7.8E-9

5.6. Unconfined Compression Test

Test results shown in Figure 14. It can be noticed that increasing the bentonite content causes an increase in unconfined compressive strength due to increasing the fine content as cementing material. Also, bentonite cause reduction in interparticle repulsion force making flocculated structure soil which means a more random particle orientation and hardening process that developed during 28 days curing period [40], so the soil shear strength will become greater when bentonite is added the same results were obtained by [8, 18, 20, 41].

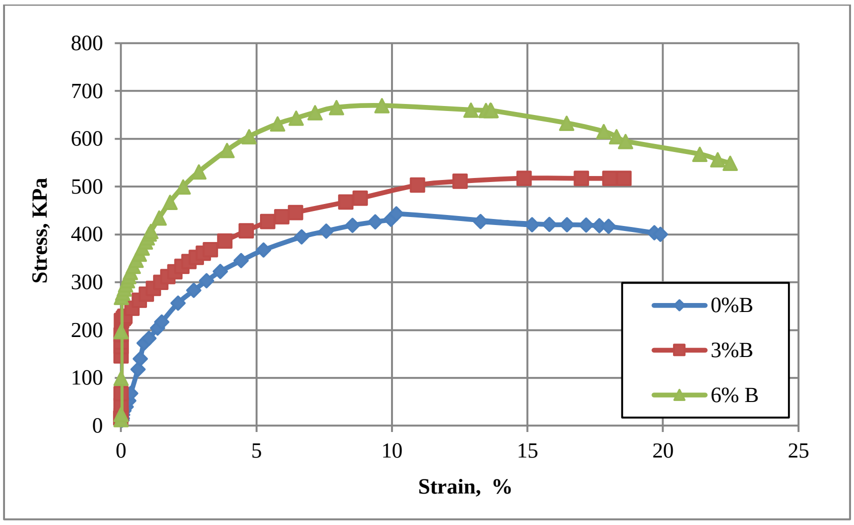


Figure 14. Unconfined compression test results

5.7. Small Scale Model Test

5.7.1. Effect of Wall and Base Thickness

An effect of wall and base thickness have been studied for the used model on the permeability of soil for crude oil and water. It has been done through using cylinders with different diameters and lengths. Figure 15 represents the effect of wall thickness through using cylinders (70,80 and 90 mm) in diameter and inserting into the model to fixed depth (80mm). Figure 16 represents the effect of base thickness through using cylinder (70mm diameter) and inserting it to different depths (80, 90 and 100 mm).

The results from Figures 15 and 16 show a decrease in ratio of volume loss to original volume from (0.91 to 0.63) and from (0.87 to 0.68) after 7 days from starting test when increasing the thickness of the wall and base from (30.5 to 40.5 mm) and (70 to 80 mm) respectively, this is due to lengthen the flow path which reduces the permeability.

The cylinder with 70 mm in diameter and 80 mm in height was chosen.

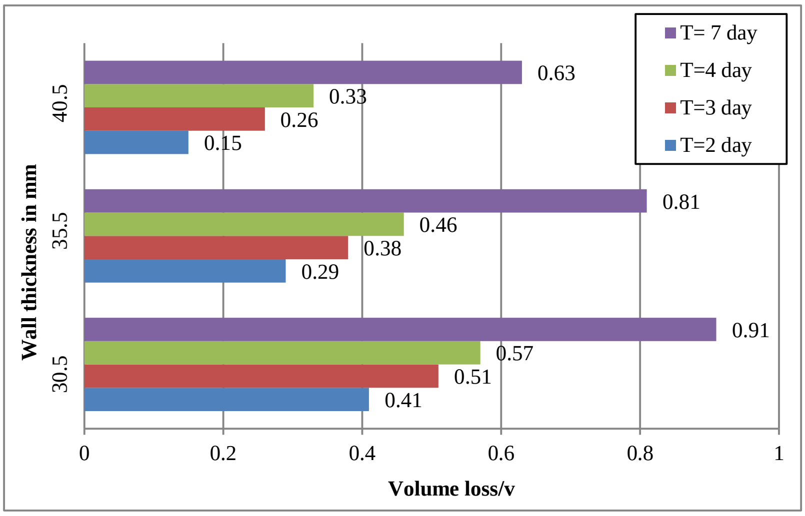


Figure 15. Effect of wall thickness

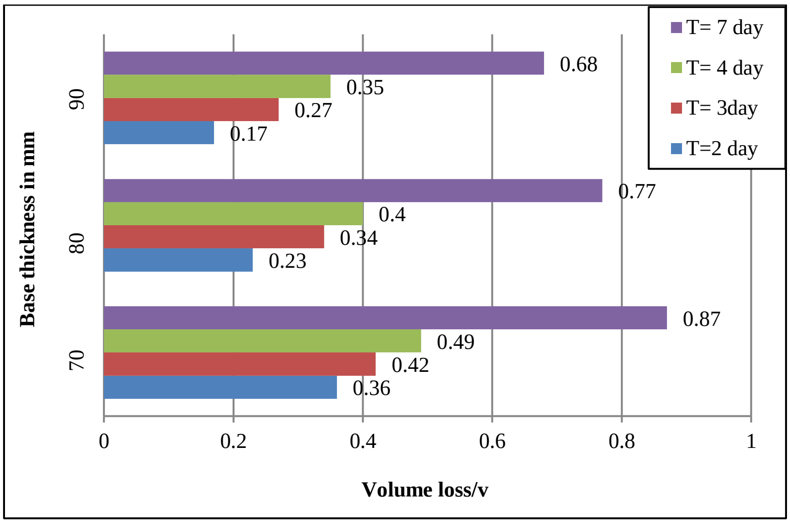


Figure 16. Effect of base thickness

5.7.2. Effect of Different Percentage of Bentonite

The cylinder with 70mm diameter and 80mm in length has been used for making a core inside the model for two fluid with two cycle.

From Figure 17a, an increase in the ratio of volume loss to original volume form (0.27 to 89), (229.6% increase) can be observed 3 days after starting the test when the bentonite content is increased from 0 to 6%, this is due to the reduction in thickness of DDL, resulting in the diffraction of clay particles and possible cracking leading to shrinkage of the soil skeletons, causing a decrease in repulsive forces that tended to flocculate and form aggregates due to attractive forces between particles, leading to a net increase in the effective flow zone and the hydraulic conductivity of the soil-pore fluid. Similar results in [42-44].

From Figure 17b ,a decrease in the ratio of volume loss to original volume from (0.94 to 0.34),(63.84% reduction) has been seen when increasing bentonite content from (0 to 6%) as the liquid was water 12 days after starting the test was due to increased bentonite swelling capacity and strong affinity between clay and water molecules, which increased the thickness of clay particles and thus reduced soil porosity. Thus, the number of effective pores, the hydraulic conductivity and water movement in the soil were reduced so that the flow path was lengthened. Similar results with [32, 36, 45, 46].

Also, bentonite causes increased plasticity of the soil, so it offers less hydraulic conductivity. It is well known that soil with a higher limit of fluid or a plasticity index should have a lower hydraulic conductivity (Mitchell 1976 [33]; Benson et al. 1994 [34]). Figures 18 and 19 shows an increase in volume loss from (0.77 to 0.835), (8.4% increase) and from (0.69 t0 0.81), (17.3% increase) respectively with refilling the core due to the effect of petrol.

(a)

(b)

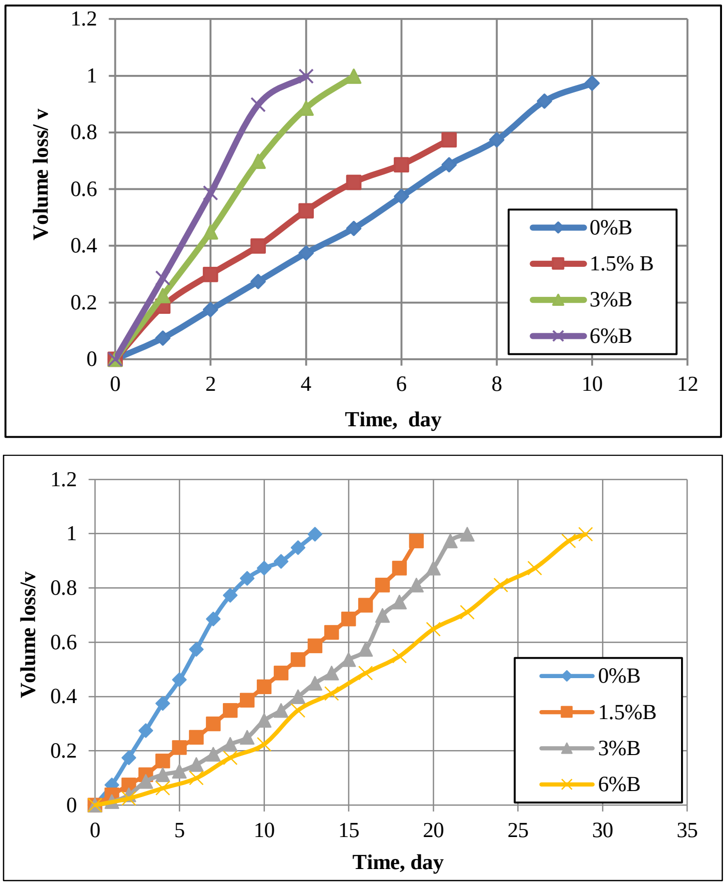


Figure 17. Comparison in the time –volume loss relationships between unmodified and modified soil (a) crude oil (b) water

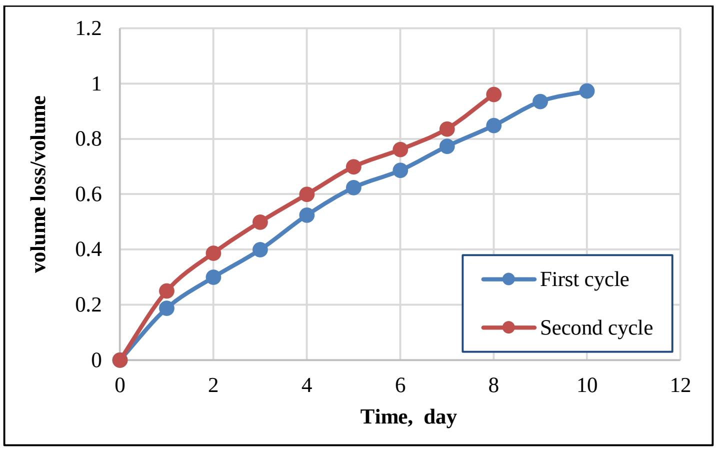


Figure 18. Effect of number of filling on volume loss – Time relationships for soil mixed with %1.5 B

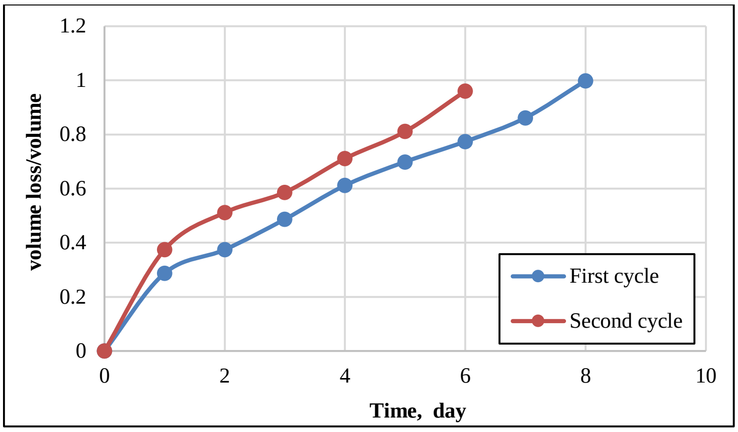
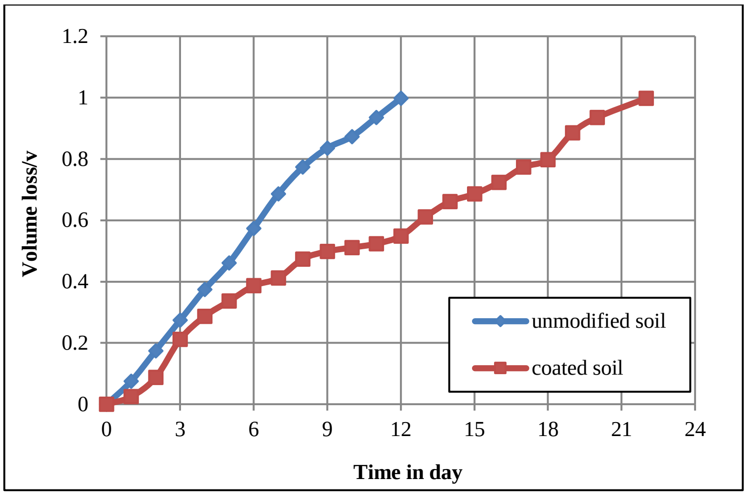


Figure 19. Effect of number of filling on volume loss- time relationships for soil mixed with 3%B

5.7.3. Effect of lining material (Nitocote ET 402)

The core which carried out by inserting cylinder 70mm in diameter and 80mm in height into the compacted soil has been coated by the Nitocote ET 402 material by using a brush. Figure 20 plot the volume loss verse the time of permeability of fluid used. From Figures 20a and 20b, there is a decrease in the ratio of volume loss to the original volume after 11days from starting test from (0.93 to 0.52), (44.65% reduction) and from (0.58 to 0.32), (45% reduction) respectively was observed. That means more time for the fluid to remain inside the core, this is due to chemical resistance and the viscosity property of the coating material. Perhaps this material leads to plug the voids so the permeability reduced as illustrated from SEM results Figure 21. That can be explained more as the Nitocote material form a waterproof layer that clogged voids.

(a)



(b)

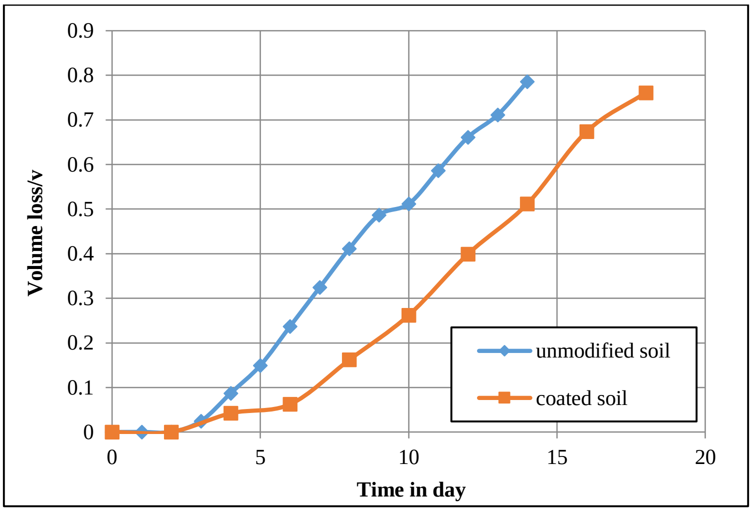


Figure 20. Comparison in the time –volume loss relation between original soil and soil lined with high build coal tar epoxy resin (a) crude oil (b) water

5.8. Micro Structure Studies

Scanning electron microscopy (SEM) images of origin soil, contaminated soil and lined soil by Nitocote material are shown in Figure 21. It is shown that a fluid crude oil has an effect on the microstructure of soil which causes an eggloramation of the soil particles that increase the voids between it and the more loss structure causes an increase in permeability as shown in Figure 21b.

Figure 21c shows the less amount of voids because the lining material (Nitocote ET402) forms a waterproof layer that plugged the voids and made more dense structure, causing a decrease in seepage. The test was conducted at the physical science laboratory, college of science in Al-Nahrain University.

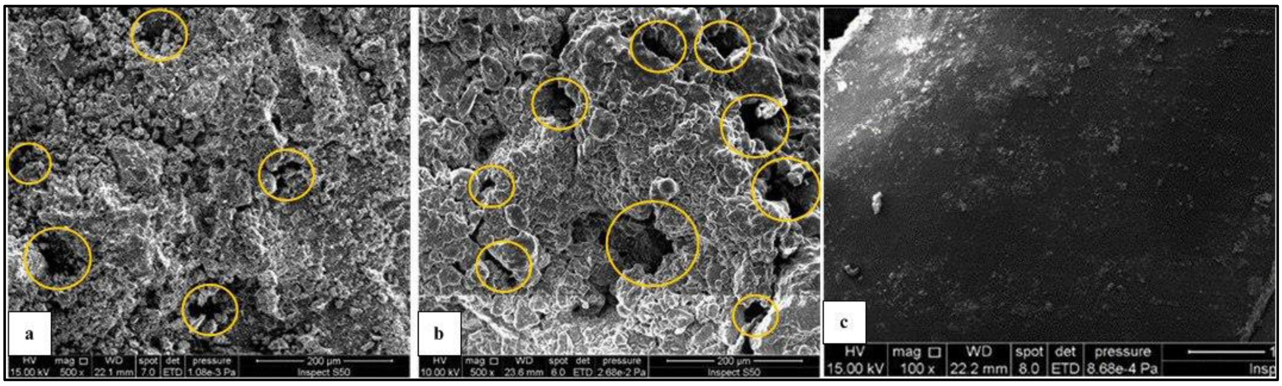


Figure 21. SEM Photo (a) origin soil, (b) contaminated soil with crude oil (c) lined soil as crude oil was a fluid

6. Conclusions

Several conclusions may be drawn from the results of current research:

- The addition of sodium bentonite increases the liquid limit, plastic limit and the specific gravity.
- When adding bentonite, there is a decrease in max dry density and increase in optimum moisture content.
- The value of coefficient of permeability (k) obtained from consolidation test tended to decrease. An increase in coefficient of compressibility (cc) and swelling index as a cause to increase the bentonite content have been observed.
- The uses of bentonite did not cause a decrease in volume loss but resulted in an increase in its values, especially when using a crude oil as a permeant fluid.
- With refilling the models, the seepage increases as a result of the petrol's effect.
- The most efficient and effective material that minimizes the seepage loss of crude oil in this research is a coal tar epoxy resin coating when using it as lining material.

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8. Conflicts of Interest

The authors declare no conflict of interest.

9. References

[1] CONCAWE, (1984). Capability of oil industry installation for the disposal of split oil. The Hague, CONCAWE.

[2] Liang, Chenju, and Yi-Yu Guo. "Remediation of Diesel-Contaminated Soils Using Persulfate under Alkaline Condition." Water, Air, & Soil Pollution 223, no. 7 (June 9, 2012): 4605–4614. doi:10.1007/s11270-012-1221-6.

[3] Gitipour, S., M. A. Hosseinpour, N. Heidarzadeh, P. Yousefi, and A. Fathollahi. "Application of modified clays in geosynthetic clay liners for containment of petroleum contaminated sites." International Journal of Environmental Research 9, no. 1 (2015): 317-322.

[4] Jokuty, P., S. Whiticar, Z. Wang, M. Fingas, P. Lambert, B. Fieldhouse, and J. Mullin. "Properties of crude oil and products." (2000).

[5] Urum, Kingsley, Steve Grigson, Turgay Pekdemir, and Sean McMenamy. "A Comparison of the Efficiency of Different Surfactants for Removal of Crude Oil from Contaminated Soils." Chemosphere 62, no. 9 (March 2006): 1403–1410. doi:10.1016/j.chemosphere.2005.05.016.

[6] Kalantary, Farzin, and Mostafa Kahani. "Evaluation of the Ability to Control Biological Precipitation to Improve Sandy Soils." Procedia Earth and Planetary Science 15 (2015): 278–284. doi:10.1016/j.proeps.2015.08.067.

[7] Uppot, Janardanan O., and R. W. Stephenson. "Permeability of clays under organic permeants." Journal of Geotechnical Engineering 115, no. 1 (1989): 115-131. doi: 10.1061/(ASCE)0733-9410(1989)115:1(115).

[8] Kumar, Sanjeev, and Woi-Leong Yong. "Effect of Bentonite on Compacted Clay Landfill Barriers." Soil and Sediment Contamination: An International Journal 11, no. 1 (January 2002): 71–89. doi:10.1080/20025891106709.

[9] Karunaratne, G.P., S.H. Chew, S.L. Lee, and A.N. Sinha. "Bentonite:Kaolinite Clay Liner." Geosynthetics International 8, no. 2 (January 2001): 113–133. doi:10.1680/gein.8.0189.

[10] Rasheed, L. M. "Possibility of increasing efficiency of clayey soil used for non- conventional oil storage." M.Sc. thesis, Civil Engineering Department, Baghdad University, Baghdad, Iraq (1999).

[11] Kavya, M. P., and T. R. Anjana., "Effect of Bentonite on Hydraulic Conductivity of Compacted Soil Liners" International Journal of Advanced Research Trends in Engineering and Technology, Vol. 3, Special Issue 23, April 2016.

[12] Goodarzi, A.R., S. Najafi Fateh, and H. Shekary. "Impact of Organic Pollutants on the Macro and Microstructure Responses of Na-Bentonite." Applied Clay Science 121–122 (March 2016): 17–28. doi:10.1016/j.clay.2015.12.023.

[13] Krishna, M. K., B. R. Chaitra, and J. Kumari. "Effect of municipal solid waste leachate on the quality of soil." International Journal of Engineering Science Invention 5, no. 6 (2016): 69-72.

[14] Yusuf, Umar Sa'eed, Matawal Danladi Slim, and Elinwa Augustine Uchechukwu. "Hydraulic Conductivity of Compacted Laterite Treated with Iron Ore Tailings." Advances in Civil Engineering 2016 (2016): 1–8. doi:10.1155/2016/4275736.

[15] Chinade, Adamu Umar, S. Y. Umar, and K. Juwonlo Osinubi. "Effect of municipal solid waste leachate on the strength of compacted tropical soil for landfill liner." International Research Journal of Engineering and Technology 4, no. 6 (2017): 3248-3253.

[16] Javadi, Sadra, Mohammad Ghavami, Qian Zhao, and Bate Bate. "Advection and Retardation of Non-Polar Contaminants in Compacted Clay Barrier Material with Organoclay Amendment." Applied Clay Science 142 (June 2017): 30–39. doi:10.1016/j.clay.2016.10.041.

[17] Sobti, Jaskiran, and Sanjay Kumar Singh. "Techno-Economic Analysis for Barrier Materials in Landfills." International Journal of Geotechnical Engineering 11, no. 5 (September 26, 2016): 467–478. doi:10.1080/19386362.2016.1232634.

[18] Naeini, Seyed Abolhasan, Naeem Gholampoor, and Mohammad Ali Jahanfar. "Effect of Leachate's Components on Undrained Shear Strength of Clay-Bentonite Liners." European Journal of Environmental and Civil Engineering (January 15, 2017): 1–14. doi:10.1080/19648189.2017.1278725.

[19] Shariatmadari, Nader, Marzieh Salami, and Mehran Karimpour Fard. "Effect of inorganic salt solutions on some geotechnical properties of soil-bentonite mixtures as barriers." International Journal of Civil Engineering 9, no. 2 (2011): 103-110.

[20] Satyanarayana, P. V. V., A. Harshitha, and D. Sowmya Priyanka. "Utilization of red soil bentonite mixes as clay liner materials." International Journal of Scientific & Engineering Research 4, no. 5 (2013): 876-882.

[21] Gleason, Mark H., David E. Daniel, and Gerald R. Eykholt. "Calcium and sodium bentonite for hydraulic containment applications." Journal of geotechnical and geoenvironmental engineering 123, no. 5 (1997): 438-445. doi: 10.1061/(ASCE)1090-0241(1997)123:5(438)

[22] Odell, R. T., T. H. Thornburn, and L. J. McKenzie. "Relationships of Atterberg Limits to Some Other Properties of Illinois Soils1." Soil Science Society of America Journal 24, no. 4 (1960): 297. doi:10.2136/sssaj1960.03615995002400040025x.

[23] Pincus, HJ, NS Pandian, TS Nagaraj, and PSRN Raju. "Permeability and Compressibility Behavior of Bentonite-Sand/Soil Mixes." Geotechnical Testing Journal 18, no. 1 (1995): 86. doi:10.1520/gtj10124j.

[24] Bowders Jr, John J., and David E. Daniel. "Hydraulic conductivity of compacted clay to dilute organic chemicals." Journal of Geotechnical Engineering 113, no. 12 (1987): 1432-1448. doi: 10.1061/(ASCE)0733-9410(1987)113:12(1432).

[25] Amadi, A. A., and A. O. Eberemu. "Characterization of Geotechnical Properties of Lateritic Soil-Bentonite Mixtures Relevant to Their Use as Barriar in Engineered Waste Landfills." Nigerian Journal of Technology 32, no. 1 (2013): 93-100.

[26] Kaya, Abidin, Seda Durukan, A. Hakan Ören, and Yeliz Yükselen. "Determining the engineering properties of bentonite-zeolite mixtures." Teknik Dergi 17, no. 3 (2006): 3879-3892.

[27] Lambe, T. William. "The structure of compacted clay." Journal of the Soil Mechanics and Foundations Division 84, no. 2 (1958a): 1-34.

[28] Arora, K. R. "Introductory soil engineering; text book. Nem Chand Jane (Prop)." (1988).

[29] Ahmed, H. AG. "Effect of petroleum products on permeability of clayey soil of normal and high swelling potential." M.Sc. thesis, Civil Engineering Department, Baghdad University, Baghdad, Iraq (1999).

[30] Rawajfih, Zahir, and Najwa Nsour. "Characteristics of Phenol and Chlorinated Phenols Sorption onto Surfactant-Modified Bentonite." Journal of Colloid and Interface Science 298, no. 1 (June 2006): 39–49. doi:10.1016/j.jcis.2005.11.063.

[31] Abeele, W.V. "The Influence of Bentonite on the Permeability of Sandy Silts." Nuclear and Chemical Waste Management 6, no. 1 (January 1986): 81–88. doi:10.1016/0191-815x(86)90091-4.

[32] Lo, Irene MC, and Xiaoyun Yang. "Use of organoclay as secondary containment for gasoline storage tanks." Journal of Environmental Engineering 127, no. 2 (2001): 154 161. doi: 10.1061/(ASCE)0733 9372(2001)127:2(154).

[33] Omidi, G. H., J. C. Thomas, and K. W. Brown. "Effect of Desiccation Cracking on the Hydraulic Conductivity of a Compacted Clay Liner." Water, Air, and Soil Pollution 89, no. 1–2 (May 1996): 91–103. doi:10.1007/bf00300424.

[34] Benson, Craig H., Huaming Zhai, and Xiaodong Wang. "Estimating hydraulic conductivity of compacted clay liners." Journal of geotechnical engineering 120, no. 2 (1994): 366-387. doi: 10.1061/(ASCE)0733-9410(1994)120:2(366).

[35] Lo, Irene M-C. "Organoclay with soil-bentonite admixture as waste containment barriers." Journal of Environmental Engineering 127, no. 8 (2001): 756-759. doi: 10.1061/(ASCE)0733-9372(2001)127:8(756).

[36] Gitipour, Saeid, Akbar Baghvand, and Saeid Givehchi. "Adsorption and permeability of contaminated clay soils to hydrocarbons." Pakistan Journal of Biological Sciences 9, no. 3 (2006): 336 340.

[37] Brown, K. W., and J. C. Thomas. "A Mechanism by which Organic Liquids Increase the Hydraulic Conductivity of Compacted Clay Materials 1." Soil Science Society of America Journal 51, no. 6 (1987): 1451 1459.

[38] U.S. Environmental Protection Agency (USEPA). ''Requirements for hazardous waste landfill design, construction, and closure.'' EPA/ 625/4-89/022, Cincinnati, (1989).

[39] Green, William J., G. Fred Lee, and R. Anne Jones. "Clay-soils permeability and hazardous waste storage." Journal (Water Pollution Control Federation) (1981): 1347-1354.

[40] Al-Soudany, Kawther, Ahmed Al-Gharbawi, and Marwa Al-Noori. "Improvement of Clayey Soil Characteristics by Using Activated Carbon." Edited by T.S. Al-Attar, M.A. Al-Neami, and W.S. AbdulSahib. MATEC Web of Conferences 162 (2018): 01009. doi:10.1051/matecconf/201816201009.

[41] Lambe, T. William. "The engineering behavior of compacted clay." Journal of the Soil Mechanics and Foundations Division 84.2 (1958b): 1 35.

[42] Kaya, Abidin, and Hsai-Yang Fang. "The Effects of Organic Fluids on Physicochemical Parameters of Fine-Grained Soils." Canadian Geotechnical Journal 37, no. 5 (October 2000): 943–950. doi:10.1139/t00-023.

[43] Quigley, R. M. "Clay minerals against contaminant migration." Geotechnical News 11, no. 4 (1993): 44-46.

[44] Arasan, Seracettin. "Effect of chemicals on geotechnical properties of clay liners: a review." Research Journal of Applied Sciences, Engineering and Technology 2, no. 8 (2010): 765-775.

[45] Patil, M. R., S. S. Quadri, and H. Lakshmikantha. "Effect of Additives on Geotechnical Properties." Indian Geotechnical Conference, (December 2010).

[46] Ibrahim Saeedi, Foroogh, and Ali Reza Sepaskhah. "Effects of a Bentonite–water Mixture on Soil Saturated Hydraulic Conductivity." Archives of Agronomy and Soil Science 59, no. 3 (March 2013): 377–392. doi:10.1080/03650340.2011.631130.