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Assessment of Bearing Capacity of Subbase Contaminated with Kerosene

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ABSTRACT

The present paper is focused towards evaluation bearing capacity of subbase layer which is contaminated with Kerosene.

Seven series of model tests were performed using steel container (500*300*300mm). The bed of subbase was compacted in three layers inside the container; each layer was 100mm in depth. Circular footing 65mm in diameter resting on the bed of subbase were loaded incrementally up to failure. Different percentages of Kerosene (0%, 5%, 12% and 20%) were added, the first series consists of uncontaminated soil layer, the second series covers the model tests with added (5%, 12% and 20%) to the top subbase layer and third series covers the model tests with added (5%, 10% and 20%) to the top and second subbase layers. Each percentage was added separately. The results showed increase in ultimate bearing capacity; with increasing of Kerosene content up to 5% then a decrease with further increase of Kerosene content.

Keyword: Bearing Capacity, Contaminated Layer, Subbase, Kerosene.

تقيم قا بلية التحمل تحت الأساس الملوثة بالكيروسين

الخلاصة

البحث الحالي مركز باتجاه حساب قا بلية التحمل لطبقة تحت الأساس الملوثة بمادة الكيروسين. تم اجراء سبعة موديلات باستخدام موديل حديدي بابعاد (*500*300* 300ملم). طبقة تحت الأساس رصت بثلاث طبقات داخل الموديل وكل طبقة بسمك 100 ملم. تم تحميل طبقة تحت الأساس باستخدام اساس دائري بقطر 65 ملم بزيادة متساوية بالحمل وصولا الى الفشل .

اضيف الكيروسين بنسب مختلفة (0%,5%,12% ,20%). المجموعة الأولى تتالف من طبقة تحت الأساس غير ملوثة , المجموعة الثانية غطت الموديلات الملوثة بكيروسين بنسب (5%,12% ,20%) مضافة الى الطبقة العلوية من تحت الأساس و المجموعة الثالثة غطت الموديلات الملوثة بكيروسين بنسب (5%,12% ,20%) مضافة الى الطبقة العلوية والثانية من تحت الأساس . واضيفت كل نسبة على حده لكل نموذج.

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واظهرت النتائج زيادة بقا بلية التحمل القصوى بزيادة نسبة الكيروسين الى 5 % يتبعها نقصان بقابلية التحمل القصوى باي زيادة بنسبة الكيروسين.

INTRODUCTION

The environment is being polluted by humans, intentionally or unintentionally, for their short term benefits. In doing so, not only air and water but the land is also being contaminated. Land contaminated is not harmful for the surface water but such actions are determined to the buildings and structures standing on it. Any change in engineering properties and behaviour of the soil strata may lead to loss of bearing capacity and increase in total and differential settlements of the foundation system of structures. Consequently, structures may undergo functional or structural failure.

Crude oil spills in most cases are accidental during transportation, as leakage from storage tanks and pipelines or during oil drilling processes. There are also cases where crude oil might be spilled purposely as what happened in the war.

The extent of contamination depends on the chemical composition of the contaminated and the properties of the soil, also in connection with the clean up works and for any possible applications of contaminated soils. Knowledge of the geotechnical properties and behaviour of contaminated soil is required. In this case, it is necessary to determine the effect of contamination on the existing structures.

Al- Mashhidani (1999) investigated the effect of some petroleum products (gas oil and Kerosene) on the Atterberg limits and permeability of compacted clayey soil of different swelling potential and predicted its ability to store the products. The test results show that the petrol caused a significant change in soil indices which may be related to the variation in permeability values, with a decrease in liquid limit and an increase in the sedimentation velocity. The test results indicated that the permeation of petrolenm products of the compacted clay may cause an increase in permeability with time and with exposures of soil to the product. The increase may reach to about 25 times.

Rasool (1999) studied the effect of Kerosene contamination on some geotechnical properties of soil. The results of testing show that the contamination of soil by oil effects on physical and mechanical properties that within oil content liquid limit increase significantly while plastic limit increase slightly. Also the results of compaction tests indicate a reduction in water content to reach maximum dry density for contaminated samples compared to uncontaminated samples. The effect on shear strength shows the cohesion decreases significantly and the friction angle increases slightly within increase in oil content.

Shin et al. (1999) presented the variation of shear strength parameters for crude oil contaminated sand and the ultimate bearing capacity of a shallow strip foundation supported by it. The results indicated decreasing in the angle of internal friction by 25% and decreasing the bearing capacity by 75% when crude oil content increase from zero to about 13%.

Habib et al. (2007) carried out one dimensional test to study the volume change behaviour of the uncontaminated and contaminated clay. The results showed that the compression index Cc increase in contaminated soil, this result depended on crude oil content in the soil.

Khamehchiyan et al. (2007) carried out standard Procter compaction tests, unconfined compression tests and examined the variation of shear strength parameters for the artificially oil contaminated soil samples. The results revealed that the presence of oil reduces the amount of water needed to reach maximum dry density. Also they found that there is an inverse relation between unconfined compression strength (q_u) and the crude oil content, a decrease in unconfined compression strength (q_u) with increase in crude oil content, however, effect of oil contamination on shear strength parameters is not uniform and it depends on the soil type .

Rahman et al. (2010) studied the geotechnical behaviour of oil contaminated fine-grained soils. Laboratory tests included all basic and advanced geotechnical tests with scanning electron microscope (SEM). Crude oil was chosen as the contaminated. The results revealed that the addition of crude oil caused an increase in the Atterberg limits and plasticity index due to extra cohesion provided to the clay particles by oil, also they mentioned that the contaminated soil marked increase in maximum density at relatively low optimum moisture content. The permeability drops down due to increase in oil content.

Zulfahmi et al. (2010) investigated the effect of hydrocarbon contamination on the geotechnical properties for two types of soils. The results showed that both liquid limit and plastic limit decreased with the increase in oil content.

Al-Baoey (2011) performed a laboratory testing program on fine grained soil brought up from AL- Samawa- Depot site. The program consisted of two parts: the first, represent the routine laboratory tests carried out on clean and contaminated soil to determine, index properties, compaction, permeability, compressibility and shear strength characteristics. The second part represents a laboratory model tests carried out to evaluate the bearing capacity and settlement. The contaminated samples were prepared by mixing the soil with crude oil for the amounts of 4,8,12 and 16% by dry weight. The results showed that the crude oil contamination decrease the liquid limit and plastic limit values. The contaminated soil also indicated a lower maximum dry density and optimum moisture content when compared with uncontaminated soil. A reduction in permeability was observed, the cohesion was clearly affected by the increase in crude oil content, the internal friction angle value was increased at crude oil content 16% due to increase of organic matter with increase crude oil content, the compression index was found to be higher for the contaminated soil. The results of the laboratory contaminated model showed increase in ultimate bearing capacity with increase of crude oil content up to 8% then a decrease with further increase of crude oil content.

MATERIALS USED

The Subbase Material

The subbase material is brought from Al-Nibaee quarry, north of Baghdad, this type of subbase is commonly used as layers in flexible pavement construction. Standard tests were performed to determine the physical and chemical properties of the subbase used. The grain size distribution curve is shown in Figure (1). Details of properties are given in Table (1). Grain size analyses were performed on subbase specimens in accordance with (BS 1377:1975, Test 7 (B)). The subbase classified as (**GW)** according to the Unified Soil Classification System (USCS), subbase is class (B) according to The State Corporation for Roads and Bridges (SORB/R6).

The Kerosene Used

The agent used in this study was Kerosene. The product was brought up from Al-Dorra Depot. The physical properties were conducted by Ministry of Oil. The results are shown in Table (2).

MODEL ASSEMBLY

Steel Container

The test was carried out using a steel container with internal dimensions of (500*300*300mm). The steel container is made of steel plates (4mm) in thickness welded by steel angles of (75mm). The container was sufficiently rigid and exhibited no lateral deformation during the preparation of the bed of subbase and during tests.

Model Footing

A (65mm) diameter circular model footing was used. The footing was made of aluminium plate (20mm) thickness.

Loading Frame

A special loading frame was designed and manufactured to apply static vertical loads on the model footing as plain strain. The loading frame model of steel shaft (18mm) diameter and (180cm) height was used to transfer the applied loads to the model footing. To prevent any side sway of the shaft during loading a special steel collar with circular hole of slightly larger diameter than the diameter of the shaft was connected to the outside members of the loading frame. The shaft has two plates used to fix the applied weights. Details are shown in Figure (2).

Dial Gauges

Two dial gauges of (0.01mm) accuracy hold by magnatic stands were used to measure average settlement of the model footing.

MODEL PREPARATION

Preparation of Ssubbase Model

The construction of subbase starts after three days of drying process. A pre-determined weight of subbase are mixed with water at moisture content of 6%, this weight is sufficient to create a layer of thickness of about (1/3 h, where h= subbase layer thickness). The thickness of subbase layer is (300mm) which can be divided into three layers, this value chosen according to selected flexible pavement design. Each layer compacted gently by manufactured metal hammer according to the required relative density.

After completing the final layer, the top surface was scraped and levelled to get as near as possible a flat surface then covered with a plastic cover to prevent any loss moisture.

Preparation of Subbase - Kerosene Model

The subbase and kerosene were blended together to prepare mixtures under dry condition. Subbase was mixed separately with various percentage of kerosene (5%, 12% and 20%) and moulded to a range of prescribed dry densities and moisture content. All mixing was done manually and proper care was taken to prepare a homogenous mixture at each stage. Testing programme for mixing model divided into two parts; the first part, adding 5%, 12% and 20% to the top layer of model only and second part, adding 5%, 12% and 20% to the top layer and second layer. Each percentage was added separately.

MODEL TESTING

After completion all steps prior to the testing, initial reading of the dial gauges was recorded and the gradual load increments were applied at equal time intervals. The corresponding reading of the dial gauges were recorded continuously till the end of the test. The average readings of the two dial gauges represent the average settlements of the model footing corresponding to each applied pressure. The process of applying load increments continued until the settlement exceeds 10% of the footing diameter which is a failure defined by Terzaghi 1947 (as cited by Brand and Brenner, 1981).

PRESENTATION AND DISCUSSION OF MODEL TESTS RESULTS

Figure (3) illustrates a section through a typical model test clarifying all notations used in this article. This discussion divided into two parts: the first, demonstrates the bearing capacity due to presence of the subbase alone and the combined effect achieved by contaminating the top layer of subbase using different percentage of kerosene (5%, 12% and 20%) in addition to contaminated the top and second layer of subbase using different percentage of kerosene (5%, 12% and 20%). The effect of kerosene is denoted by the term “bearing capacity ratio” defined as bearing capacity for contaminated subbase divided by bearing capacity for uncontaminated subbase, simply given the notation $q_t/q_{unt: ,}$ the second part of the discussion is devoted to reduction in settlement gained by each contamination , defined as the ratio of the settlement of the contaminated subbase to the settlement of the uncontaminated subbase and given the notation S_t/S_{unt} .

Model Tests on Uncontaminated Samples

The model tests performed on uncontaminated samples were taken as a reference or benchmark to the proposed techniques. Figure (4) demonstrates the relationship between bearing capacity (q) and the settlement ratio (S/D %) for subbase only. It is observed that the model tests exhibits a general mode of failure. If the bearing capacity at failure is considered as the stress corresponds to settlement equal to 10% of the diameter of footing, then the ultimate bearing capacity being 390 kPa.

Model Tests on Contaminated Samples

The term “top layer contaminated samples” refers to model tests where a layer of subbase material immediately underneath the model footing contaminated by different percentage of kerosene. Three model tests were performed, using a layer thickness denoted by h=100mm for each percentage of kerosene (5%, 12% and 20%). Figure (5) demonstrates the relationship between bearing capacity (q) and the settlement ratio (S/D %) for top layer contaminated. From these results, it can be seen that the general trend demonstrated that the bearing capacity increases considerably when increase percentage of kerosene to 5% followed by a slightly increase in bearing capacity as increasing percentage of kerosene to 12%, while a drop in bearing capacity was observed when adding 20% of kerosene to the top layer compared to the uncontaminated layer, the values of bearing capacity for three percentage of kerosene were (1000 kPa, 620 kPa and 475 kPa) respectively. This behaviour can be attributed to presences of kerosene of higher viscosity than water which might block the inter-spaces of the soil particles. Similar observation was noticed by Shin et al. 1999, Shin and Das, 2001 and Al-Baoey, 2011.

For top and second layer contaminated samples demonstrates in Figure (6) the relationship between bearing capacity (q) and the settlement ratio (S/D %) contaminated by different percentage of kerosene (5%, 12% and 20%). The family of curves indicates that a very slightly increase in bearing capacity appeared when adding 5% and 12% kerosene for top and second layers.

The values of bearing capacity were 468 kPa for 5% kerosene and 425 kPa for 12% kerosene; while a drop in bearing capacity was noticed when adding 20% of kerosene for top and second layer where the model becomes fully saturated with kerosene. The value of bearing capacity was 250 kPa compared with uncontaminated samples. Table (3) summarized the results of bearing capacity at failure. Pictures for models at failure are shown in Figure (7).

Bearing Capacity Ratio

It is of interest to quantify the effect of kerosene. The term bearing capacity ratio ($q_t/q_{unt:}$) is introduced representing the bearing capacity (q) at failure for the contamination models divided by the corresponding values of uncontamination models. Figure (8) demonstrates a relationship between the bearing capacity ratio at failure versus the percentage of kerosene used for two cases (top subbase contaminated and top and second subbase contaminated). The Figure indicates a bell relationship. The results indicates that the bearing capacity ratio increase with increase of kerosene content up to 5% then a decrease with further increase of kerosene content. This is probably due to fact that kerosene has partially occupied the inter particles spaces and the occurrence of kerosene has changed the subbase to a state of loosing material than an uncontaminated subbase. Table 4 summarized the results at failure and the corresponding bearing capacity ratios obtained from experimental model tests.

Settlement Reduction Ratio

Figure (9) clarify the settlement reduction ratio at failure versus the different percentage of kerosene used for two cases (top subbase contaminated and top and second subbase contaminated). A dramatic decrease in settlement reduction ratio was noticed when 5% kerosene used then a gradual increase in settlement reduction ratio when percentage of kerosene increased. Table (5) shows results of settlement reduction ratio at failure.

CONCLUSIONS

The results of this study have led to the following conclusions:

1- For uncontaminated model test, the ultimate bearing capacity being 390 kPa and the mode of failure is general mode of failure.

2- For top subbase contaminated model test, there is an increase in bearing capacity when adding 5% kerosene, a slightly increase in bearing capacity when adding 12% kerosene while a drop in bearing capacity when increase kerosene to 20%. The bearing capacity values are (1000, 620,475kPa) respectively.

3- For top and second subbase contaminated model test, there is slightly increase in bearing capacity when adding 5% and12% kerosene while a noticeable drop in bearing capacity when % kerosene is 20%. The bearing capacity values are (468,425,250kPa) respectively.

4- The bearing capacity ratio increases with increasing percentage of kerosene content up to 5% then decrease with further increasing in kerosene content. For top subbase layer contaminated with (5%, 12% and 20% kerosene), the bearing capacity ratio values at failure are (2.56, 1.58 and1.22) respectively. While the bearing capacity ratio values at failure are decreased to (1.2, 1.09 and 0.64) respectively for the same percentages of kerosene contaminated top and second subbase layers.

5- A reduction in settlement reduction ratio when kerosene used. Optimum results were obtained for top layer when percentage of kerosene equal to 5%.

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Table (1) Physical and Chemical properties of Subbase used.

Test No.	Index Property	Index Value	Test Method
1	Total unit weight (kN/m^3)	21	BS 1377
2	Max.dry unit weight (kN/m^3)	20	BS 1377
3	Min.dry unit weight (kN/m^3)	14.89	BS 1377
4	C.B.R	45%	ASTM D 1883
5	Optimum Moisture Content	6%	BS 1377
6	Liquid Limit% (LL)	NL	AASHTO T 89
7	Plasticity Index% (PL)	NP	AASHTO T 90
8	SO3 Content%	1.48*	BS 1377 test No. 9
9	Total Dissolved Salt TDS%	2.58*	Earth manual of U.S. Bureau
10	Gypsum Content%	0.76*	AASHTO T 112
11	Organic Matter%	0.06*	Test No. 8 of BS 1377

*Tested in laboratories of State Company of Geological Survey and Mining.

Table (2) Physical properties of Kerosene used.

Test	Index Property	Index Value
1	Gravity API @ 60° F	40
2	Specific Gravity @ 15° C	0.80
3	Viscosity @ 100° F	33
4	Density (g/cm^3)	0.78 - 0.81
5	Reid Vapour Pressure , RVP (psia)	0.1
6	Boiling Point @ 1 atm	200-260 ° C
7	Freezing Point	- 45.6 ° C
8	Flash Point	37- 65 ° C
9	Autoignition Temperature	220 ° C
10	Latent Heat of Vaporization	$2.5*10^5$ J/kg
11	Liquid Surface Tension@ 20° C (N/m)	0.023 – 0.032
12	Liquid water Interfacial Tension@ 20° C (N/m)	0.047 – 0.049

Table (3) Results of bearing capacity at failure.

Cases	**Bearing capacity at failure, q (kPa)**			
% of kerosene	0%	5%	12%	20%
Top subbase layer contaminated	390	1000	620	475
Top and second subbase layers contaminated	390	468	425	250

Table (4) Results of bearing capacity ratio at failure.

Cases	**Bearing capacity ratio at failure, (q_t/q_{unt})**			
% of kerosene	0%	5%	12%	20%
Top subbase layer contaminated	1	2.56	1.58	1.22
Top and second subbase layers contaminated	1	1.2	1.09	0.64

Table (5) Results of settlement reduction ratio at failure.

Cases	**Settlement reduction ratio at failure, (S_t/S_{unt})**			
% of kerosene	0%	5%	12%	20%
Top subbase layer contaminated	1	0.46	0.53	0.8
Top and second subbase layers contaminated	1	0.61	0.8	2.0

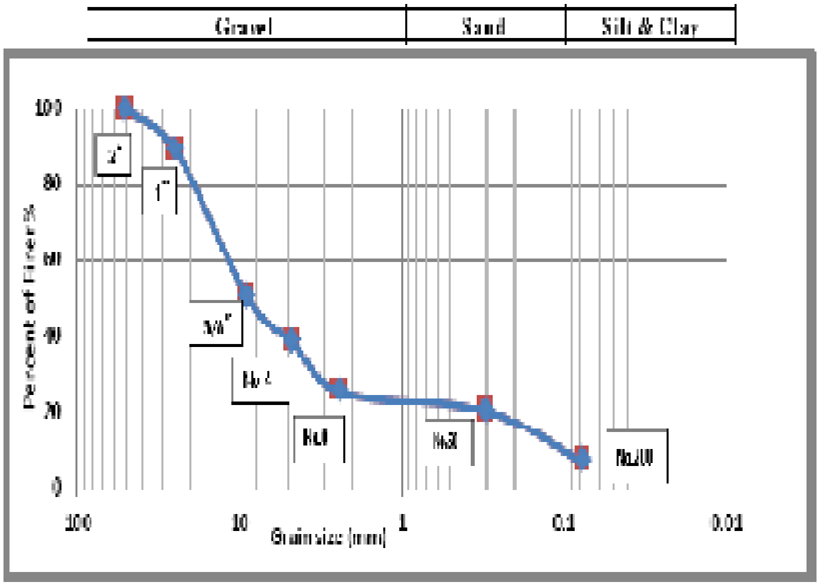
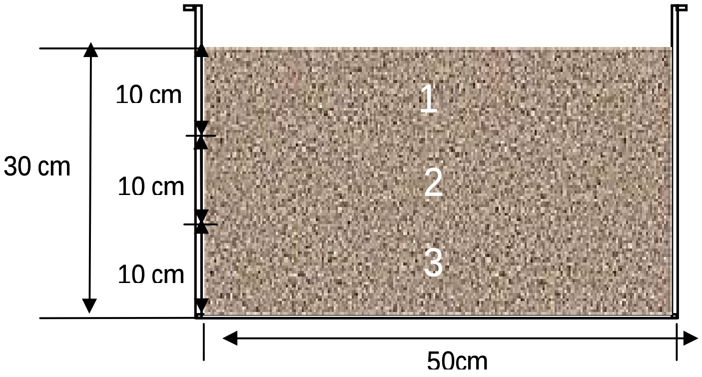
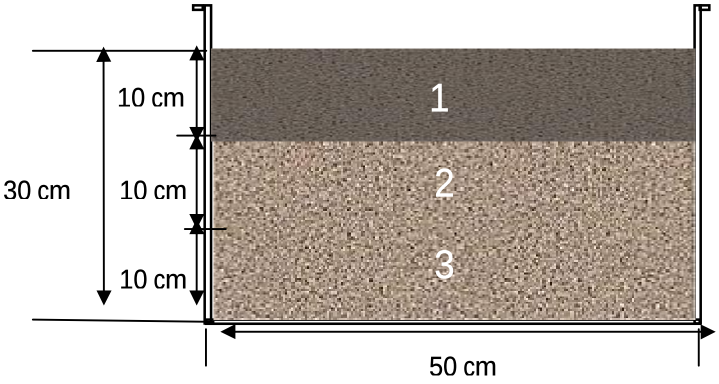


Figure (1) Grain Size Distribution of Subbase material.

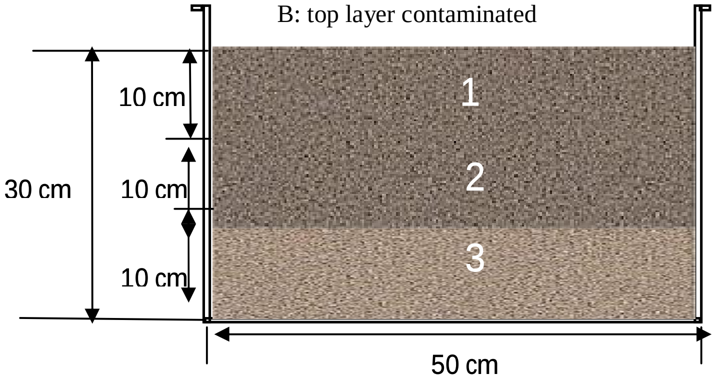
Figure (2) Test system used in preparing the model.



A: Subbase only



B: top layer contaminated



C: top and second layer contaminated

Figure (3) Sketch of Model.

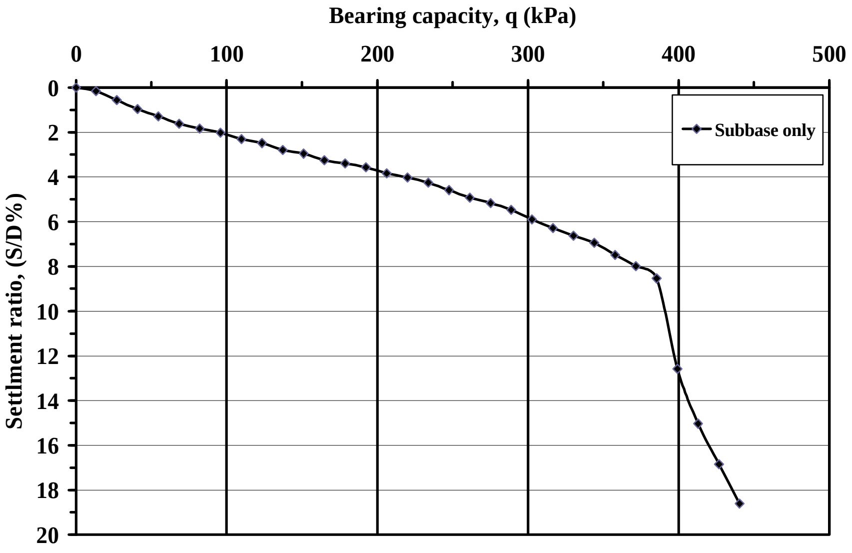


Figure (4) Relationship between bearing capacity and the Settlement ratio for Subbase.

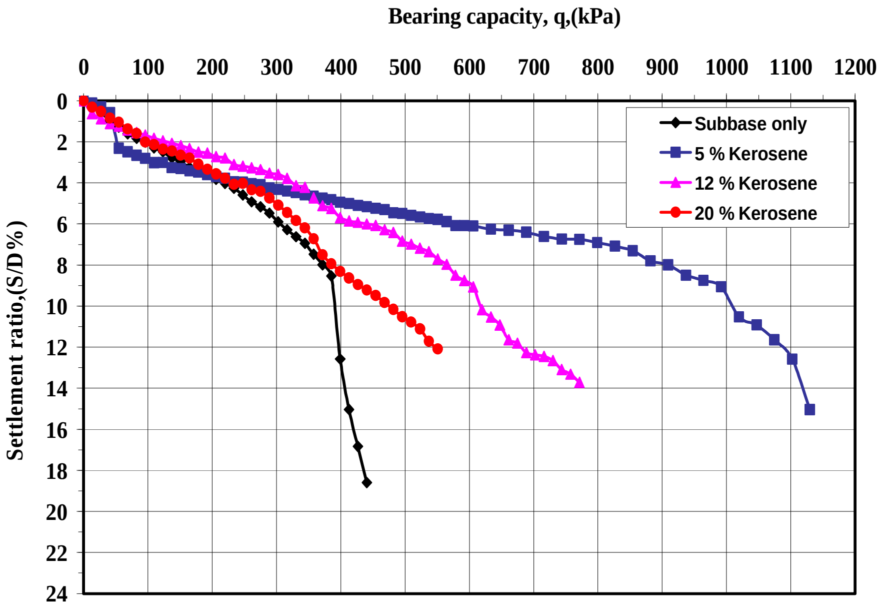


Figure (5) Relationship between bearing capacity and the settlement Ratio for top layer contaminated.

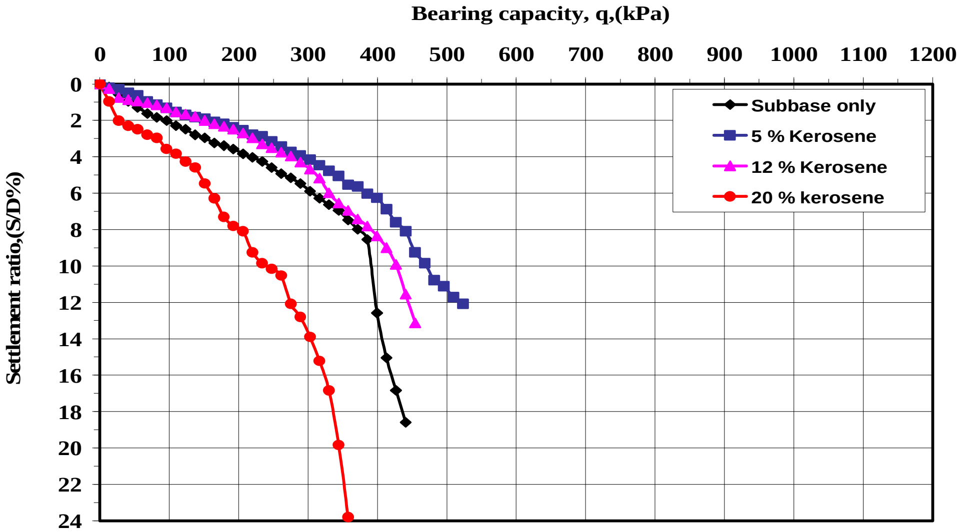


Figure (6) Relationship between bearing capacity and the settlement ratio for top and second layer contaminated.

A- Uncontaminated B- Top layer contaminated

C- Top and second layer contaminated

Figure (7) Pictures for models at failure.

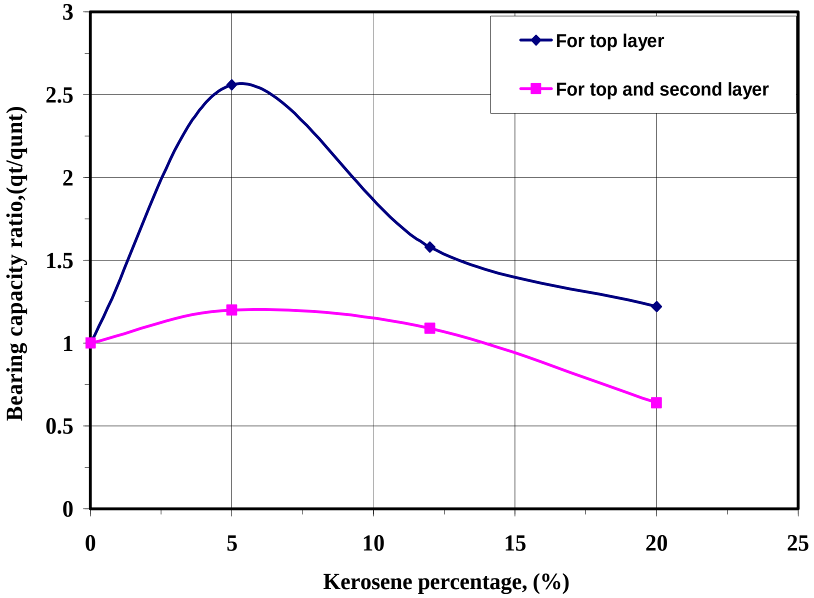


Figure (8) Relationship between bearing capacity ratio and different percentage of Kerosene.

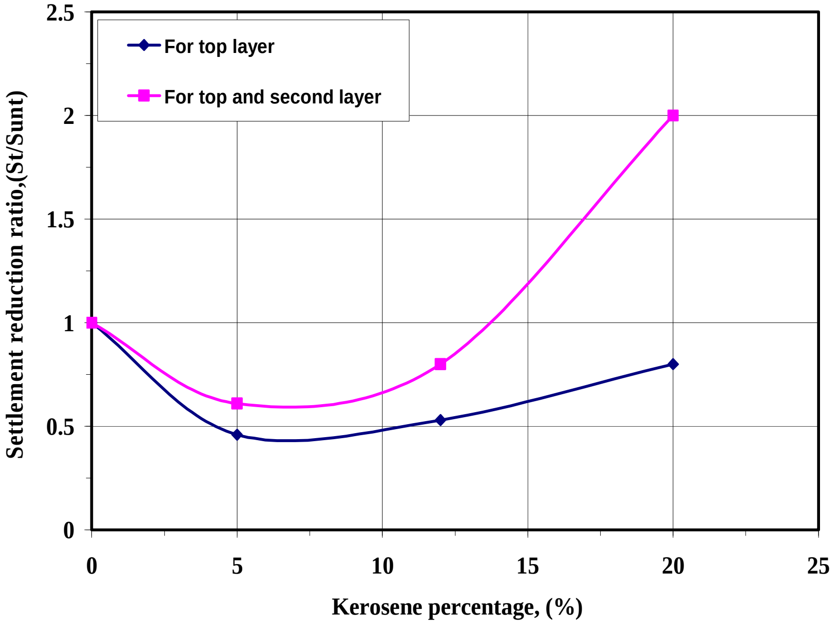


Figure (9) Relationship between settlement reduction ratios and different percentage of Kerosene.