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Evaluation of Suitability of Red Clay from Selected Areas of Gercus Formation, Sulaimaniyah, North Iraq, for the Construction of Embankment Dams

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Abstract

In this research, a geotechnical assessment was conducted for clay of the Gercus Formation to determine its suitability for embankment dams. The selected area is located in the north of Iraq. Six samples were collected from two sites in Dokan (Sulaimaniyah) and Haibat Sultan mountain (Koysinjaq), three samples each. Various geotechnical (physical, mechanical and chemical) tests were conducted based on standard specifications.

The results of the grain size test of clay samples showed their conformity with Zone C curves and their suitability for the construction of embankment dams, according to the Iraqi standard for roads and bridges. The results of the plasticity limits test showed that the soil is made of fine, low plasticity silt (ML), and low plasticity clay (CL), according to the unified standard soil classification. The water content and plasticity limit tests (liquid limit, plastic limit, and plasticity index) demonstrated that these clays are conformable with the limits of the Iraqi standards. The results of the modified compaction test found a maximum dry density value of 1.962 g/cm³ with an optimum moisture content of 11.5%. The results of the permeability index (K) revealed low permeability according to the Das classification and, therefore, showed the suitability of the samples as raw filling materials in the construction of dams. Chemical tests (sulfate content, organic materials content, total dissolved salts, gypsum content, and pH value) showed compatibility with the requirements for the use in dams construction under the Iraqi standard (SoRB/ R5).

Keywords: Geotechnical assessment, Physical tests, Dam filling materials, Dokan, Haibat Sultan mountain.

تقييم صلاحية اطيان تكوين جركس للاغراض الاملائية في مناطق مختاره من السلبيمانية /شمال العراق

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قسم علوم الأرض التطبيقية، كلية العلوم، جامعة تكريت، تكريت، العراق

الخلاصة

تم في هذا البحث اجراء تقييم جيوتكنيكي لأطيان تكوين جركس. لمعرفة صلاحيتها لأغراض السدود الاملائية، منطقة الدراسة تقع في شمال العراق. تم جمع (6) نماذج من موقعين: الموقع الأول_دوكان (السلبيمانية) بواقع (3) نماذج والموقع الثاني جبل هيبب سلطان (كويسنجق) بواقع (3) نماذج ايضاً لغرض

اجراء الفحوصات الجيوتكنيكية المختلفة عليها المتمثلة بالفحوصات الفيزيائية والميكانيكية والكيميائية وفق المواصفات القياسية ذات العلاقة .

اظهرت نتائج التقييم الجيوتكنيكي للفحوصات الفيزيائية من خلال اجراء التحليل الحجمي مطابقتها لمنحني نطاق (Zone C) واظهرت ملائمتها لأغراض السدود الاملائية، بحسب المواصفة العامة للطرق والجسور .

تبين من خلال نتائج فحوصات حدود اللدونة لأطيان منطقة الدراسة بأن التربة من النوع الناعم بعضها غرينية ذات لدونة واطئة (ML) والبعض الآخر طينية ذات لدونة واطئة (CL) بحسب التصنيف الموحد للتربة.(USCS). المحتويات المائية لحدود اللدونة (حد السيولة، حد اللدونة، معامل اللدونة) لهذه الاطيان تقع ضمن حدود المواصفة العامة للطرق والجسور التي تم الاعتماد عليها في هذا البحث .

وبالنسبة لنتائج فحص الرص المعدل_وجدت ان الكثافة الجافة العظمى لا تقل عن (1.962) غم /سم³ و المحتوى الرطوبي الامثل (11.5%) وبالتالي تتوافق مع حدود المواصفة العامة كما اظهرت نتائج معامل النفاذية (K) لأطيان منطقة الدراسة انها ذات نفاذية واطئة بحسب تصنيفDas، وبالتالي اظهرت ملائمتها كمواد اولية في انشاء السدود الاملائية. اما بالنسبة للفحوصات الكيميائية المتمثلة بفحوصات محتوى المواد العضوية، مجموع الاملاح الكلية القابلة للذوبان، محتوى الجبس والقيمة الحامضية وجدت انها تلائم المتطلبات الواجب توفرها للاستخدام لأغراض السدود الاملائية بحسب المواصفة العراقية.

1. Introduction

A great expansion of building projects has been recently observed in Iraq, including urban expansion and large projects such as building dams. Raw materials, such as mud rocks, along with proper assessing of their suitability for the construction of dams, have become necessary. Building materials, such as those found in the study area, are worthy to investigate, given their availability in large quantities, the ease of investment, the proximity of the formation to transportation routes, and ease of access to the material.

Embankment dams are among the most prevalent types of dams in the world because of their advantages, which include the use of local natural raw materials, the ease to design and construction, and the use of few devices and equipment in the construction [1]. The requirements of the foundations are not strict compared with those for the concrete dams, where the weight of construction is dispersed by the base. The wide range of this type of dams is attributed to their suitability for different types of foundations, due to the greater resistance to water pressure and lower economic cost as compared to other types of dams [2].

The study area is located within two locations in Sulaymaniyah governorate; the first location is the Dokan District, located southwest of Dokan Dam and the second site is the Haibat Sultan mountain, located southeast of the city of Koysinjaq, about 40 km from the city of Dokan (Figure-1). The study area is located between the longitudes (36 ° 6'0" - 35 ° 57'0") and latitudes (44 ° 54'0" - 44 ° 39'0"), as measured by geographic system units (WGS-1984-Geographic-zone). Figure-1 represents a geological map of the study area, showing the sampling locations.

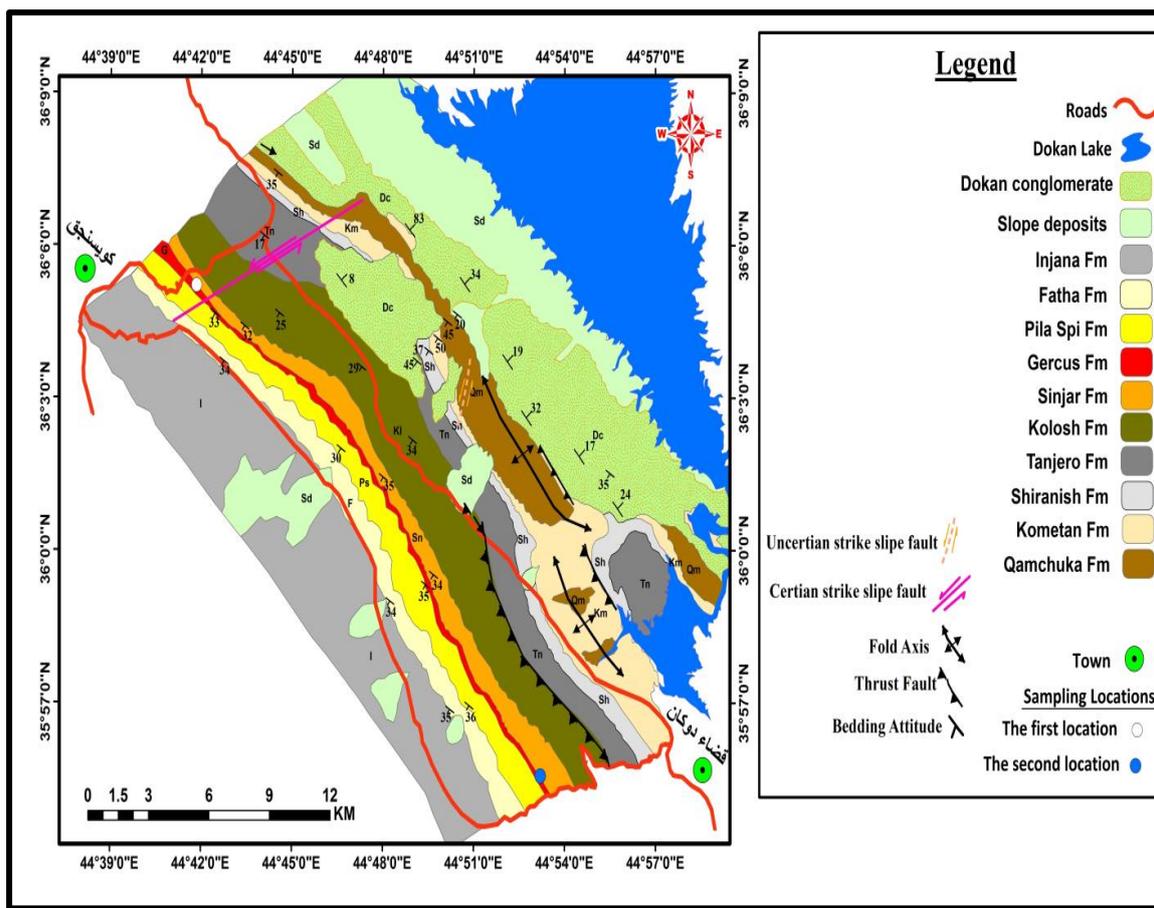


Figure 1-Geological map of the study area showing the sampling locations [3].

The stratigraphy of the study area consists of the following formations ordered from the oldest to the youngest: Qamchuqa , Kometan , Shiranish , Tanjero , Kolosh , Sinjar , Gercus , Pilaspi , Fatha and Injana Formations, as well as the Quaternary deposits represented by the deposits of Dokan Conglomerate unit and Slope sediments [4].

The present study aims to conduct geotechnical tests, such as petrophysical and chemical tests, for the clay samples of Gercus Formation to evaluate their suitability as a filling material in dams.

2. Methodology

Samples from the proposed sites were collected after an exploratory tour to the study area for the identification of the exposed formations and the sampling locations, using Garmin GPS positioning device, and build a complete visualization of the area. Samples (60 kg) were taken from each station in special bags, marked with the station number and the sample number for laboratory testing.

The first series of tests included the grading analysis and Atterberg indices, which are classified as indicator tests. These tests are used in the design of the structure to provide the designers and technicians with valuable information regarding the nature and characteristics of the materials. The second series of tests included the compaction, specific gravity, permeability, direct shear, and triaxial tests. These tests provide data to be used for the design of embankments and to specify how the materials must be placed during construction [5]. The chemical tests included gypsum ratio, total soluble salts, and organic matter content.

3. Results and Discussion

The preferable soil to be used in the installation of embankment dams is the soil which consists of different sizes of granules (well-graded) because it is more cohesive and resistant to erosion as compared to soil of one grain size [6]. Two separate and completely different methods are used to calculate the wide range of grain size distribution present in the soil, which are the mechanical (sieve) and wet (hydrometric) test methods, according to the American standard [7].

The results of the grain type distribution of Gercus formation clays showed ranges of sand content from 7% to 16.4%, silt from 30.91% to 52.75%, and clay from 40.34% to 59.39%), as demonstrated in Table (1) and Figure-2.

Table 1- Results of grain type distributions in the studied stations.

Station No.	Sand %	Clay %	Silt %
1	10.12	40.34	49.54
2	13.1	34.13	52.75
3	7.5	46.69	45.81
4	16.4	40.51	43.09
5	14.83	46.89	38.28
6	9.7	59.39	30.91

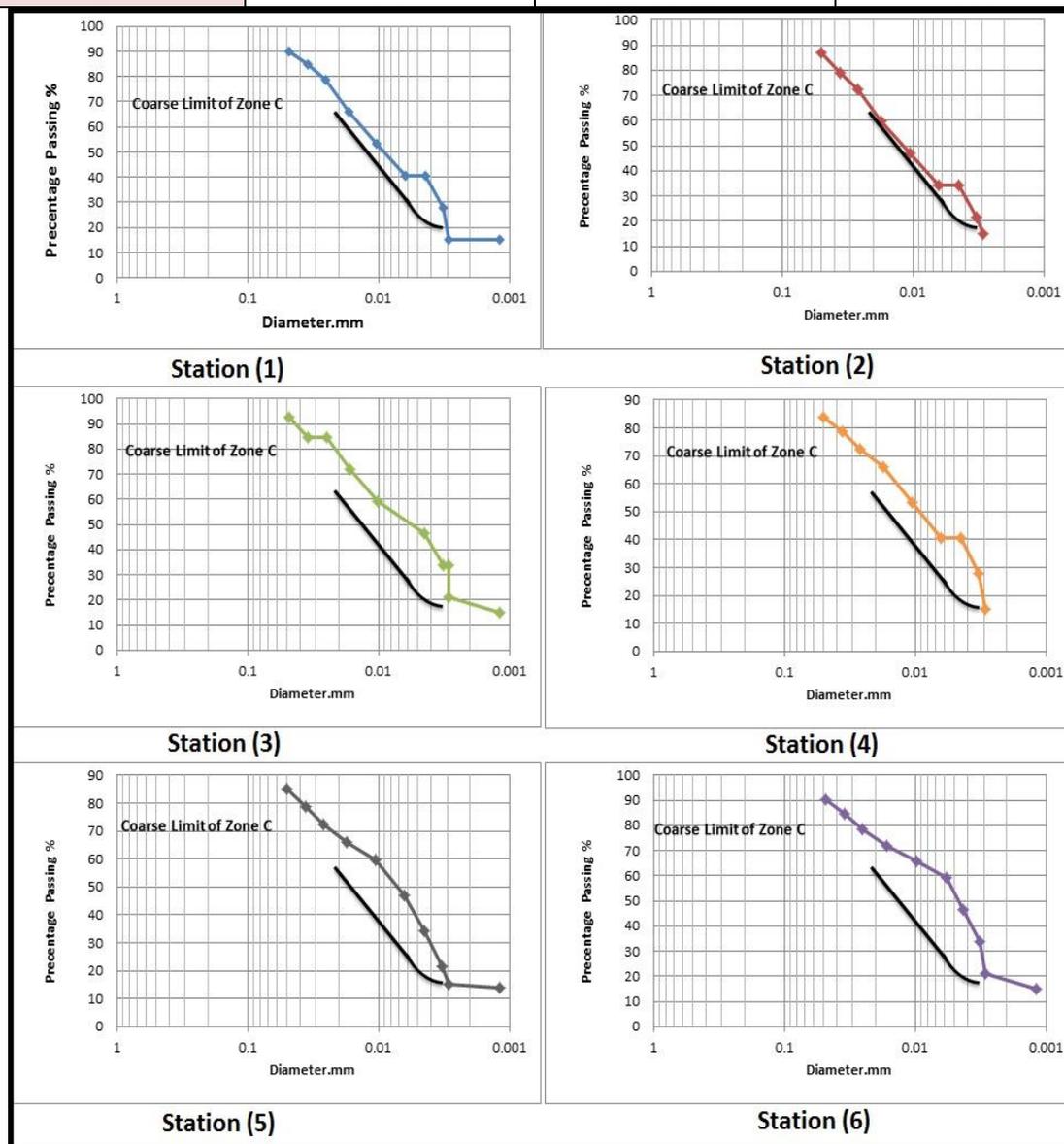


Figure 2- Grain size and distribution curves for all stations of the study area and their compatibility with the Zone C curve.

The specific gravity test of the claystone of the study area was measured according to a previously described method [8], where the values ranged between 2.477 and 2.684 (Table 2).

Table 2- Values of specific gravity for all the samples

Station No.	Specific Gravity
1	2.532
2	2.592
3	2.593
4	2.477
5	2.684
6	2.528

According to earlier reports [8-10], the limits of Atterberg are defined as the soil water content, in which the soil passes from one state to another. These limits are divided into the liquid limit, plastic limit, and shrinkage limit. The liquid limit and plastic limit tests were performed using a Casagrande device, according to a previously described method [10].

The results listed in table (3) show that the liquid limit values ranged 28.84% -40.63%, while the plastic limit values ranged 15.95% - 25.30% . According to the general specifications of roads and bridges (SORP / R5) [11], the clays used as raw materials in the construction of embankment dams should not exceed a liquid limit of 55% and plastic limit of 30%, whereas the plasticity index must be between 10 and 20%. Accordingly, Gercus formation clays can be considered as suitable for use as raw materials in the construction of embankment dams.

The samples of Gercus formation clays were classified according to the plasticity index [12] and found to range from elastic soil to medium plasticity soil. The value of plasticity index ranged between 4.97% and 17.59%). The samples were also classified in the stations based on the unified standard classification (U.S.C) [13], as shown in Figure-3.

Table 3-Results of Atterberg limits for all stations of the study area

Station No.	Liquid Limit (L.L, %)	Plastic Limit (P.L, %)	Plasticity Index (P.I, %)	Plasticity Index (U.S.C) [13]	Plasticity Index (Thabit and El-Asho, 1993) [12]
1	30.26	25.30	4.97	CL	Rather Plastic soil
2	29.69	19.45	10.24	ML	Medium Plasticity soil
3	28.84	19.78	9	CL	Low Plasticity soil
4	40.63	23.04	17.59	CL	Medium Plasticity soil
5	28.22	21.68	6.54	CL	Low Plasticity soil
6	32.70	15.95	16.76	CL	Medium Plasticity soil

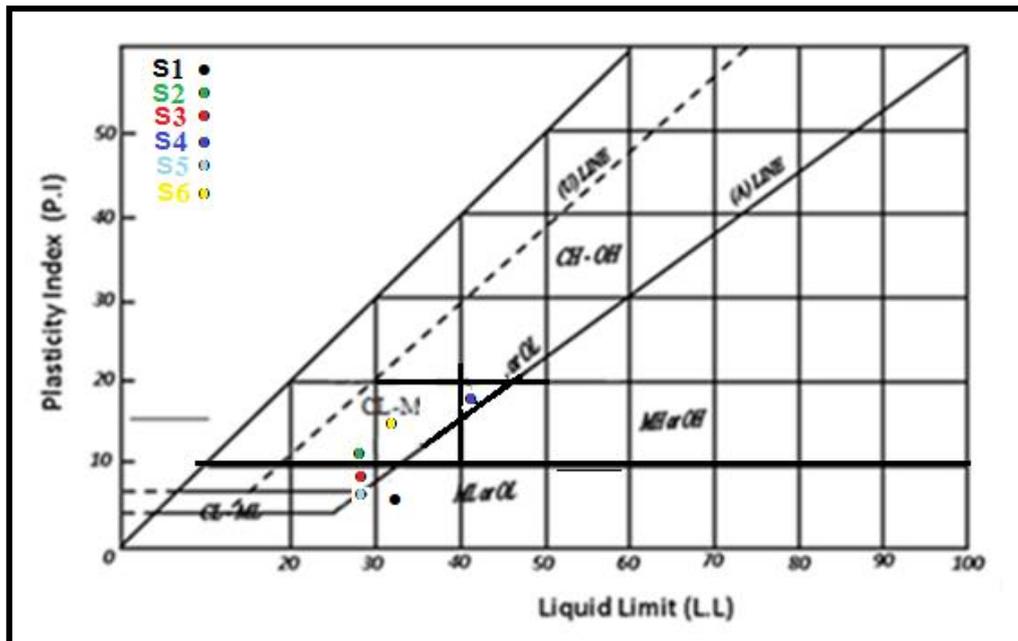


Figure 3- Classification of the study area's clay samples by plasticity chart [13].

The engineer P. Proctor) was the first to create the Standard Limiting Proctor, which was carried out in a cylindrical mold with an inner diameter of 6 inches and a height of 4.58 inches. The modified compaction test was conducted according to another study [14] at the national center for laboratories and construction research in Baghdad.

The modified compaction test was conducted for two samples of the study area, one representing Gercus formation clays in Dokan area (station 1) and the other representing mount Haibat sultan (station 4).

The results of maximum dry density, derived from the modified compaction test, for four soil samples from station1 showed an average value of 1.962 g/cm^3 with an optimum moisture content of 11.5%. The same results for station 4 were 2.011 g/cm^3 and 13.5%, respectively (Figure-4). Based on the SORP / R5 [11], clays used in embankment soils, in the form of beds not exceeding 25 cm in thickness, should have maximum dry density in the final bed compaction that is not lower than 1.7 g/cm^3 . Accordingly, Gercus formation clays are suitable for use as raw materials in the construction of embankment dams.

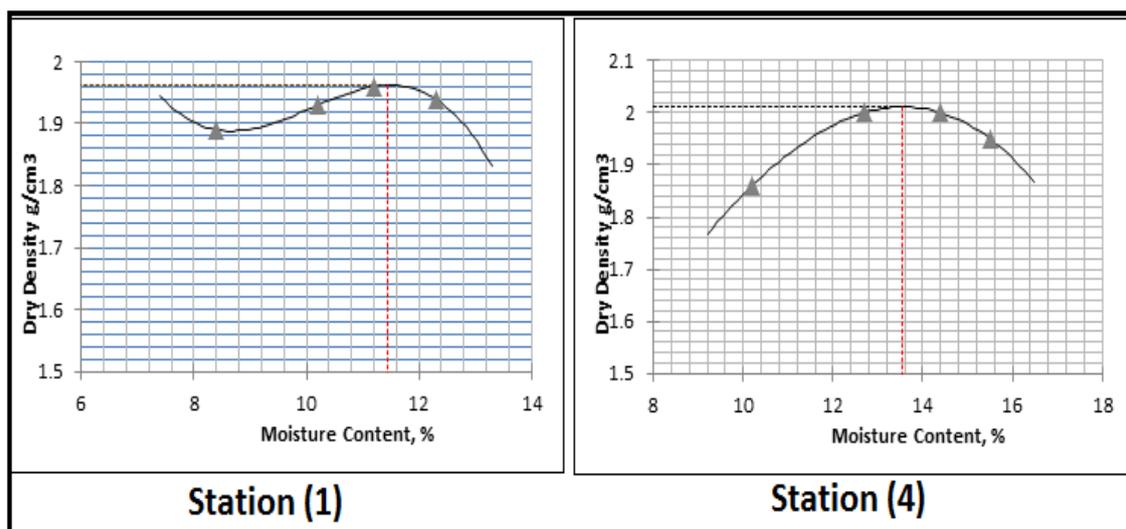


Figure 4- The relationship between the maximum dry density and the optimum moisture content of stations 1 and 4.

The permeability index (K) of the clays of the study area was calculated using the falling head test, by equation (1) [8, 15].

$$K = 2.30 \frac{aL}{At} \log 10 \frac{h_1}{h_2} \dots \dots \dots (1)$$

a = area of the pipe section

A = area of the soil sample section

L = length of soil sample

h₁ = initial height of the water level in the pipe

h₂ = final height of the water level in the pipe

t = the time the water level in the pipe decreases from h₁ to h₂.

The results of the permeability index showed a range of 0.0002 - 0.0015 cm/sec, as listed in Table-4. According to the applied classification [15], Gercus formation clays are considered to have low permeability and classified as high ratio sand ,silty sand. Therefore, they are considered to be suitable for the construction of embankment dams.

Table 4- Permeability index values (K) and the degree of permeability for all stations of the study area.

Station No.	Permeability index (K) (Cm/Sec)	Degree of permeability according to classification (Das,2008)[15].
1	0.0015	Low
2	0.0003	Low
3	0.0002	Low
4	0.000381	Low
5	0.00031	Low
6	0.00081	Low

The value of cohesion is affected by the moisture content of the soil, as it has a negative impact on the cohesion of the soil as well as the content of gypsum , because gypsum dissolves in water. This leads to a decrease in the density of the soil and thus causes a decrease in the value of cohesion. The cohesion value for samples collected from stations 1 to 6 ranged between 9 and 37 kN / m², as shown in Figures- (5), (6), (7), (8), (9), and (10), respectively, and Table -5.

The internal friction angle (φ) is affected mainly by the density of the soil; the higher the density of the soil, the greater the value of the internal friction. Maharaj [16] explained that the low angle of internal friction is due to the presence of some clay minerals, such as elite and chlorite, which cause sliding and reduce shear resistance.

The friction angle values for the study area clay samples ranged 15-22 °.

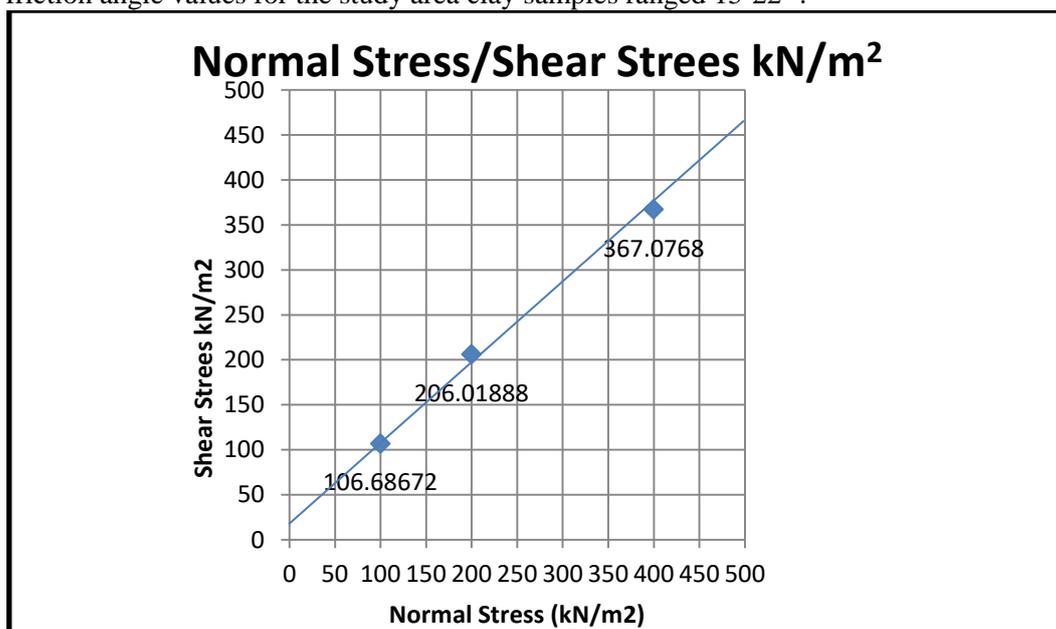


Figure 5-Direct shear test results for Sample 1.

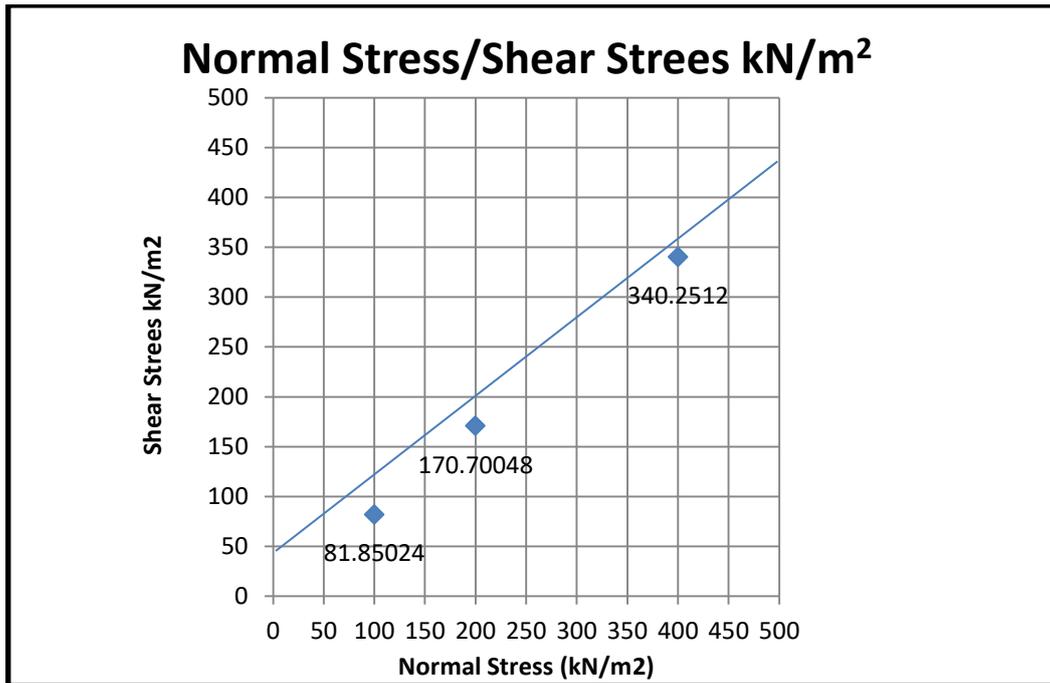


Figure 6- Direct shear test results for Sample 2.

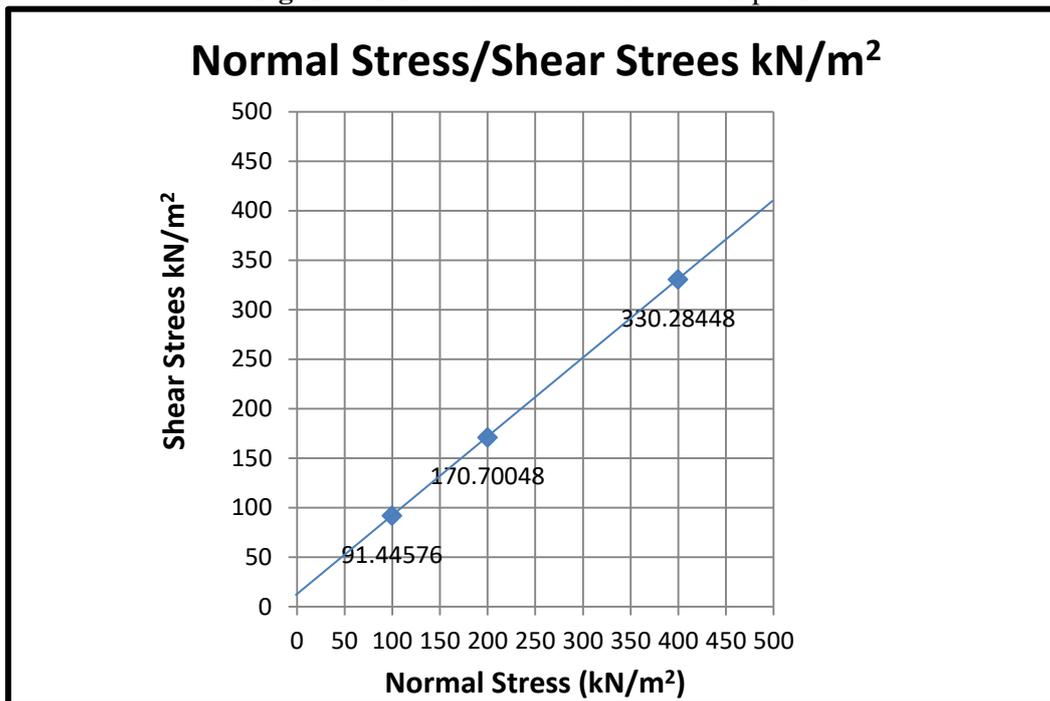


Figure 7- Direct shear test results for Sample 3.

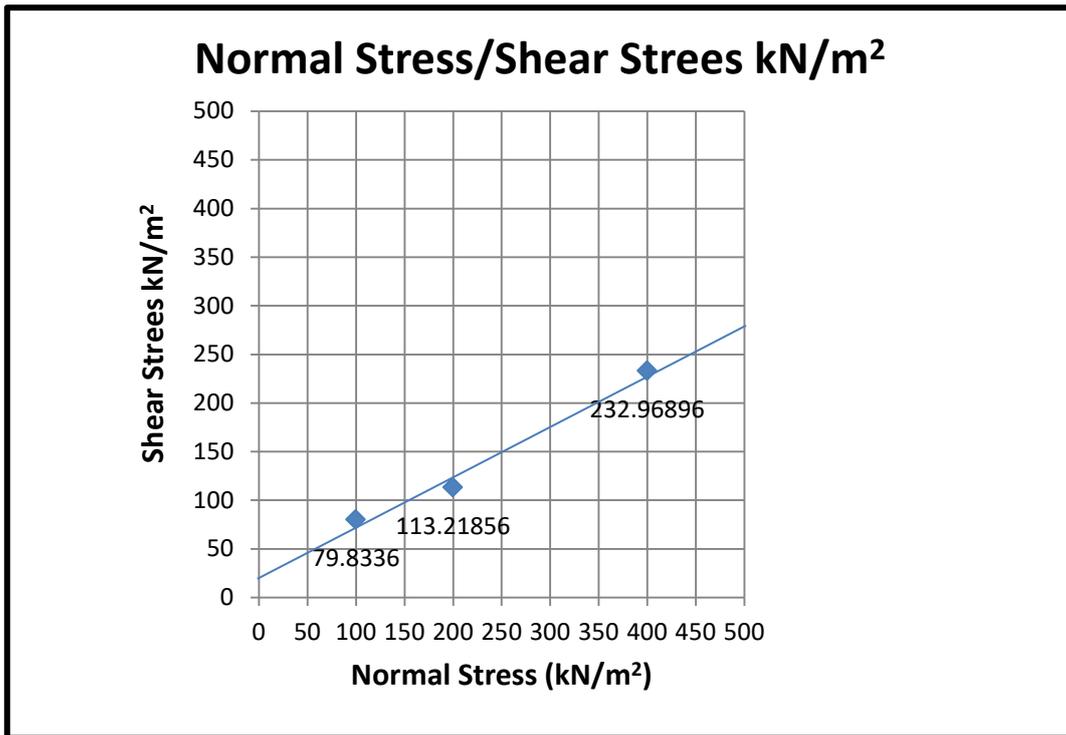


Figure 8- Direct shear test results for Sample 4.

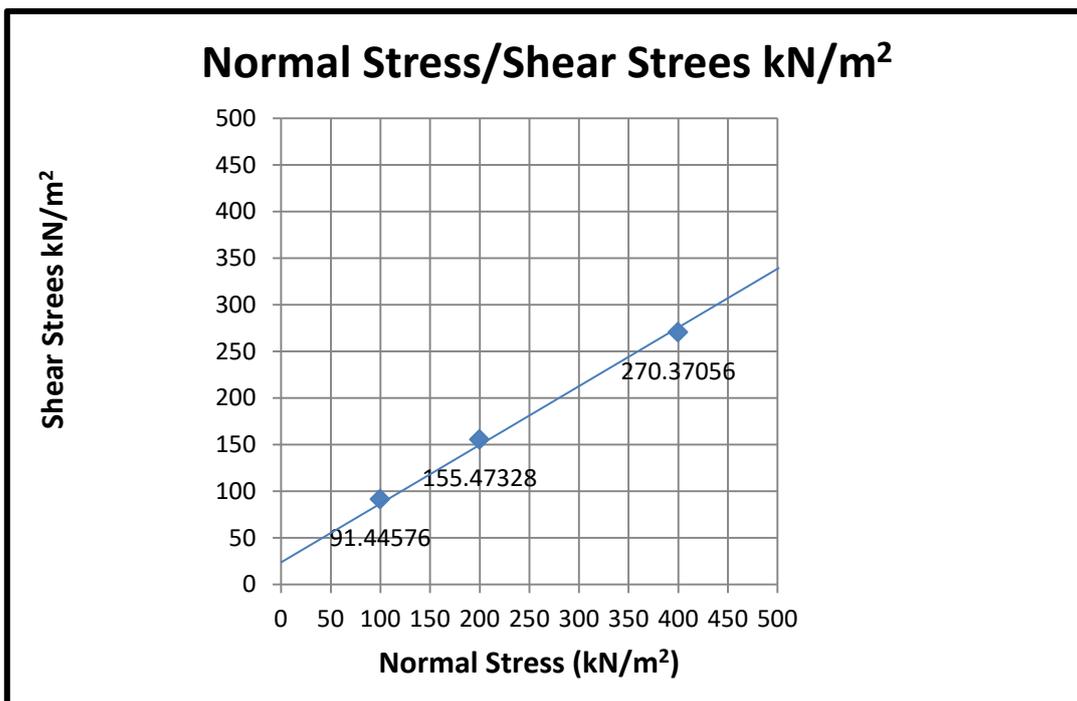


Figure 9- Direct shear test results for Sample 5.

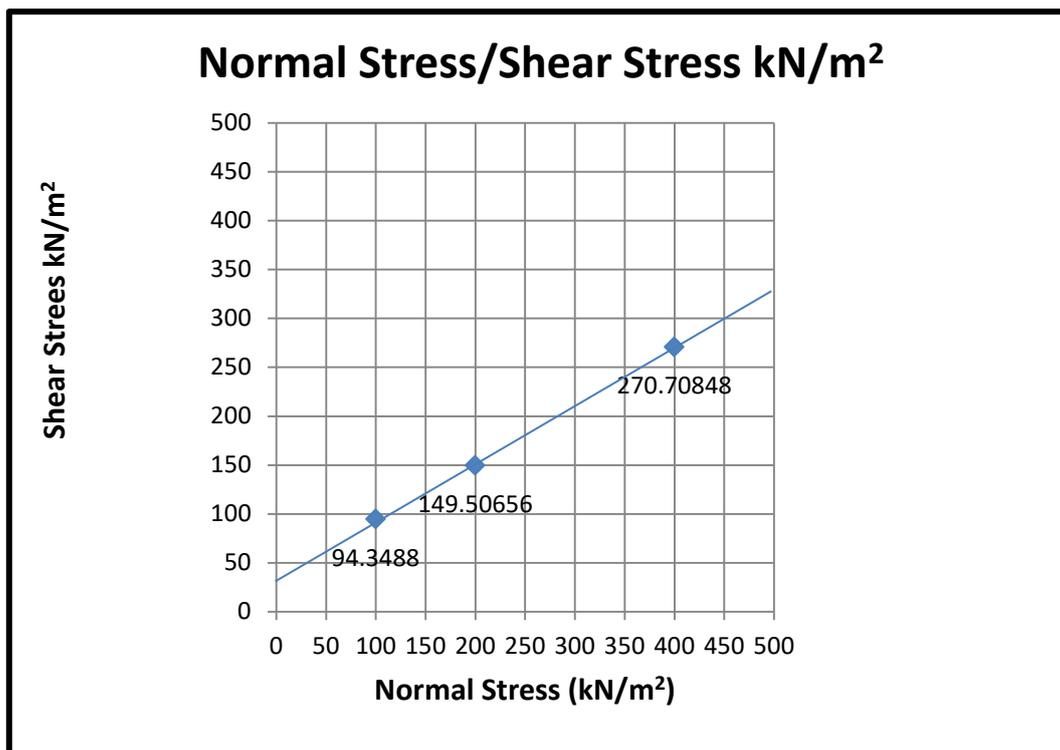


Figure 10-Direct shear test results for Sample 6.

Table 5- Values of cohesion and internal friction angle (ϕ) for all the stations studied

Station No.	c (kN/m ²)	ϕ
1	17	42°
2	9	38°
3	15	39°
4	19	26°
5	25	31°
6	34	29°

The physical and chemical properties of the study area's clay were correlated with the Iraq specification for the embanked dams [11], which are listed in Table-6.

Table 6- Iraqi specification of the physical and chemical properties of embanked soil [11].

Physical and chemical properties of embanked soil	Ranges
Plasticity index	10-20 %
Grain size analysis	Concordant with curve (C)
Gypsum content	Not more than 3%
TDS	Not more than 4.4%
Liquid limit	Not more than 55%

Chemical analyses that include gypsum ratio (Gyp, %), Total dissolved Salts (T.D.S, %), and organic materials content (O.M.C, %) were carried out at the national center for laboratories and structural research in Baghdad, according to published methods [8, 18].

The showed that the soil samples comply with the requirements of the SORP/R5 [11], as shown in Table-7; Therefore, Gercus formation clays is suitable for use as raw material in the construction of filling dams.

Table 7-Chemical analysis results for all stations of the study area.

Tests	Station No.						Limits of Iraqi standard [11]
	1	2	3	4	5	6	
T.D.S.%	1.01	0.61	1.09	0.71	0.97	0.54	4.4% Max
O.M.C %	3.609	3.977	3.237	3.747	1.575	2.810	12% Max
Gyp %	0.360	0.399	0.24	0.316	0.371	0.223	3% Max

4- Conclusions

The study concludes that the soil of the studied area is of a fine silt type with low plasticity (ML) in some places, while in others it is clay with low plasticity (CL).

The values of the specific gravity ranged 2.477 - 2.684.

The maximum dry density ranged between 1.962 and 2.011 g/cm³, with an optimum moisture content of 11.5% to 13.5%, which is higher than the minimal limit of 1.7 g/cm³ required by the Iraqi specification.

The value of cohesion ranged 9-37 kN / m² and the friction angle value ranged 15-22 °.

The results of chemical analysis showed that the values were within the Iraqi specification limits.

The permeability Index of showed low permeability according to Das classification.

We finally conclude that Gercus formation clays are suitable as raw materials in the construction of filling dams, according to the SoRB / R5.

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