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Validity of sand dunes sediments as a fine aggregates for roads works: a case study on sand dunes sediments, Al-Nasiriya city, Southern Iraq

Esraa A. Mandhour [1]
[1] Department of Applied Geology, Collage of Science, Thi-Qar University

ABSTRACT

In light of the development and urban growth of the city of Al-Nasiriya, the road construction sector consumes the largest amount of aggregates. The research aims to study suitability of the sediments of the sand dunes extending on one side of the international road between Nasiriya – Baghdad near the check point of Fadak as fine aggregate used for the purposes of roads construction. The results of the geotechnical evaluation of physical properties showed that the grain size analysis of the fine aggregate did not meet the requirements of the Iraqi specification and according to these results, the aggregate needs to modify. Based on liquid limits and plasticity indices and according to Iraqi specification the deposits are suitable for using as sub-grade course materials and to construct the shoulders of the road but not suitable for using as sub-base course materials. While the results of chemical tests indicate that incompatibility of the rates of organic matters and calcium carbonates with Iraqi specification. On the other hand, the chemical analysis of the sediments showed that the rates of the chlorides, sulfates, gypsum, total soluble salts and pH they were within acceptable limits of standard specifications. The mineral components of the soils were characterized by clay minerals (kaolinite and montmorillonite) and non-clay minerals (quartz, feldspar, and calcite).

Keywords: Al-Nasiriya; Chemistry and mineralogy; Geotechnical properties; Roads works; Sand dunes

Corresponding Author:
Esraa A. Mandhour,
Department of Applied Geology, Thi-Qar University
Address: Thi-Qar, Iraq
E-mail: I.mandhour_geo@sci.utq.iq

1. Introduction

The problem of desertification is one of international environmental problems facing most arid, semi-arid and sub-humid regions. This phenomenon is widely known as soil degradation, and in Iraq, the desert lands cover nearly two third of Iraq area [1]. The phenomena of desertification and dust storms are common in the southern regions of Mesopotamian due to the deterioration of the agricultural sector and the effect of erosion and sandstorms so because of the frequency of the dry seasons due to low amounts of precipitation besides low supplies of water from rivers of Tigris and Euphrates [2-6]. In addition to mismanagement of water resources which has greatly affected the agricultural land as well as increase to salinization which led to an increase desert areas and creep of dry lands across arable areas.
The movement of sand dunes led to the most serious problems for roadway, airport, bridge, factories and others, but most of the solutions used to face the movement of sand dunes are methods to stabilization sand dunes. Earth materials used in road construction include coarse and fine aggregates (gravel, sand and soil), these materials are mainly used as sub-base and subgrade. Moreover, sand dunes are one of the most important sources of natural fine aggregates (sand), so it is possible to use sand of sand dunes in paving and concrete works. Aggregates are used in limited or certain grades to form subgrade and sub-base, which may sometimes require processing by use of binder materials such as lime, cement and asphalt. Aggregates can also be mixed with soil to improve soil properties. Therefore, sand can be used to reinforce the bearing capacity of foundation by insert sand columns or as trench backfill materials [7-9]. Several Iraqi studies refer to the presence of huge amount of coarse and fine aggregates, but they do not meet the Iraqi general specifications especially in terms of granular gradient [9, 10].

It has been observed that the materials used to construct the pavement behave poorly after a period of time, possibly due to mineralogical and chemical properties. Moreover, many researchers have confirmed that the mineralogical and chemical characteristics are good indicators for assessing the raw materials for construction of roads besides engineering and physical characteristics [11-14].

The aim of this study is to investigate suitability of the sand dunes sediments as a fine aggregate for roads works.

1. Location and geology

The study area is located in south of Iraq, Northwest of Thi-Qar governorate between latititude 31° 09′ 00"N and 31° 10′ 00"N north and between longitude 45° 58′ 00″E and 45° 59′ 00"E east within Mesopotamian plain. The study area is located within the middle sand belt and which is located between the flood plain of Euphrates river from west and the Tigris river and Shatt Al-Gharraf (Al-Gharraf river) from east Figure 1.

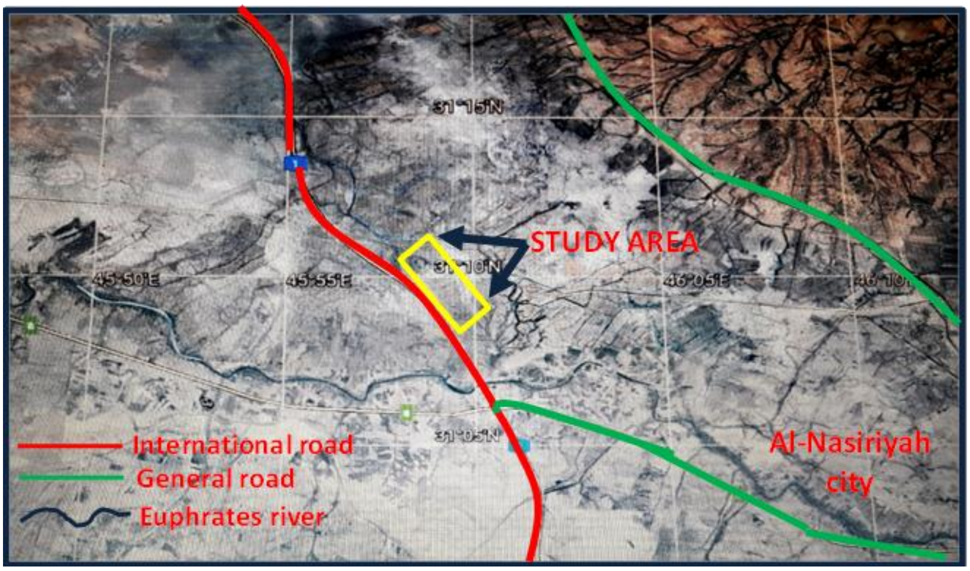

Figure1. Satellite map of the studied area

By a geological point of view, Quaternary sediments cover the study areas which are represented by sediments of flood plain and Aeolian sediments, generally composed of fine sand. This area is composed of sand dunes and sand flats, sand dunes are mostly in crescent shapes (Barchan) in addition to longitudinal shapes (Sief). These shapes of sand dunes reflect the prevailing wind effect in the region.

As is known, there are two types of sand dunes in Iraq. The first type is known as pseudo or false sand dunes and contains high percentage of clay and silt grains, which are located in the middle and southern parts of Iraq. While the second type is called the true sand dunes and contains high percentage of sand grains, which mainly cover northern middle parts of Iraq [15].

Phenomenon of sand dunes encroachment is widespread in the study area, Sand dunes generally composed of fine sand grains with an increase in the proportion of clay grains in addition to presence of river shells (shells of dead organisms) in large numbers. Further, sand dunes also called as named false sand dunes

3. Materials and methods

Soil samples were collected from five sites at Thi-Qar governorate from the area adjacent to the international road (highway) between Nasiriya – Baghdad near Fadak check point, from the right side toward Baghdad as shown in the map of the site. The samples were obtained during the field work program for students of the Department of Applied Geology in 2017. The laboratory tests were conducted at the laboratories of national center for construction laboratories. The American and British international standards (ASTM and B. S.) [16-18] have been used to conduct laboratory tests for the study area in order to determine the geotechnical properties which included the physical and chemical properties of the soil of the study area. The Fourier transform infrared spectrometry FTIR technique was used to identifying minerals in whole samples, the tests of FTIR technique were conducted at department of chemistry, college of science, university of Thi-Qar.

4. Results and discussion

Physical and chemical properties of soils are important indicators for soil evaluation in engineering terms. The physical and chemical characteristics of the studied soil samples were summarized in Table 1.

Table 1. Properties of used soils

Properties			Symbol	Soils				
				Soil 1	Soil 2	Soil 3	Soil 4	Soil 5
Physical properties	Grain size analysis	Clay%	C	1	-	1	-	-
		Silt%	M	28	40	54	36	30
		Sand%	S	71	60	45	64	70
	Atterberg limits	Liquid limit%	LL	33	33	40	36	27
		Plastic limit%	PL	24	24	30	27	14
		Plasticity index%	PI	9	9	10	9	13
Chemical properties	Organic matter		O.M.	4.2	3.6	3.9	3.7	3.7
	Chlorides %		Cl^-	0.035	0.027	0.04	0.038	0.042
	Calcium carbonate %		CO_3^{-2}	28	35	38	27	30
	Gypsum %		Gyp.	4.8	6.2	7	5.8	6.7
	Sulfates %		SO_4^{-2}	0.79	0.6	1.34	0.86	0.9
	Total soluble salts %		T. S. S.	4.62	3.11	2.36	2.2	4.5
	Power of hydrogen		pH	7.8	8.2	7.9	8.3	9.1

The particle size analysis of soil is consider as the basic of physical properties of the soil through which soil can be classified and identified, grain size analysis test were conducted according to ASTM D 422. As shown in Table 1, the percentage of sand ranged between (45-71%) while the percentage of silt ranged between (28-54%) as for the percentage of the clay is very low and does not exceed (1%) in both soil 1 and 3 and is not found in the rest samples of soils. Figure 2 shows the grain size distribution curves for samples of soils.

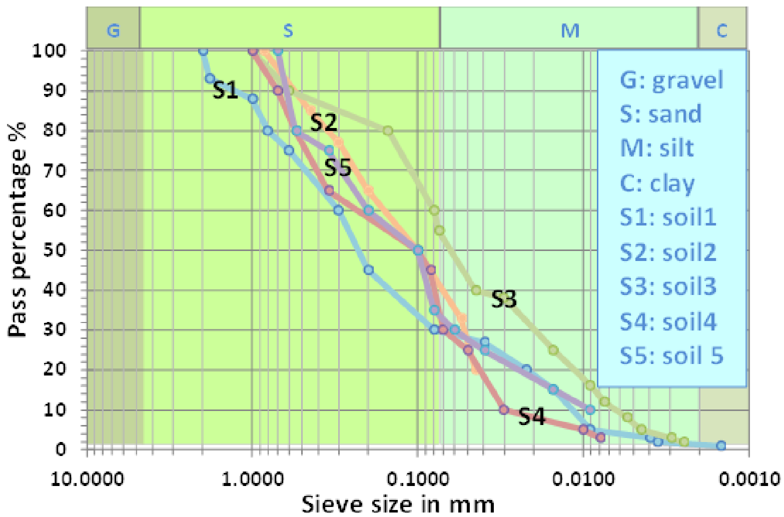

Figure 2. Grain size distribution of soil samples

According to the standard AASHTO T112 for selected granular material as sub-base, the five samples for fine aggregates meet the requirements as percent of materials passing through No.200 mesh sieve does not exceed two-thirds of the materials passing through No. 40 mesh sieve. However, the percent of materials passing through sieve No.200 exceeds the acceptable limits for gradient classes. But it can removed fine materials by washing (SORP 5 and 6) [19]. The limits of Atterberg are important indicators of the physical properties of soil, and these properties affect the engineering properties of soil, these limits are well known as soil consistency, namely, plastic limit (PL) and liquid limit (LL). Tests of atterberg limits were performed according to ASTM D 4318.

The percentages of the liquid limit (LL) ranged between (27-40%) and plastic limit ranged between (14-30%) thus the plasticity index (P.I) has value ranging from (9-13%) as shown in Table 1, Figure 3 shows the variations in the limits of soils consistency which used in this study.

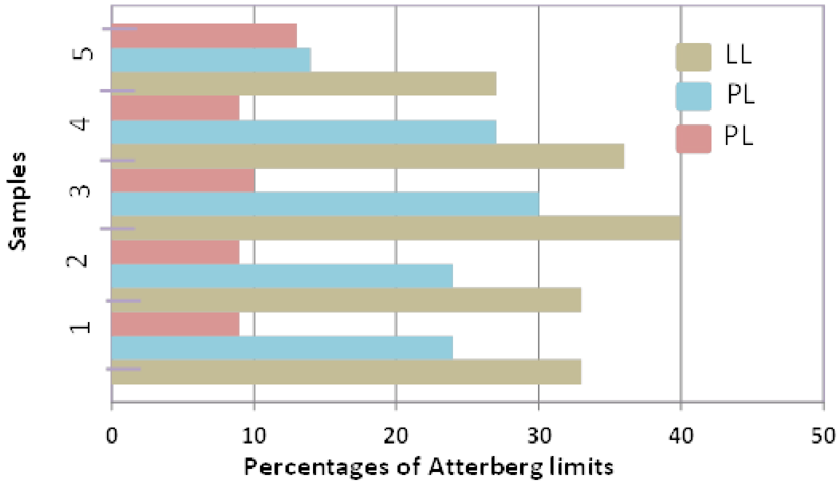

Figure 3. Graph showing variation in the atterberg limits

Atterberg limits were used to classify the soil for engineering purposes as well as to provide the information which are used interpreting some of the physical and mechanical properties of the soil [20]. the Unified Soil Classification System (USCS) has been used to classify the studied soils samples, accordingly the soils 1, 2, 3 and 4 can be classified as silts of medium plasticity, while soil 5 can be classified as clay of low plasticity (CL) as shown in Figure 4.

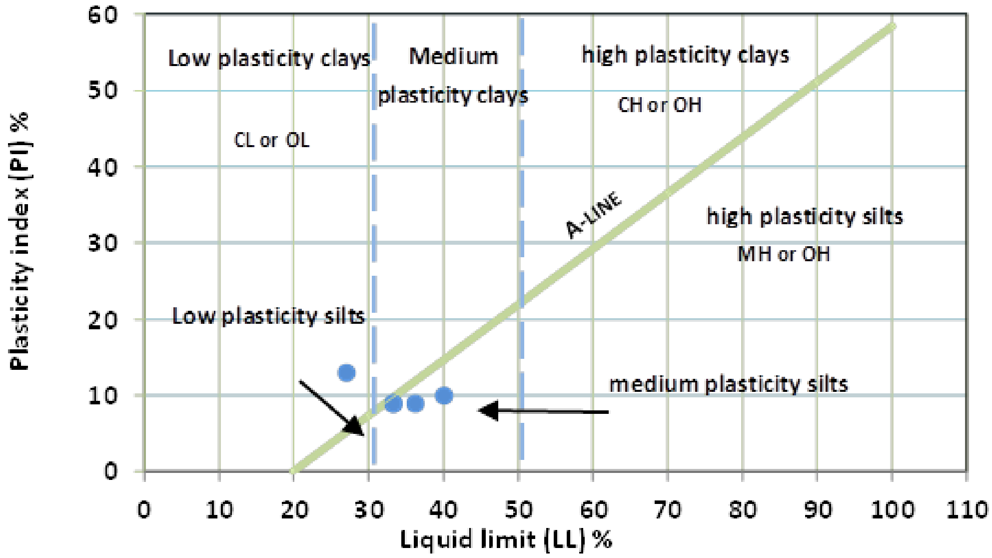

Figure 4. Casagrande diagram and soil classification in the study area

Further, according to American Association of State Highway and Transportation Officials (AASHTO) Figure 5 shows that soil 1 is classified as A-2-4, while soils 2,3 and 4 are classified as A-4, soil 5 is classified as A-2-6.

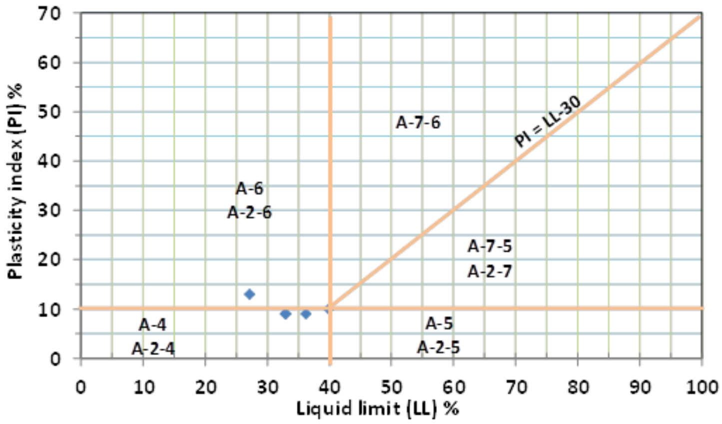

Figure 5. AASHTO diagram and soil classification in the study area

For the atterberg limits, The liquid limits and plasticity indices of the study area samples exceeded the limits of the standard specifications AASHTO T89 and AASHTO T90 respectively which means the aggregates are not suitable for selection as granular materials for the sub-base course but we can see that the samples 1, 2 and 5 compatible with the standard specification of the liquid limit While samples 1, 2 and 4 compatible with the standard specification of the plasticity index therefore, these aggregates can be used in the construction of the shoulders of the roads. On the other hand, aggregates can be used as a subgrade material because the requirements of liquid limit and plasticity index did not exceed the limits specified in the standard (SORP 6) [19].

Just as physical properties are important in soil works for road construction, chemical properties are also important, numerous studies have shown that the use of chemically unsuitable materials lead to failure in pavement surface [21,22]. Chemical laboratory tests included calculating the percentage of organic matter (O. M.), chlorides (Cl), calcium carbonate (CaCO3), gypsum (CaSO4.2H2O), sulfates (SO4-2), total soluble salts (T. S. S.), and power of hydrogen (pH). These tests were carried out according to the British standard (B. S. 1377), Table 1 and Figure 6 represented the chemical analysis results for deposits in the studied area.

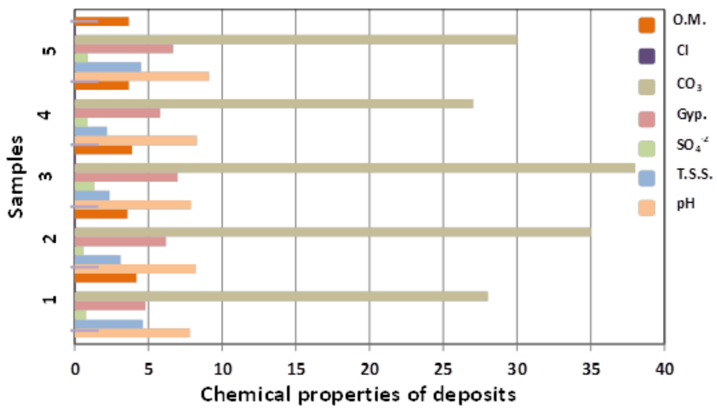

Figure 6. Chemical properties ratios in soil samples of study area

The presence of organic matter in small amount can affect the engineering properties of soil such as compressibility, shear strength and bearing capacity [23]. The organic matter ratios of the region samples ranged between 3.6-4.2. and it is higher than the specification limits that require values less than 2%. For chlorides, the percentage that higher than 0.1% is unacceptable, so the sediments of the study area showed values ranging from 0.027-0.042% thus, it is less than specified value. On the other hand, 30% of calcium carbonate is considered dangerous and can lead to major engineering problems. It can be seen that the percentage of calcium carbonate is close to the limits of the standard specification in the samples 1,4 and 5 or more in the samples 2 and 3 as shown in Table 1.

The gypsum concentrations ranged between 4.8-7% and is considered within the limits of the standard specification while the percentage of gypsum is considered risk if more than 10%. As for the percentage of sulfate values of the samples of the study area ranged between 0.6-1.34% and therefore these ranges did not exceed the limits of the specification where the percentage should not exceed 5%. The effect of the presence of salinity in the soil appears on the road pavement and bituminous surfacing [24]. The total soluble salts ranged between 2.2-4.62% that is, it is less than 10% concentration required by the standard specifications. Finally, from the results of laboratory tests, the soil of the study area has pH level greater than 7 for all studied samples because of the high percentage of calcium carbonate. In turn the effect of pH on soil strength properties makes it unsuitable for highway construction [25].

All samples were subjected to Fourier transform infrared spectrometry FTIR to determine the minerals present in the soils from the position of the peaks form the notable Fourier transform infrared spectrometry absorption peaks. In comparison with the available literature, the minerals were identified. Figures 7-9 show FTIR spectra for soil samples of studied area while Table 2 illustrates the positions of the observed peaks in wave number units together with minerals.

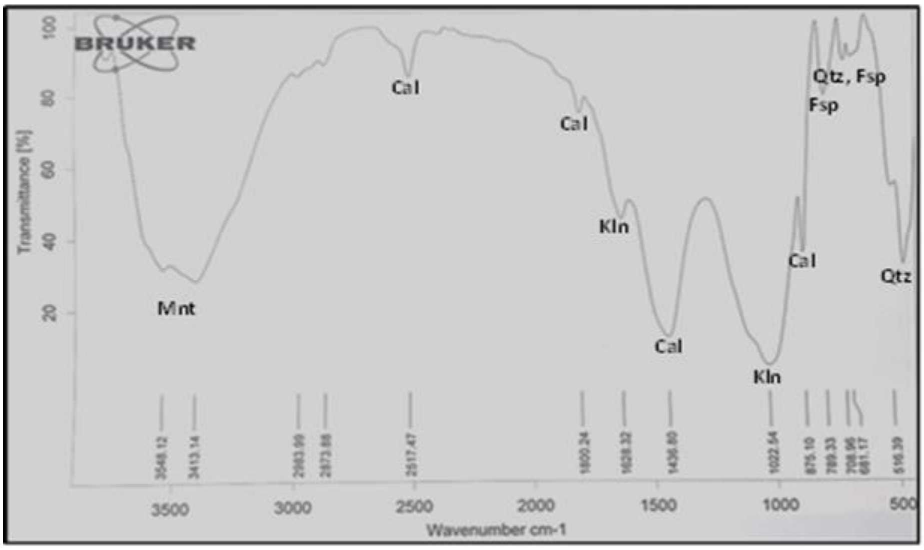

Figure 7. FTIR spectrum for soil-1

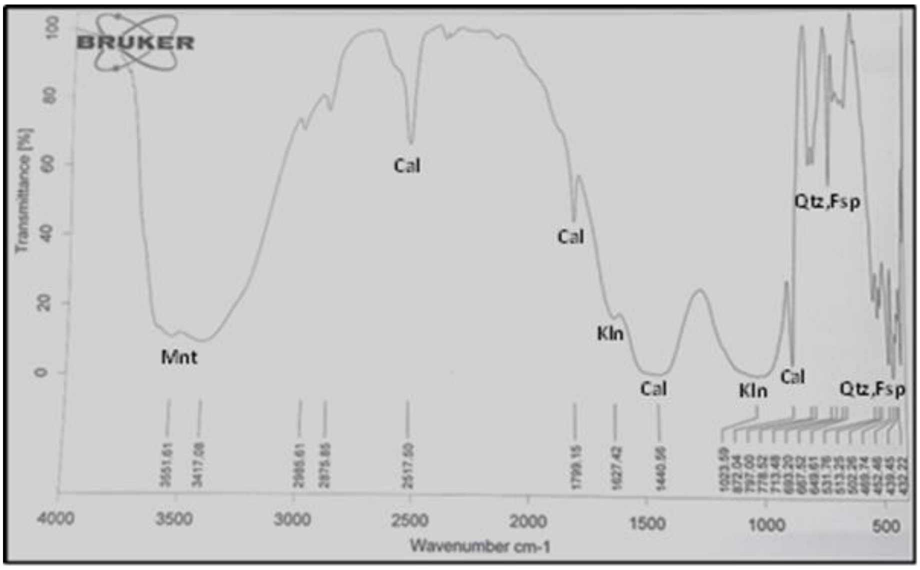

Figure 8. FTIR spectrum for soil-3

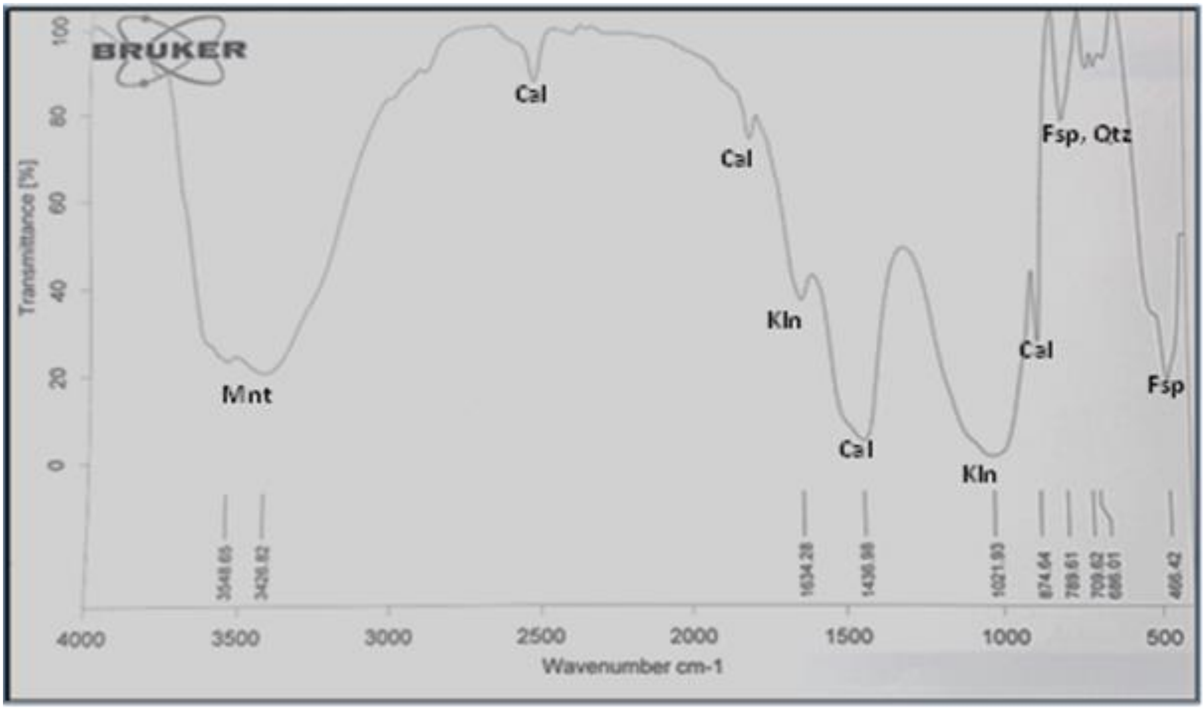

Figure 9. FTIR spectrum for soil-5

Table 2. FTIR observed Frequencies (cm^{-1}) of soil samples of studied area with mineral

Samples	Quartz (Qtz)	Feldspar (Fsp)	Calcite (Cal)	Kaolinite (Kln)	Montmorillonite (Mnt)
Soil 1	516.39	789	2517.47, 1800.24, 1436.80, 875.10	1628.32, 1022.54	3548.12, 3413.14
Soil 3	513.25	469.74, 452.46, 332.22	2517.50,1799.15, 1440.56	1627.42, 1023.59	3551.61, 3417.08
Soil 5	709.62	789.61, 466.24	2513, 1800, 1436.98, 874.84	1634.28, 1021.93	3548.65, 3426.82

According to the Table 2, it can be observed that the FTIR absorption peaks which appearing at709.62, 516.39 and 513.25cm^{-1} may be indicator the presence of quartz in the soil. The FTIR absorption peaks of quartz were assigned by many researchers [26-30]. While the peaks which observed at 789.61, 789, 469.74, 466.24, 452.46 and 332.22cm^{-1} may be indicator the presence of feldspar [26, 28, and 29]. The presence of FTIR absorption peaks at 2517.47, 2517.50, 2513, 1800.24, 1800, 1799.15, 1440.56, 1436.98, 1436.80, 875.10 and 874.84 cm^{-1} in the soils may be indicator for calcite [30, 31, 32].

Kaolinite was observed in the samples by the presence of peaks at1634.28, 1629.32, 1627.42, 1023.59, 1022.54 and 1021.93 cm^{-1} [29, 33, 34] while the peaks at 3551.61, 3548.65, 3548.12, 3426.82, 3417.08, and 3413.14cm^{-1} are indicator for montmorillonite [29, 33, 35]. The FTIR patterns showed that the soils consist of Kaolinite and Montmorillonite as major clay minerals and Quartz, Feldspar, and Calcite as non-clay minerals.

The mineral composition of the soil effects on its geotechnical properties and on this basis, the presence of quartz is very effective due to its inactivity, hardness, and durability when used as aggregates. This means that the quartz mineral will not react under normal conditions [36]. Further, the presence of calcite mineral in the soil is as a cement material that has the ability to dissolve in water [37]. Also, the presence of Montmorillonite is important due to its high swelling ability because it makes the soil unsuitable for use as road building material [38, 39, 40, 41].

5. Conclusions

From the results of the proposed research work, the main findings can be included as follows:

1) The grain size analysis of the sediment shows deviation from the gradient limits of the Iraqi standard specification.
2) Liquid limits and plasticity indices of the study samples do not comply with the limits of the standard specification for using as the sub-base materials. Most likely, it is suitable for using as the sub-grade materials and to construct the shoulder of the road.
3) From a chemical point of view, organic matter and calcium carbonate exceeded the limits of the standard.
4) The chemical analysis of the sediments shows that the rates of the chlorides, sulfates, gypsum, total soluble salts and pH they were within acceptable limits of standard specifications.
5) On mineralogical point of view, the mineral composition of the soil effects on its geotechnical properties, therefore the presence of quartz increases aggregate stiffness and durability due to its inactivity, hardness, and durability. On the contrary, the presence of calcite and clay mineral decreases aggregate stiffness.
6) Sand dunes sediments of the study area are suitable for use as fine aggregate after processing.

Availability of Data

The study findings which are supported by the data are obtainable by the corresponding's writer upon requests.

Interest Conflicts

The writers affirmed that they hadn't interest conflicts.

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References

[1] M. M. Rammal, and A. A.Jubair, "Sand dunes stabilization using silica gel and cement kiln dust". Al-Nahrain University, college of engineering journal, vol. 18, no. 2, p: 179-191, 2015.

[2] United Nations Environment Programme (UNEP). Desk study on the environment in Iraq, 2003.

[3] A. H. Al-Marsoumi, and M. M. Al-Asadi, "Dust storms and their environmental impacts at the northwest part of Arabian gulf (a review)", Journal of Iraqi desert studies, special issue of 1st scientific conference, vol. 2, no. 2, p: 43-53, 2010.

[4] I. M. Aliyas, "Dimensions of desertification on sustainable development in Iraq", International journal of advanced research, vo. 4, no. 9, p: 1553-1562, 2016.

[5] A. A. Suliman, and A. F. Farhood, "Monitoring the movement of sand dunes in Thi-Qar governorate using some spectral indicies", International journal of scientific engineering and research, vol. 5, no. 4, p: 113-118, 2017.

[6] N. Adamo, N. Al-Ansari, V. K. Sissakian, S. Knutsson, and J. Laue, "Climate Change: Consequences on Iraq's environment", Journal of earth sciences and geotechnical engineering, vol. 8, no. 3, p: 43-58, 2018.

[7] B. J. Abbas, "The settlement evaluation of improved soft clay using sand columns and partial replacement technique", International journal of engineering research and technology, vol. 5, no. 7, p: 348-355, 2016.

[8] P. Bhattacharya, and J. Kummar, "Bearing capacity of foundation on soft clays with granular column and trench", Soils and foundations, vol. 57, no.3, p: 488-495, 2017.

[9] G. M. Tetteh, and D. S Alakun, "Asphalt road deterioration associated with mineralogy of rock aggregates – A petrographical study". International journal of scientific research engineering and technology, vol. 7, no. 7, p: 572-578, 2018.

[10] A. J. Al-Dulaimy, "The effect of fine aggregate on properties of concrete". M. SC. thesis, university of Baghdad, college of engineering. 2005.

[11] R. S. Al-Rawi, A. M. Abdullateef, and A. J. Al-Dulaimy, "The effect of grading of fine aggregate on some properties of concrete", Journal of kerbala university, vol. 7, no. 1, p: 251-257, 2009.

[12] Y. Millogo, K. Traore, R. Ouedraogo, K. Kabore, P. Blanchart, & J. H. Thomassin, "Geotechnical, mechanical, chemical and mineralogical characterization of a lateritic gravels of Sapouy (Burkina Faso) used in road construction". Journal of construction and building Materials, vol. 22, no. 2, p: 70–76, 2008. doi10.1016/j.conbuildmat.2006.07.014

[13] B. T. Kamtchueng, V. L. Onana, W. Y. Fantong, A. Ueda, R. F. D. Ntouala, M. H. D. Wongolo, G. B. Ze Ndongo, A. A. Kamgang, V. K .B. and J. M. Ondoa, "Geotechnical, chemical and mineralogical evaluation of lateritic soils in humid tropical area (Mfou, Central-Cameroon):Implications for road construction" International journal of geo-engineering, p: 1-21, 2015., https://doi.org/10.1186/s40703-014-0001-0

[14] W. T. Hyoumbi, P. Pizette, A.S. L. Wouatong, and N. Abriak, "Mineralogical, chemical, geotechnical and mechanical investigations of bafang lateritic fine soils formed on basalts (west-Cameroon) for road embankment purpose". Earth science research, vol. 7, no. 2, p: 42-57, 2018.

[15] A. M. Fadhil, "Sand dunes monitoring using remote sensing and GIS techniques for some sites in Iraq", Conference paper in proceeding of SPIE-the international society for optical engineering, 2013, DOI: 10.1117/12.2019735

[16] ASTM, D 422-63, Standard Test Method for Particle-Size Analysis of Soils, 2004.

[17] ASTM, D 4318-00, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, 2004.

[18] BS 1377-3., Methods of Test for Soils for Civil Engineering Purpose, Part 3: Chemical & Electrochemical Tests, 1990.

[19] National center for laboratory and construction research. "specification of construction materials" No. (SORP/R5 and R6), General Specification of Rods and Bridges, Earth work. 187, 2003.

[20] Y. Deng, C. Cai, D. Xia, S. Ding, J. Chen, and T. Wang, "Soil atterberg limits of different weathering profiles of the collapsing gullies in the hilly granitic region of southern china", Solid earth, vol. 8, p: 499-513, 2017.

[21] A. A. Kifae, "Chemical and physical effects on engineering properties of gypseous sub-grade soil", Al. Qadisiya journal for engineering sciences, vol. 3, no. 3, p: 18, 2010.

[22] M. R. Abood, M. E. Kheder, and L. M. Rawee,"Sutibility of quaternary deposits in Alam area as filling materials in earth fills dams", Tikrit journal of pure science, vol, 22, no. 9, p: 83-87, 2017.

[23] F. Hamouche, and R. Zentar, "Effect of organic matter on mechanical properties of dedged sediments for beneficial use in road construction", Environmental Technology, p: 1-13, 2018.

[24] R. Carteret, B. Olivier, and S. Fityus, "A review of the effects of salinity on road pavements and bituminous surfacing". 24th ARRB conference – building on 50 years of road and transport research, Melbourne, Australia. P: 1-16, 2010.

[25] O.M. Osuolale, O. D. Falola, and M. A. Ayoola,"Effect of pH on geotechnical properties of laterite soil used in highway pavement construction", Civil and Environmental Research, vol. 2, no. 10, p: 23-28, 2012.

[26] J. Hlavay, K. Jonas, S. Elek, and J. Inczedy, "Characterization of the particle size and the crystallinity of certain minerals by IR spectrophotometry and other instrumental methods-II. Investigations on quartz and feldspar", Clays and Clay Minerals, vol. 26, no. 2, p: 139-143, 1978.

[27] F. B. Reig, J. V. Adelantado, M. Moya "FTIR quantitative analysis of calcium carbonate (calcite) and silica (quartz) mixtures using the constant ratio method". Application to geological samples. Vol. 58, no. 4, p: 811-21, 2002.

[28] R. Ravisankar, G. Senthikumar, S. Kiruba, A. Chandrasekaran, and P. Jebakumar, "Mineral analysis of costal sediment samples of Tuna, Gujarat", India.indian journal of science and technology, vol. 3, no. 7, p: 774-780, 2010.

[29] S. Sivakumar, R. Ravisankar, Y. Raghu, A. Chandrasekaran, and J. Chandramohan, "FTIR spectroscopic studies on coastal sediment samples from Cuddalore district", India.indian journal of advances in chemical science, vol. 1, p: 40-46, 2012.

[30] N. I. A. Acevedo, M. C. G. Rocha, and L. C Bertolino, "Mineralogical characterization of natural clays from Brazilian southeast region for industrial applications". Ceramica, vol. 63, p: 253-262, 2017. http://dx.doi.org/10.1590/0366-69132017633662045.

[31] R. Ravisankar, S. Kiruba, A. Naseerutheen, A. Chandrasekaran, and C. Maheswaran, "Estimation of firing temperature of some Ancient potteries of Tamilnadu, India by FT-IR Spectroscopic technique", Der Chemica sinica, vol. 1, no. 2, p: 157-163, 2011.

[32] M. B. Toffolo, L. Regev, S. Dubernet, Y. Lefrais, and E. Boaretto, "FTIR-based crystallinity assessment of aragonite-calcite mixtures in archaeological lime binders altered by diagenesis". Minerals, MDPI, vol. 9, no. 121, p: 1-14, 2019. doi:10.3390/min9020121

[33] V. C. Khang, M. V. Korovkin, and L. G. Ananyeva, "Identification of clay minerals in reservoir rocks by FTIR spectroscopy". IOP Conference Series: Earth and Environmental Science, 43 (2016) 1-4, doi:10.1088/1755-1315/43/1/012004.

[34] M. Diko, G. Ekosse, and J. Ogola, "Fourier transform infrared spectroscopy and thermal analyses of kaolinitic clays from south Africa and Cameroon". Acta geodyn. Geometer., vol. 13, no. 2, p: 149-158, 2016, doi: 10.13168/AGG.2015.0052.

[35] H. Wanyika, E. Maina, and D. Marika, "Instrumental characterization of montmorillonite clays by x-ray fluorescence spectroscopy, Fourier transform infrared spectroscopy, x-ray diffraction and UV/visible spectrophotometer". Journal of agriculture, science and technology, vol. 17, no. 1, p: 224-239, 2016.

[36] B. A. Varghese, "Analysis of aggregate mineralogy using LIBS", M. SC. thesis, university of Rowan, college of engineering. 2017.

[37] F. Ma, J. Yang, and X. Bai, "Water sensitivity and microstructure of compacted loess". Transportation geotechnics, vol. 11, p: 41-56, 2017.

[38] O. Ademila, and O. J. Adebanjo, "Geotechnical andmineralogical characterization of clay deposits in parts of southwestern Nigeria", Geotechnical Research, vol. 2, no. 2, p: 127-137, 2017. https://dx.doi.org/10.22606/gr.2017.22006

[39] E. A. Mandhour Alfatlawi, N. K. Thabbah Al-Obaidy "Evaluation the Efficiency of Installing Stone Columns in Ground Improvement of Al-Nassiriya City Soil". Thi-Qar University Journal for Engineering Sciences, vol.2, no.3, p: 44-56, 2011.

[40] E. A. Mandhour Alfatlawi, "Study of Some Geotechnical Properties of Selected Areas in Al- Nassiriya City (South of Iraq)". Journal of Thi-Qar Scienc, vol.3, no.1, p: 163-174, 2011.

[41] E. A. Mandhour, "Assessment of the liquefaction susceptibility of Al-Nasiriya city soil based on plasticity properties" Periodicals of Engineering and Natural Sciences, vol. 8, no. 1, pp. 542-551, 2020.

[42] S. Kh. Zamim1, N. S. Faraj, I. A. Aidan, F. M. S. Al-Zwainy, M. A. AbdulQader, I. A. Mohammed, " Prediction of dust storms in construction projects using intelligent artificial neural network technology" Periodicals of Engineering and Natural Sciences, vol. 7, no. 4, pp. 1659-1666, 2019.