



Physical and Mechanical Properties of the Lower Zab River Deposits and Their Possibility to be Used for Concrete Works in Dibbs Area, Northwestern Kirkuk, Northern Iraq

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ABSTRACT

This research investigates the physical and mechanical properties of the lower Zab River deposits in the Dibbis area, northwestern Kirkuk, where three samples were collected from the area to evaluate their suitability for concrete works through a number of tests. The results of the sieve size analysis of coarse aggregate are shown to be not correspondent with the Iraqi specification limits (IQS,45/1984), and for fine aggregate are correspondent for all sites. The flattening index ranges between (23.406 - 26.773%), and the elongation index ranges between (11.453 - 12.506%). The apparent specific gravity of coarse aggregate ranges between (2.616 - 2.680), and the saturated specific gravity range is (2.624 - 2.658), as well as the absorption ratio ranges between (0.2 – 0.4 %). For the fine aggregate, the dry specific gravity ranges between 2.605 - 2.633, saturated specific gravity (2.637 - 2.660), and absorption ratio ranges between 0.8 – 1.2%. The results of the Los Angeles test show the ratio of loss in weight is (14.801, 12.623, 16.861%) respectively, which are suitable for concrete works according to (IQS,41/1989) and (AASHTO, T96-02, 2019). The soundness test results (1.36, 1.84, 1.12 %) for coarse aggregate, and for fine aggregate (2.37, 2.04, 1.95 %), conform to the specification limits of (ASTM, C-88-05, 2004). The results of the uniaxial compressive strength (UCS) test according to Anon (1977) indicate that all the samples are classified within the (very strong – extremely strong) range.

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الخواص الفيزيائية والميكانيكية لترسبات نهر الزاب الاسفل وامكانية استخدامها في اعمال الخرسانة في منطقة الدبس شمال غرب كركوك / شمال العراق

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ملخص	معلومات الارشفة
يهدف البحث الى فحص الخواص الفيزيائية والميكانيكية لرواسب نهر الزاب الاسفل في منطقة الدبس شمال غربي كركوك، حيث تم جمع ثلاثة نماذج من منطقة الدراسة لغرض تقييم صلاحيتها في اعمال الخرسانة من خلال اجراء عدد من الفحوصات. بينت نتائج التحليل المنخلي للركام الخشن عدم ملائمتها مع حدود المواصفة (IQS 45/1984)، اما نتائج التحليل المنخلي للركام الناعم تبين ملائمتها مع الحدود لنفس المواصفة. وتراوحت نتائج عامل التسطح بين (23.406 - 26.773%) وعامل الاستطالة (11.453 - 12.506%). تراوحت قيم نتائج الوزن النوعي للركام الخشن (2.616 - 2.680) والمشيبي (2.624 - 2.658) ونسبة الامتصاص (0.2 - 0.4) % وتراوحت نتائج الوزن النوعي للركام الناعم (2.605 - 2.633) والمشيبي (2.637 - 2.660) ونسبة الامتصاص (0.8 - 1.2%). اظهرت نتائج فحص لوس انجلوس ان نسبة الفقدان في الوزن كانت (12.623, 14.801, 16.861%) على التوالي، وهي تتلاءم مع حدود المواصفتين (IQS, 41/1989) و (AASHTO, T96-02, 2019). كما ان نتائج فحص الثبات للركام الخشن (1.36, 1.84, 1.12 %) وللركام الناعم (2.37, 2.04, 1.95 %) حيث تتلاءم مع حدود المواصفة (ASTM, C-88-05, 2004). اما نتائج فحص متانة الانضغاط أحادي المحور (UCS) فقد صُنفت بالاعتماد على (Anon, 1977) جميع النماذج بأنها تقع ضمن مدى التصنيف المتين جدا الى فائق المتانة (very strong – extremely strong).	تاريخ الاستلام: 25- أغسطس-2024 تاريخ المراجعة: 01- أكتوبر-2024 تاريخ القبول: 01- نوفمبر-2024 تاريخ النشر الإلكتروني: 01- أكتوبر-2025 الكلمات المفتاحية: كركوك الخواص الفيزيائية ترسبات ركام خرسانة المراسلة: الاسم: اسراء منصور محمد Email: esraamansor289@gmail.com

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Introduction

Concrete is a man-made building material composed of filling (aggregate) materials and binding (cement paste) materials (McNally, 1998). Aggregate is a group of gravels or sands created as a result of erosion and weathering processes that act on sedimentary, igneous, and metamorphic rocks (Miliutenko, 2009). Since the aggregate comprises the main component of the concrete mix, with a range of ratios of 70-75% of the total concrete volume (Neville and Brooks, 2010). So, the aggregate properties are mainly responsible for concrete strength, durability, and structural performance (Neville, 2011). The most essential reasons for the current research are to determine the physical and mechanical properties to decide the possibility of being exploited as local raw materials accumulated on the Lower Zab River banks in Dibbs region in Kirkuk Governorate. This study aims to identify the validity of Lower Zab River deposits for concrete work Location of the study area is decided due to studying the physical and mechanical properties of the deposits. Some previous studies on the issue of the research, e.g., who studied the validity of the Tigris River sediments for concrete works in Tikrit Governorate, northern Iraq. He deduced that the sediments conform to the required standards for concrete constructions. Mohammed et al. (2022) studied the suitability of the Euphrates River bank deposits for concrete construction between Baghdad and

Fallujah. They concluded that these deposits are appropriate for engineering uses in concrete works and advised that they be washed to remove impurities, salts, and harmful elements. Al-Saady and Al-Zubaydi (2019) studied the suitability of Injana Formation sandstone powder for concrete manufacturing in Karbala Governorate. They concluded the possibility of the resulting sandstone powder to the standard specifications. Hassan et al. (2023) studied the validity of Lower Zab River deposits for concrete construction in the southwest of Kirkuk. They concluded that the deposits can be used in building concrete according to Iraqi and international standards specifications.

Location of the study area

The study area is located in the Dibbs region, northwest of Kirkuk Governorate in northeastern Iraq. It lies between longitudes ($44^{\circ} 03' 14''$ - $44^{\circ} 02' 25''$) E and latitudes ($35^{\circ} 39' 07''$ - $35^{\circ} 40' 52''$) N, 37 km away from the city center (Fig. 1).



Fig. 1. Location Map of the study area (obtained from Google Earth Pro).

Geological setting

Tectonically, the study area belongs to the unstable shelf on the foothill zone as a part of the Chemchemal-Butmah subzone (Jassim and Goff, 2006) (Fig. 2).

There are several different Tertiary geological formations in the region (Fatha, Injana, Mukdadiya, and Bai-Hassan), which are covered by Quaternary recent deposits. The Fatha Formation is composed of sandstone, siltstone, claystone, marl, anhydrite, gypsum, limestone, and conglomerate (Buday and Jassim, 1987; Sadeq and Mohammed, 2022). It was deposited in a shallow marine environment (Buday, 1980). The lower part of the Injana Formation was deposited in a transitional environment, and the upper part was deposited in a fluvial environment (Tamar-Agha and Salman, 2015). It is composed of carbonate-rich sandstone alternating with marls, mudstone, and brownish-red siltstones, as well as relatively rare freshwater limestone (Bellen et al., 1959, and Jawad Ali et al., 1988).

Mukdadiya Formation consists of pebbly sandstone, sandstone, claystone, siltstone as well and conglomerate in contact with the Bai Hassan Formation (Al-Naqib, 1959). It was deposited in the fluvial environment (Al-Naqib, 1960; Ali, 2021).

The Bai Hassan Formation is made up of thick conglomerate layers interbedded with sandstone, claystone, and siltstone (Buday, 1980), which was deposited in a fluvial environment (Al-Janabi, 2008).

Quaternary deposits are composed of inherent deposits of gravel, sand, silt, and clay in an overlapping way of Pleistocene-Holocene age covering the Bai Hassan Formation.

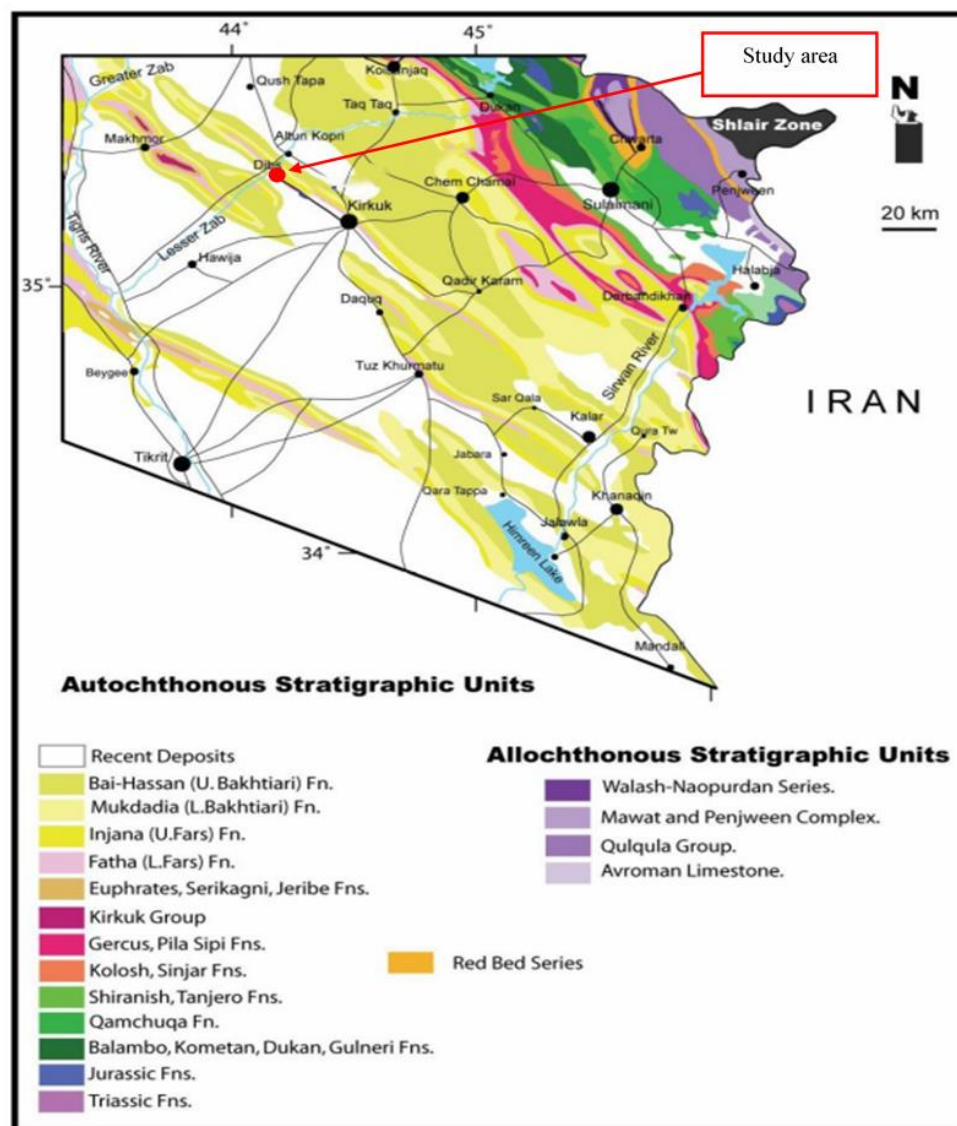


Fig. 2. Geological map of the study area (Modified from Sissakian, 2000).

Materials and Methods

The field work involved sample collection from the three selected stations of the study area, which represent the Lower Zab River deposits according to ASTM-D75 (2004), in addition to using a GPS device to locate the study area and the stations. The laboratory works include the sample preparation using the quartile method and conducting some physical and mechanical tests in the National Center for Laboratories and Construction Research in Kirkuk Governorate, following IQS and international standard specifications, as well as the laboratories of the Applied Geology Department, College of Science, University of Kirkuk.

Physical Tests

Sieve analysis test

It is a test used to determine the grain grading, which has a great influence on the concrete properties, such as workability and strength. The good grading of the grains means a smaller gap between the particles, thereby requiring less cement paste (Greene et al, 2016). The test was performed corresponding to IQS,45/1984, at the National Center for Construction Laboratories and Research (Kirkuk branch). Tables (1 and 2) show the limit of the standard specification IQS 45/1984 for coarse and fine aggregates, respectively. Table (3) shows the results of the sieve analysis test for coarse and Table (4) shows the results of fine aggregate.

Table 1: Grading limits of coarse aggregate

Sieve size (mm)	Percentage passing		
	5-40 mm	5-20 mm	5-14 mm
75	100	-	-
63	-	-	-
37.5	95-100	100	-
20	35-70	95-100	100
14	-	-	90-100
10	10-40	30-60	50-85
5	0-5	0-10	0-10
2.36	-	-	-

Table 2: Grading limits of fine aggregate

Sieve size (mm)	Percentage passing			
	G A N0.1	G A N0.2	G A N0.3	G A N0.4
10	100	100	100	100
4.75	90-100	90-100	90-100	95-100
2.36	60-95	75-100	85-100	95-100
1.18	30-70	55-90	75-100	90-100
0.6	15 – 34	35- 59	60-79	80 -100
0.3	5 – 20	8- 30	12-40	15-50
0.15	0 – 10	0-10	0-10	0-15

Table 3: The results of the coarse aggregate grading.

Sieve size (mm)	Percentage passing		
	S1	S2	S3
75	100	100	100
63	100	100	100
37.5	97.9	97.49	97.9
20	93.96	93.18	93
10	48.78	47.39	48.39
5	0.02	0.02	0.03

Table 4: Results of the fine aggregate grading.

Sieve size (mm)	Percentage passing		
	S1	S2	S3
10	100	100	100
4.75	99.67	100	98.94
2.36	78.31	80.13	78.88
1.18	25.83	28.79	27.68
0.6	18.39	21.52	20.18
0.3	9.78	13.16	11.68
0.15	0.45	3.8	2.35

Shape parameters test

Increasing the elongation and flattening aggregate particles is considered as unwanted particles because they lead to a large number of voids then produces harsh concrete (Oluwasola et al., 2020). This test represents the flattening index test and the elongation index test. Figure 3 illustrates the used instrument.



Fig. 3. Flakiness and elongation instrument.

1- Flattening index

This index describes the percentage of the aggregate particles with a thickness less than 0.6 mm from their nominal size of the aggregate to the total weight of the sample (Smith and Collis 2001). The test is conducted in the National Center for Construction Laboratories and research (Kirkuk branch) according to (IQS 45/1989), and the results are compared with (BS812, Part 105, 1990). The flattening index is calculated by this equation, depending on (BS812, Part 105, 1990):

$$\text{Flattening index} = \frac{\text{weight of the particles of thickness less than 7.2mm}}{\text{total weight of particles}} * 100 \quad (1)$$

The results of the test conform to the specification limits.

2- Elongation index

The index that refers to the percentage of aggregate particles whose lengths exceed 1.8 than their nominal size (the general average of the length of the granules) to the total weight of the sample (Smith and Collis, 2001). The test is conducted in the National Center for Construction Laboratories and research (Kirkuk branch) according to (IQS 45/1989), and the results are compared with (BS812, Part 105, 1990). Elongation index can be calculated using this equation (BS812, Part 105, 1990):

$$\text{Elongation index} = \frac{\text{weight of the particles of the length greater than 21.6 mm}}{\text{total weight of particles}} * 100 \quad (2)$$

The results of the test conform to the specification limits.

Fineness modulus (FM)

It is an index used to define the aggregate average size using sieve size test information (Imbert, 1973). Fineness modulus is calculated by this equation (Zongjin, 2011):

$$\text{Fineness modulus} = \frac{\sum(\text{cumulative retained percentage})}{100} \quad (3)$$

According to (ASTM C33-03), which determined the fineness modulus of fine aggregate, the results range is (2.3-3.1), showing an inconformity with the limits of the specification.

Specific gravity and absorption ratio

It is defined as the unit weight of the aggregate in air divided by the same volume of unit weight of distilled water at a specific temperature (Bodó and Jones, 2013). The specific gravity of the coarse aggregate is calculated in the National Center for Construction Laboratories and Research (Kirkuk branch) according to ASTM C-127-88 (2004), while the specific gravity of the fine aggregate is calculated according to ASTM C 128 (2004). The results are shown in Table 5.

Table 5: Results of the coarse and fine aggregate tests.

Laboratory tests	Coarse aggregate			Fine aggregate		
	1	2	3	1	2	3
Flattening Index	26.773	24.026	23.406	-	-	-
Elongation Index	12.086	11.453	12.506	-	-	-
Fineness Modulus (FM)	7.5	7.6	7.5	3.6	3.5	3.6
Dry specific gravity	2.649	2.680	2.616	2.616	2.605	2.633
Saturated surface dry specific gravity	2.658	2.685	2.624	2.637	2.637	2.660
Absorption (%)	0.3	0.2	0.4	0.8	1.2	1.0
Loss Angeles abrasion test %	14.801	12.623	16.861	-	-	-
Soundness test %	1.36	1.84	1.12	2.37	2.04	1.95

Mechanical Tests

Los Angeles abrasion test

It is defined as the test that is used to characterize the hardness of the aggregate by measuring the resistance of the aggregate to abrasion (Neville, 2011). The test is conducted in the National Center for Construction Laboratories and research (Kirkuk branch) according to (ASTM C-131-01, 2004). The results of the test conform to the specification limits of (AASHTO, T96-02, 2019) and (IQS,41/1989). Figure 4 exhibits the used instrument.



Fig. 4. Los Angeles abrasion machine.

Soundness test

This term refers to the aggregate's resistance capability to volume changing when subjected to some temperature changes, such as the wetting and drying cycles and freezing and thawing cycles (Smith and Collis, 2001). This test is conducted in the National Center for Construction Laboratories and Research (Kirkuk branch) according to ASTM C-88-05 (2004). The results of the test conform to the specification limits of the standard.

Point load test

It is an index test used to estimate the value of the uniaxial compressive strength. Figure 5 shows the used instrument.

The test is conducted in the Department of Applied Geology, College of Science, University of Kirkuk, according to (ISRM, 1985). Three irregularly shaped gravels are taken for each sample and subjected to load by the point load test machine until the sample got to failure, then uniaxial compressive strength (UCS) is calculated using the point load test values by the equation given by Bieniawski (1975). It is found by applying the relationship between the infinite compressive strength and the point load strength function:

$$UCS = K * Is (50) = 24 * Is (50) \dots\dots$$

where: K = function of the strength conversion factor; Is = point load strength index.

The results are classified according to Anon (1977), where all samples plot within the (very strong–extremely strong). Table 6 shows the results of the UCS.



Fig. 5. Point load test instrument.

Table 6: Results of the UCS of the coarse aggregate.

Laboratory tests	S	No. of samples for each station	Ranges of UCS (MPa)
Point Load	1	3	163.8 - 375.10
	2		112.8 - 211.2
	3		163.2 - 384.24

Results and Discussion

Tables (3 and 4) show the results of the sieve analysis test for the study area samples, where the coarse aggregate turned out to be inappropriate when compared with the nominal

size (5-20 mm) of the IQS,45/1984. As there is a deviation in the granular size of (37.5 and 20 mm) in all samples, except (10 and 5 mm) are suitable (see Figs. 6,7,8). For the nominal size limits of (5-14 mm), also not conform with it due to the presence e a deviation for the grain size (20 and 10 mm), except that the grain size (5 mm) is suitable for all samples. About the nominal size limits of (5-40 mm), the results are shown to be unsuitable due to the presence of a deviation at the grain size (10 and 20 mm), but they are suitable for the grain size (37.5 and 5 mm) for all samples. The results of the sieve analysis of the fine aggregate show that they correspond to the limits of the gradient of the first region in the first sample and the second sample, as well as the third sample, with the presence of some deviation in (1.18 mm) granular size for all samples (see Figs. 9, 10, and 11).

The results of the flattening and elongation index test conform to the specification limits (BS812, Part 105, 1990). The results of the fineness modulus show uncomfoting with the limits of the specification (ASTM C33-03) for all samples. The values of the dry specific gravity of coarse aggregate are (2.649, 2.680, 2.616), while the saturated specific gravity values are (2.658, 2.685, 2.624), as well as the absorption ratio (0.3, 0.2, 0.4%), respectively. The dry specific gravity values of fine aggregate are (2.616, 2.605, 2.633), while the saturated specific gravity values range is (2.637, 2.637, 2.660), and the absorption ratio is (0.8, 1.2, 1.0 %) for each.

The values of the Los Angeles abrasion test show the weight loss of coarse aggregate is (14.801%, 12.623%, 16.861%) respectively, which conforms with the specification limits of (IQS,41/1989) that specified the maximum loss of weight should not exceed (40 %). As well as conforming with the specification (AASHTO, T96-02, 2019), which in role establishes that the weight loss values should not be greater than 35 %.

About the soundness test, the results show the loss in weight of the coarse aggregate using sodium sulphate for 5 cycles are (1.36 %, 1.84 %, 1.12 %), and (2.37 %, 2.04 %, 1.95 %) for the fine aggregate. This conforms to the specification limits that specify the loss ratio for the coarse aggregate, which should not exceed 12 % in sodium sulphate solution, and 10 % for the fine aggregate in the same aqueous solution.

The results of the UCS test inferred by the point load test values show that all samples of all stations are located within the range of (very strong–extremely strong) according to the classification of Anon (1977).

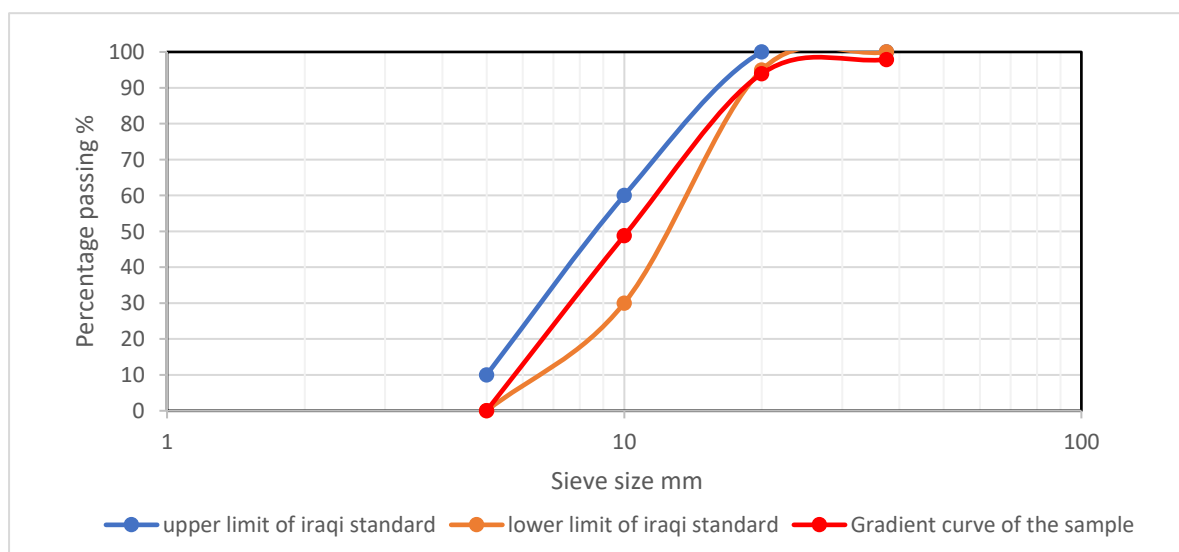


Fig. 6. Grain grading of coarse aggregate for Sample 1.

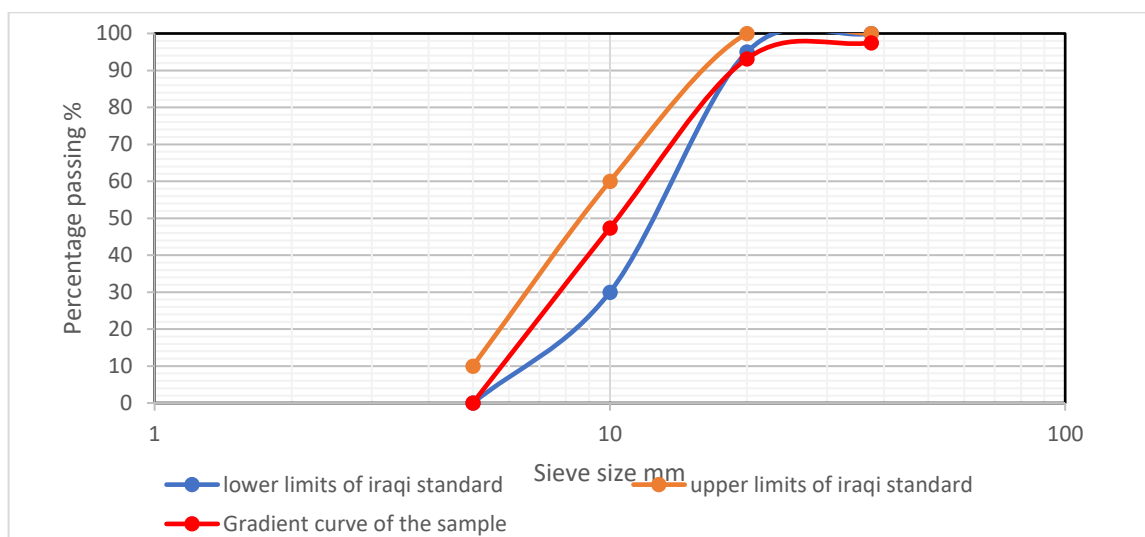


Fig. 7. Grain grading of coarse aggregate for Sample 2.

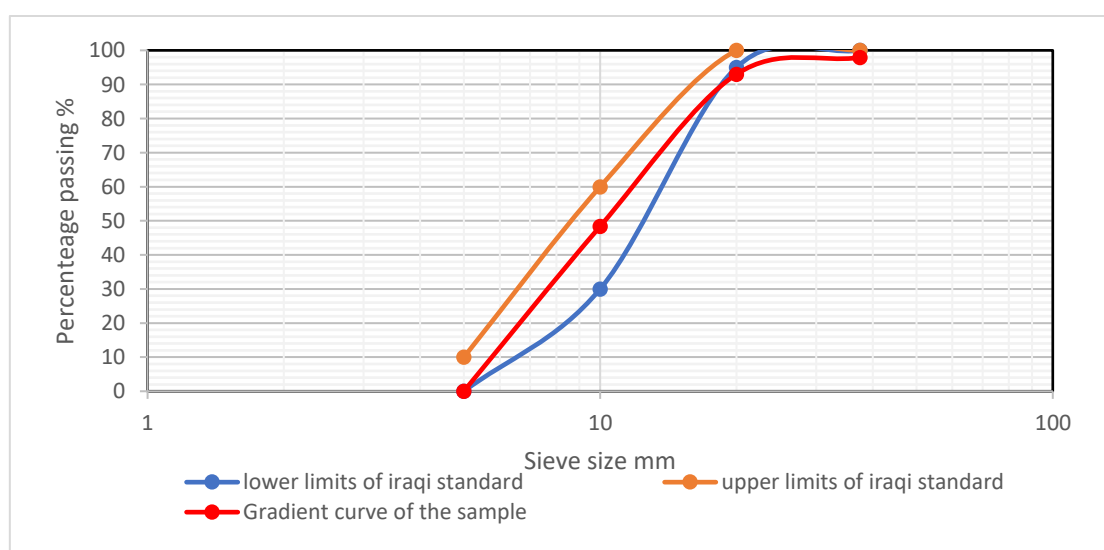


Fig. 8. Grain grading of coarse aggregate for Sample 3.

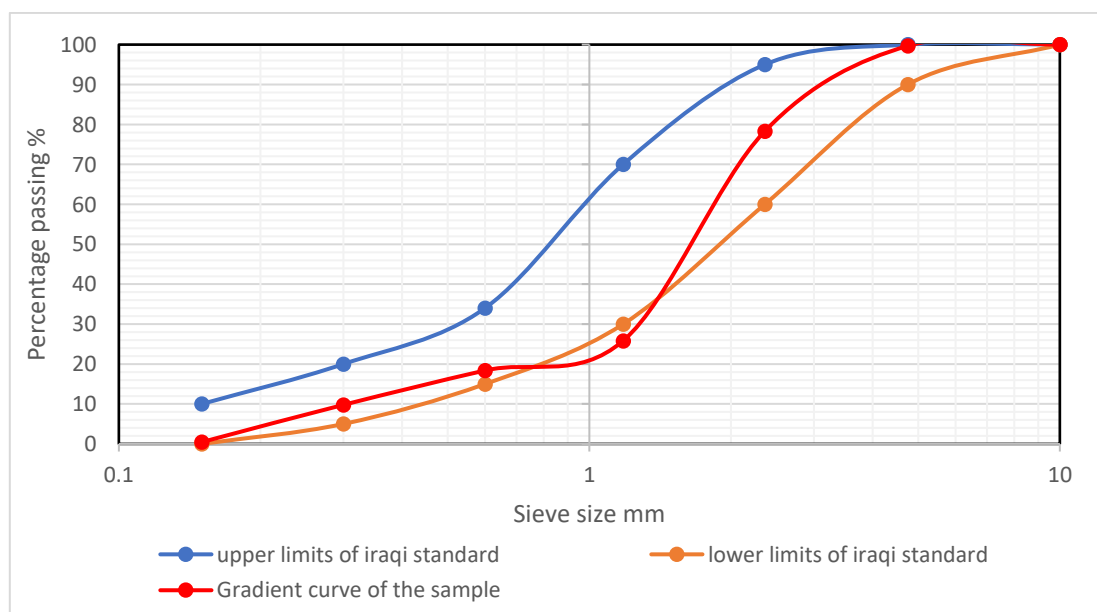


Fig. 9. Grain grading of fine aggregate for Sample 1.

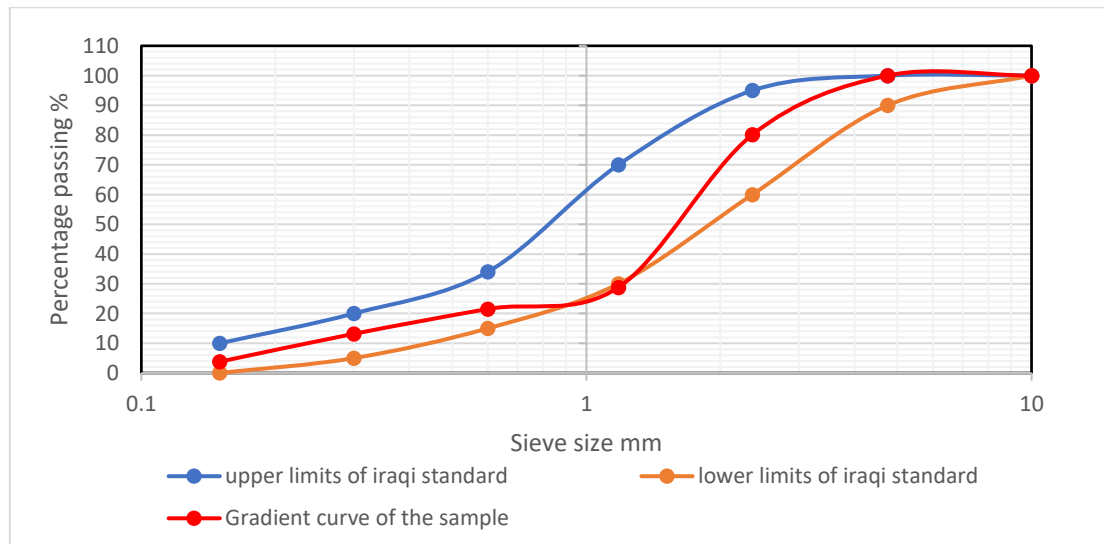


Fig. 10. Grain grading of fine aggregate for Sample 2.

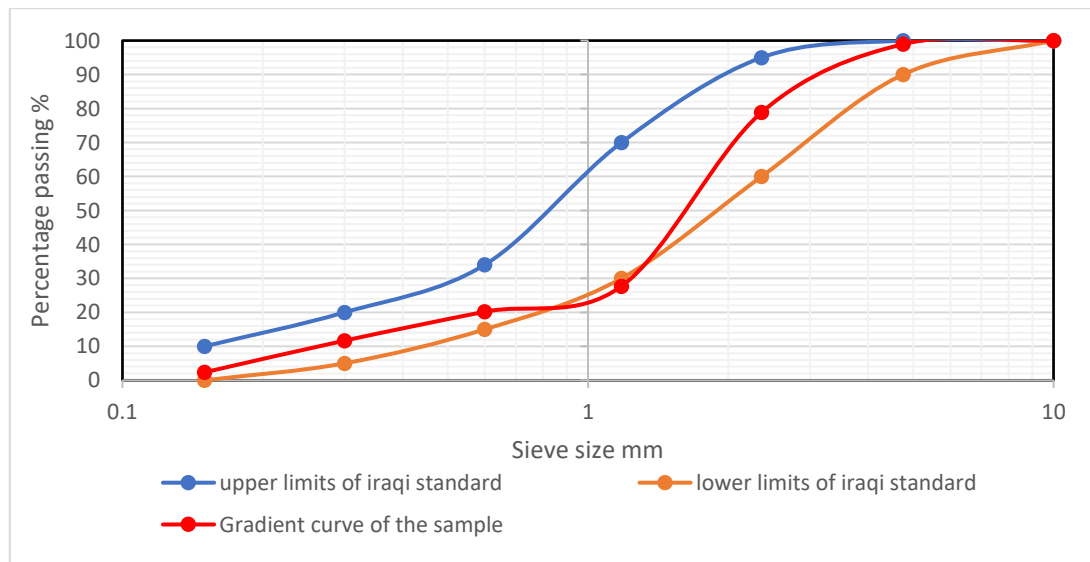


Fig. 11. Grain grading of fine aggregate for Sample 3.

Conclusion

The results of the experiments of the aggregate extracted from the Dibbs area northwest of Kirkuk, northern Iraq, indicate the following: the coarse aggregate is not suitable to be used in concrete production works according to the IQS,45/1984 specification, while the fine aggregates can be used for concrete production works. As well as the fineness modulus results do not conform to the standard specification limits ASTM C33-03. The flakiness and elongation coefficients are conformed to (B.S 812, part 105, 1990). The results of the specific gravity of coarse and fine aggregate conform to the specifications limits. In addition, the results of the soundness test for the coarse aggregate conform to specification limits. The results of the Los Angeles test are shown to be suitable for concrete works. The uniaxial compressive strength test shows that all samples are suitable for the concrete works.

It is recommended to conduct a geotechnical assessment of the same area for other engineering purposes, such as sub-base road layer, asphalt, and construction materials.

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