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Analyze the Geotechnical Properties of Aggregate in Al-Mahzam area and Evaluation of its Suitability for Using in road purposes

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Abstract
This research studies the geotechnical properties of the Quaternary deposits aggregate in Al-Mahzam area in Tikrit city/Salahadin governorate. Samples are collected from three sites on the western bank of Tigris River for studying the physical, mineralogical, chemical, strength and durability properties and evaluating its suitability for sub base in road works. The results for the physical tests through the grain size distribution test show that the aggregate is well graded and suitable to use in road works as sub base for class A. Specific gravity and density tests were carried on according to ASTM, D854,C127 Liquid limit value are (5.10, 2.2 and 4) % and the samples are non-plastic while the value of the elongation and flakiness index according to ISS, 45/1989 are (21.65, 16.04 and 15.85)% and (26.11, 28.65 and 36.00)% respectively.
Mineral composition test of gravel particles revealed that carbonate gravel forming the high percentage of the mineral composition, chert and quartz, sandstone, igneous and metamorphic rocks respectively. Strength test for aggregate Impact Value were carried out according to ISS,47/1970 and B.S.812-112,1990 are (7.06,9.79 and 8.8)% which is classified to exceptionally strong which is specified that shall not exceed 30% for using in road works, and compression strength value which is derived from point load test are (197, 189.3 and 182.4) MPa. according to Hawkins classification is very strong. The durability test results represented by the loss angles test are (26.72, 26.18 and 29.55)% which is suitable for sub base road work, and the average of the soundness test results were ranges (0.62-3.54)% for coarse and fine aggregates which is within the specification and suitable to use the aggregate in roadwork as the sub base. For the chemical tests the values of organic matter, pH value, TDS and sulfate salts (gypsum %) are within the specification and suitable for using in sub base course for road.

Key words: Aggregate, Geotechnical properties, Al-Mahzam, Sub base use.

Introduction
Aggregate refers to any crushed rock product, plus some naturally fragmented materials such as river gravel and sand. It is used to make concrete, used in the production of asphalt, and great quantities are needed to build roads and pipelines. Aggregate is also used in water filtration systems. Also for spread it on roads in winter to provide traction. Different types of aggregate have different engineering properties [1].
In the present studied area, most of quarries of gravels and sand are of Quaternary deposits which consider the main source of construction materials. The Quaternary deposits comprised of Pleistocene and recent deposits. These deposits include alluvial deposits which consist of a mixture of gravel, sand, silt, clay and conglomerates derived of the post Pliocene deposits [2].
Quaternary sediments cover more than one third of the surface area of Iraq. Mostly within the Mesopotamian plain where they comprise fluviatile, lacustrine, deltaic and aeolian sediments [3]. Sand and gravel deposits are normally considered together as sources of naturally occurring fine and coarse aggregate found mainly in alluvial environments. The soundness and stable mineralogy of sand and gravel deposits result from their having been subjected to comminution and sorting by natural- mainly fluvial- processes of erosion and transportation. Alluvial sources include fans, terraces, channel fills and point bars[4].

Location of study area
The study area Al-Mahzam is located in Salahadin governorate and about (9) km north of Tikrit city which is about (170)Km north Baghdad. The aggregate quarry in Al-Mahzam area is along the western bank of Tigris river. Figure 1.

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Figure 1. Location of the study area in A-Iraq. B. Tikrit. C. Al-Mahzam.

● Sample collection stations

Aims of study

Analyze the geotechnical properties of aggregates in the Al-Mahzam area and evaluate the suitability of Al-Mahzam quarry aggregates for road uses.

Methodology

Three sites were chosen, in Al-Mahzam area, samples were collected from the sites near the western bank of Tigris River according to. Channels or pits were made about (1-1.25)m. diameter and (1.5-2.0)m. depth. With weight about(60) kg. for each station. According to[5] and [6] .

The represented samples were prepared and dried in the laboratory for the following tests:

1. Physical tests

a. Particle size distribution according to[7].
b. Specific gravity, Density and absorption rate according to [8] and [9].
c. Atterberge limits according to [10].
d. Particles shape according to [11].

2. Durability tests

a. Loss angles Test according to [12] and [13].
b. Soundness test according to [14].

3. Mechanical tests. (Strength Tests)

a. Aggregate Impact Value according to[15] and [16].
b. Point Load Test according to [17].

4. Mineralogical composition according to [18].

5. Chemical tests.

a. Gypsum content according to [19].
b. Total dissolved salts according to[20].
c. Organic matter content according to [21].
d. pH value according to [22].

Results:

1. Physical Tests

a. Particle size distribution.

This test is performed to determine the percentage of different grain sizes contained within a sample. The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles. The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis result, Table 1 and Figures 2,3 and 4 provides the grain size distribution, and it is required for soil classifications.

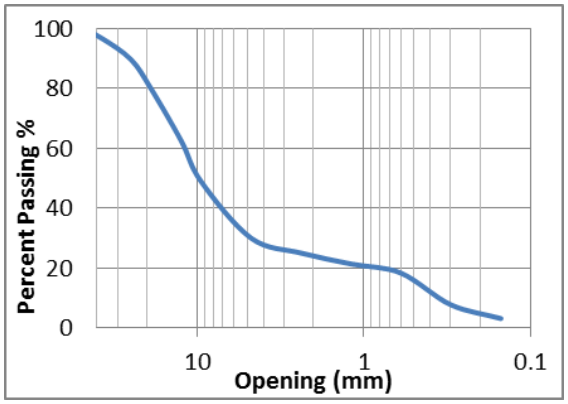

Figure 2. Grain size distribution for sample 1.

From grain size distribution curve:
% Gravel= 69 %Sand= 12 % Fines= 19

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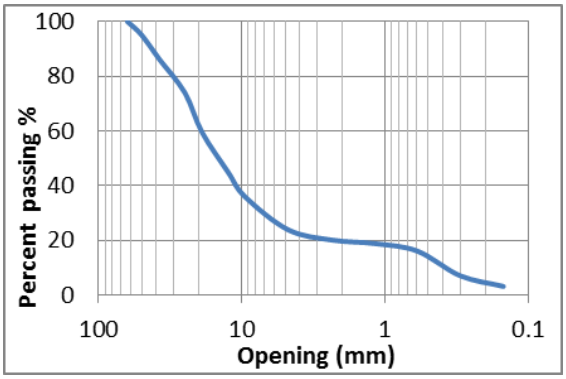

Figure 3. Grain size distribution for sample 2

From grain size distribution curve:
% Gravel= 76 % Sand=7 % Fines= 16

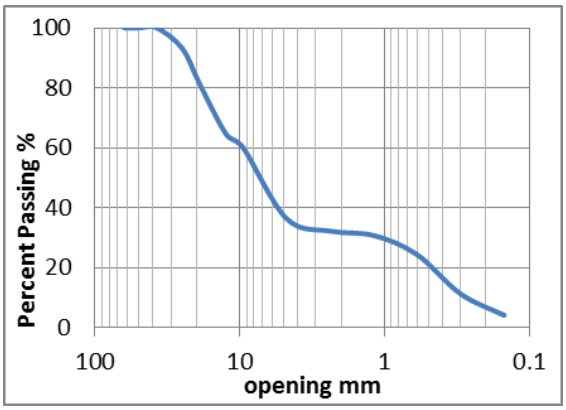

Figure 4. Grain size distribution for sample 3

From grain size distribution curve:
% Gravel=64 % Sand= 9 % Fines= 27

Table 1. The sieve analysis test results for the three samples.

Sieve size (mm)	% Passing		
	Sample 1	Sample 2	Sample 3
63	100	100	100
50	100	95	100
37.5	96.80	86.05	100
25	89.70	73.95	93.10
19	80.05	59.48	81.30
12.5	62.60	44.90	64.60
9.5	49.00	35.85	60.00
4.75	30.05	23.77	36.30
2.36	25.02	20.04	32.23
1.18	21.40	18.76	30.74
0.6	18.42	16.03	24.42
0.3	7.82	6.98	11.32
0.15	3.22	3.10	4.18
0.075	1.90	1.95	1.40
Total weight	9810	9805	9860

Specific gravity

Specific gravity is the ratio of the density of the substance to the density of water. The specific gravity of an aggregate particle is dependent upon the specific gravity of the minerals making up the particle and upon the porosity of the particle. [9]
These may be defined as follows:

1) All of the pore space (bulk specific gravity)
2) Some of the pore space (effective specific gravity)
3) None of the pore space (True specific gravity)

Bulk specific gravity dry=A/B-C
Bulk specific gravity =B/B-C
True specific gravity dry=A/A-C
% Absorption=(B-A/ A)*100
Where;
A=Dry weight of the sample, B= saturated sample weight, C=submerged sample weight.

The tests were carried on according to the standard coarse aggregate specific gravity and absorption test [8] and [9] ,the results are shown in Tables 2 and 3.

Table 2. The specific gravity for coarse aggregate.

Specific gravity	Sample 1	Sample 2	Sample 3
Dry	2.63	2.66	2.64
Sat. surf. Dry	2.70	2.67	2.70
True	2.78	2.71	2.78
% Absorption	0.7	0.2	0.60

Table 3. The specific gravity for fine aggregate.

Specific gravity	Sample 1	Sample 2	Sample 3
Dry	2.58	2.59	2.60
Sat. sur. dry	2.61	2.65	2.66
True	2.68	2.69	2.72
% Absorption	1.7	1.2	2.6

Moisture-density relation (Compaction) test

This test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified compactive effort, which is the amount of mechanical energy that is applied to the soil mass. Several different methods are used to compact soil in the field, and some examples include tamping, kneading, vibration, and static load compaction. This test will employ compaction method using the type of equipment and methodology developed by R. R. Proctor in 1933.The modified compaction test were carried out according to [23] and [24], Table 4. shows the result of the compaction test.

Table 4. Compaction test results.

Sample No.	Max. Density gm/cm^3	Optimum Moisture Content %
1	2.29	4.5
2	2.28	5
3	2.26	4.5

The liquid limit

The liquid limit (LL) is defined as the water content, in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2in.) when subjected to 25 shocks from the cup being roped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The test is carried out according to**[10]** and the liquid limit values shown in Table -5-.

Table 5. Standard test method for liquid limit.

Sample no.1			
w = Water content, w%	4	7.8	12
No. of blows (N)	27	20	10
Liquid limit	5.10		
Sample no.2			
w = Water content, w%	1.8	4	7
No. of blows (N)	26	23	13
Liquid limit	2.2		
Sample no.3			
w = Water content, w%	2	6.2	9.2
No. of blows (N)	30	20	11
Liquid limit	4		

Particles shape

The particles shape of aggregates is determined by the percentages of flaky and elongation particles. According to [11] and [25] the following tests were:

Elongation index%:

Aggregate particles are classified as elongation when they have a length (greatest dimension) of more than 1.8 of their mean sieve size which are the grains with more than (21.6)mm length. The elongation index is found by separating the elongation particles and expressing their mass as a percentage of the mass of sample tested Table 6. The test is not applicable to material passing (6.30)mm sieve or retained on (50)mm sieve. [25]

E.I.= (weight of particles with length more than (21.6mm)/total weight of sample)*100

Flakiness index

Aggregate particles are classified as flaky when they have a thickness (smallest dimension) of less than 0.6 of their mean sieve size. The grains taken which their thickness are less than (7.2) mm. The flakiness index of an aggregate sample is found by separating the flaky particles and expressing their mass as a percentage of the mass of the sample tested. This test is not applicable to aggregate passing 6.30mm sieve and retained as 63.0 mm. sieve, according to [25], Table. 6.

M 1= sample weight(gm), M2= weight of grains with more than 21.6mm. length(gm).

M3= weight of grains with less than 7.2mm. thickness (gm).

F.I=(weight of particles with thickness less than (7.2 mm)/total weight of sample)*100

Table 6. Results of elongation and flakiness test.

Sample No.	M1	M2	M3	E.I.	F.I.
1	785	170	205	21.65	26.11
2	698	112	200	16.04	28.65
3	695	110	253	15.85	36.00

Mineralogical composition of gravel:

Two hundred gravel have been collected from each site of the studied area. This examination is performed on the pass 19.00mm retained on 9.5mm and should contain a minimum 200 particles Mineralogical Composition of gravel help in the study of resources rocks and in determination the distance of transportation of the sediment from the source to the basin of deposition. [18] and [26].

The gravel mostly composts of carbonate ,chert and quartz ,sandstone ,igneous and metamorphic, Table 7.

Table 7. Mineralogical composition of gravel.

Mineral Type	Carbonate	Chert & quartz	Sandstone	Igneous	Metamorphic	Others
Parentag_ Al-Mahzam	40	33	10	9	8	0

a. Aggregate impact value

This test is done based on [15] and [16]to determine the aggregate impact value of coarse aggregates. The apparatus used for determining aggregate impact value of coarse aggregates is Impact testing machine conforming to sieves of sizes: 12.5mm, 10mm and 2.36mm.

A cylindrical metal measure of 102mm dia. and 50mm depth, A tamping rod of 10mm circular cross section and 230mm length, rounded at one end and oven. Table 8. shows the test result values.

Table 8. The aggregate impact values.

Sample No.	1	2	3
Total weight of dry Sample (W_1 gm.)	375	398	341
Weight of portion passing 2.36 mm sieve (W_2 gm.)	26.50	39	30
Aggregate Impact Value (percent)= W_2/W_1X100	7.06	9.79	8.8

Classification of aggregates using Aggregate Impact Value is as given in Table 9.[27].

Table 9. Aggregate impact value classification.

Aggregate Impact Value	Classification
<10%	Exceptionally Strong
10 – 20%	Strong
20-30%	Satisfactory for road surfacing
>35%	Weak for road surfacing

b. Point load Test

This is an index test and is intended to be used to classify rock strength. Specimens in the form of rock cores, blocks, or irregular lumps with a test diameter from 30 to 85 mm can be tested by this test method. This index provides a method for establishing rock strength classification.[1] and [17]

The unconfined compression strength of the three samples are shown in Table 10.

Table 10. The result of point load test.

Sample No	Diameter (mm)	P KN	Is (MPa)	Corrected Is(MPa)	UCS (MPa)
1	25.2	7.1	11.18	8.21	197
2	27	7.6	10.42	7.89	189.3
3	30	8.52	9.47	7.6	182.4

2. Durability test

a. Loss angles test

Los Angeles test is commonly used to evaluate the hardness of aggregates. The aggregate used in surface course of the highway pavements are subjected to wearing due to movement of traffic. Therefore, the road aggregates should be hard enough to resist abrasion. Resistance to abrasion of aggregate is determined in laboratory by Los Angeles test machine. The test is carried out according to [12] on the sample of aggregate which is A class [18] and [19].

Table 11. are the values of the %loss which is suitable for sub base layer because it is less than 30% according to[13]

Table 11. Loss angles test result.

Sample No.	1	2	3
Original Weight (gm.) A	5000	5000	5000
Weight Retained on 1.7 (gm.) B	3663.6	3690.97	3522.4
Loss Angles% LA=(A-B/A)*100	26.72	26.18	29.55

b. Soundness test

The soundness test determines an aggregate's resistance to disintegration by weathering and freeze-thaw cycles. The soundness test repeatedly submerges an aggregate sample in a sodium sulfate or magnesium sulfate solution. This process causes salt crystals to form in the aggregate's water permeable pores. The formation of these crystals creates internal forces that apply pressure on aggregate pores and tend to break the aggregate. [14].. Six aggregate samples are subjected to five cycle of submerges of sodium sulfate solution and drying repetitions, the aggregate is sieved to determine the percent loss of material. Table 12. for fine aggregate and Table 13. for coarse aggregate according to [14].

Table 12. Soundness test for fine aggregate

Sample No.	Soundness
1	3.21
2	3.54
3	3.18

Table-13 -Soundness for coarse aggregate

Sample No.	Soundness
1	0.94
2	0.85
3	7.62

The chemical tests

Chemical properties determine the aggregate's solubility and reactivity. They also are a factor in weathering resistance.

The chemical tests included the organic matter content, pH value, total dissolved salts(TDS) and percentage of sulphate salt (%gypsum).

soil organic matter is defined as the organic fraction of the soil exclusive of undecayed plant and animal residues and is considered synonymous with humus. Schnitzer (2000) referred to soil organic matter as the sum total of all organic carbon- containing substances in the soil, which comprises of a mixture of plant and animal residues in various stages of decomposition, the organic content is the ratio, expressed as a percentage, of the mass of organic matter in a given mass of soil to the mass of the dry soil solids,[21]. Table 14.

Soil pH generally refers to the degree of soil acidity or alkalinity. Chemically, it is defined as the log10 hydrogen ions (H^+) in the soil solution. Table 13. and the total dissolves salts Total dissolved solids (TDS) is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular suspended form. Also percentage of sulfate salts(% gypsum) were determined Table 14 and the sulphate content usually refers to the total acid soluble sulphate content expressed as a percentage of SO_3 and methods for carrying out this are included in several British Standards for testing aggregates and related materials [19], [20] and [22]

Table 14. The chemical test results

SampleNo.	1	2	3
pH value	9.16	9.11	9.13
TDS%	1.35	1.38	1.27
Organic matter content%	0.2	0.13	0.17
Gypsum%	0.111	0.045	o.137

Discussion

The test result of the three samples of aggregates of Al-Mahzam for the grain size analysis shows that the aggregate samples are well graded with average specific gravity, %absorption and density are (2.615, 1.166 and 2.27) respectively and the density values for the samples show very closely values to each other because of the grain size distribution, and suitable to use for sub base course for class A for the sample No. one and No. three with a little deviation to the sample No. two in sieve size 4.75mm according to [7].

The liquid limit values are (5.10,2.2,4.0)which is low plasticity for fine particles according to[10] .

Elongation and flakiness are (21.65, 16.04, 15.85) and (26.11, 28.65, 36.00) respectively. It is found that the carbonate gravel forming the high percentage of the mineral composition, also the limestone gravel are of different types such as dolomite, chalky limestone and calcite, which indicate different sources of limestone derived from the older carbonate formations. The chert and quartz gravels are more abundance in Al-Mahzam mostly with dark colors and well rounded. The source rocks of chert and quartz are mostly derived from the older formations such as Mugdadia and Bi-Hassan. The igneous and metamorphic gravels also present in the Quaternary gravel with less percentage and mostly derived from the older detrital formations such asAl- Fatha and Injana.

The aggregate impact value are (7.06, 9.79 and 8.8) according to the aggregate classified to exceptionally strong and for compressive strength which is taken from the point load test are (197,189.3 and 182.4) according to Hawkins classification [28] is very strong. Durability tests(Loss Angeles Test) results shows that the weight loss for the three samples are (26.72, 26.18 and 29.55) which is suitable to use according to [12] and[13] that must not exceeds %45 for sub base and 30% for base. Also soundness test result show the weight loss for the fine aggregate are (3.21, 3.5 and 3.18) and for coarse aggregate are (0.94, 0.85 and 0.62) which is suitable to use in sub base and base road works. The chemical test included organic matter content were (0.2, 0.13 and 0.17), pH value are (9.16, 9.11 and 9.13), also TDS values are 1.35, 1.38 and 1.27) , Calcium sulfate occurs as a white odorless powder or as crystals that may be tinged with color by impurities. and is only slightly soluble in water, gypsum % content in the aggregate samples are (0.1119, 0.045 and 0.137).

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تحليل الخصائص الجيوتكنيكية للركام في منطقة المحزم وتقييم استخدامها لأغراض الطرق

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الملخص

تهدف البحث الى دراسة الخصائص الجيوتكنيكية للركام في منطقة المحزم في مدينة تكريت/ محافظة صلاح الدين حيث تعود الركام الى ترسبات العصر الرباعي ,تم جمع النماذج من ثلاث مواقع على الضفة الغربية لنهر دجلة لغرض دراسة الخصائص الفيزيائية والكيميائية والمقاومة و الديمومة.

بينت نتائج الفحوصات الفيزيائية من خلال فحص التدرج الحبيبي بان الركام جيد التدرج وملائم لاستخدامها في اعمال الطرق لطبقة ما تحت الاساس ومن صنف (أ) مع وجود انحراف قليل في النموذج الثاني لحجم(4.74) وتم فحص الوزن النوعي والكثافة للنماذج وكذلك نسبة الامتصاص تتراوح قيمها (0.2–0.7),اما بالنسبة للتركيب المعدني يتكون الركام من الحصى الكاربونية ,(37-41.5) % و الحجر الرملي (14–17)% وحجر الصوان والمرو (22–33)% اما الصخور النارية تكون (7–8)% والصخور المتحولة. أصل الحصى غالبا مشتق من التكاوين الاقدم المكشفة في المنطقة مثل انجانة, وبلغت حد السيولة(5.10,2.2,4) % اما حد اللدونة يساوي صفر اي النماذج غير لدنة.

قيمة معامل الاستطالة ومعامل الترقق بلغت (21.65,16.04,15.85) و(26.11,28.65,36.00) على التوالي. اما بالنسبة لفحوصات المقاومة بينت فحص مقاومة الصدم (AIV) (7.06,9.79,8.8)% وقيمة المقاومة الانضغاطية والمشتقة من فحص حمل النقطة كانت (197,189.3,182.4)MPa. نتائج فحوصات الديمومة المتمثلة بفحص لوس انجلوس كانت (26.72,26.18,29.55)% وملائمة لاستخدامها في اعمال الطرق لطبقة ما تحت الاساس. ونتائج فحص الثبات كانت تتراوح بمعدل للركام الخشن والناعم (0.62–3.54)%. وكانت ضمن المواصفة وملائمة لطبقة ما تحت الاساس حسب المواصفة العراقية والمواصفة الامريكية .

اما بالنسبة لفحوصات الكيميائية فان القيم لمحتوى المادة العضوية وقيمة الاس الهايدروجين ونسبة الاملاح الكلية القابلة للذوبان ونسبة الاملاح الكبريتية كانت ضمن المواصفة وملائمة للاستخدام لاعمال الطرق في طبقة تحت الاساس.

كلمات الدالة: الركام ، الخواص الجيوتكنيكية ، المحزم ، استخدامه كطبقة ما تحت الاساس .