Qualitative assessments of Sub-base deposits of Dibdiba formation and determine their suitability for construction and engineering purposes in selected quarries at Karbala governorate/ middle of Iraq

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Abstract

In this geotechnical study a qualitative assessment was made on the Sub-base deposits of the Dibdiba Formation from selected quarries in Karbala Governorate, central Iraq. Where 4 quarries were selected and 6 samples were taken from each quarry, bringing the total number of samples studied to 24. Physical tests such as (grain size analysis, CBR% test, Modified proctor compaction test, Atterberg limits test, and scraping ratio test ) were performed, as well as chemical tests such as ( sulfate content SO3%, gypsum percentage CaSO4.2H2O% test, Total soluble salts%, and organic matter% test ) and the results showed that the Sub-base deposits in Dibdiba Formation in the study area falls under the class (B) according to the general specification for roads and bridges (SORB / R6,1999). The chemical tests of the studied models showed that the percentage of harmful substances is very low and that the studied Sub-base deposits are very good in terms of suitability for use for construction, engineering and road works. It is worth noting that the results of the scraping ratio test were very close, and therefore this indicates that the origin of these deposits studied is from one source.

Keywords : Geotechnical study, Physical properties, Grain size analysis, Sub-base

Introduction

Geotechnical studies are very important to know the validity of natural materials such as sub base, gravel and sand for various construction purposes. Where in this research a qualitative assessment of the sediments of Dibdiba Formation in Karbala Governorate was carried out . These sediments are represented by deposits of pebbly sandstone ( sub-base deposits ), it's mixture of fine and coarse aggregates ( sand and gravel ) and little amount of silt and clay ( Hassan, 2004 ) , which are an important materials in various construction and engineering works such as road works, sub-base works and concrete works . The necessary geotechnical tests were carried out on these deposits and the results of these tests were compared with the limits of international and Iraqi standards to reach the suitability of these deposits (sub-base deposits) for construction and engineering works.
The study area

The study area is located within the Karbala governorate in central Iraq and lies about 40 km south-west from the city of Karbala and includes the quarrying sites near the Al-Ukhaidir area, as well as the quarries adjacent the Al-Ukhaidir-Nukhayeb road within Wadi Al-Abyadh as in Fig. (1), where the study included Four quarry sites, as follows:

1- Location (M1) with coordinate: (32° 26' 37.57” N – 43° 37’ 42.51” E) (55 m elevation).

2- Location (M2) with coordinate: (32° 25' 57.74” N – 43° 40’ 49.06” E) (49 m elevation).

3- Location (M3) with coordinate: (32° 26' 51.24” N – 43° 40’ 33.39” E) (48 m elevation).

4- Location (M4) with coordinate: (32° 27' 56.07” N – 43° 39’ 06.84” E) (58 m elevation).

Fig. 1: Location of study area
Methodology

Stage of Data Acquisition

At this stage, all available data about the study area were collected, such as published research, scientific reports, theses, papers, and all previous studies related to the study of engineering and geotechnical properties of the study area quarries. Also, all available geological and topographical maps and satellite images were collected for the study area.

Stage of Field Work

A field trip was conducted to the study area and the quarries of the construction materials spread on both sides of Wadi Al-Abyadh were identified, and four of them were selected to conduct a qualitative assessment of sub-base deposits. The four quarries were chosen on the basis of the difference as much as possible in the type of deposits used in the construction materials extracted from them, as most of the quarries in the study area are similar in terms of the quality of the materials due to the near lack of lateral variation in the layers of geological formations in the studied area, and the coordinates of these quarries were determined by GPS device and its height above sea level was also determined. The field study of these selected quarries included examining the quality of the sediments extracted from them and determining the formations targeted for the production of these sediments. It was found that the sediments extracted in general are pebbly sand (sub-base deposits) and that the target layers for their extraction are the layers of the Dibdiba formation. The field trip to the study area consisted of collecting 24 samples from these four selected quarries to conduct geotechnical laboratory tests on them. Six samples were collected from each quarry, and these samples were collected in a way that completely covers the area of the quarry taken from it.

Stage of Laboratory

This part of the study includes conducting geotechnical laboratory tests for sub-base deposits samples that taken from selected quarries within the study area and comparing the results of these tests with the Iraqi and international standard specifications to find out the suitability of these deposits for engineering work as following:

A- Physical Tests:

1- Grain Size Analysis

Grain size analysis is considered one of the most important physical analyzes to study the geotechnical properties of construction materials and soil as well. This analysis is represented by separating grains with diameters greater than (0.074 mm) by a set of standard sieves whose sizes vary between a sieve with a hole measuring (3 inches) or equivalent to (75) mm to a sieve No. (200) which is the sieve that has a...
hole (0.075 mm). This analysis was carried out in the laboratories of the Department of Applied Geosciences at the College of Science at the University of Babylon and in accordance with the General Standard for Roads and Bridges (SORB / R6,1999).

2- Californian bearing ratio test (CBR)

It is a test used to find the carrying strength of soil as a natural ground for paving work. And its value can be calculated laboratory from knowing the force required to insert a standard piston inside the sample to be examined for a certain distance to the force needed to insert the same piston and at the same distance within a standard sample. The value of the CBR ranges between (0 - 100). This examination was carried out in the construction laboratory of Maysan Governorate, according to the general specification for roads and bridges (SORB / R6,1999).

3- Modified proctor compaction test

Compaction occurs in soil after subjecting it to pressure that results in rearrangement of the grains under a certain water content. The main purpose of conducting a soil compaction test is to find the maximum dry density (\( \gamma_d \text{ max} \)) and also to find the corresponding optimum moisture content (OMC) as in Fig. (2). Where the optimal water content is a separating boundary, so if the water content is less than the optimal water content, the soil will be rough and difficult to compact and the spaces between the grains are large and thus the dry density will decrease, while if the water content is greater than the optimum water content, the grains of soil will slip and diverge, thus reducing dry density as well. This test was carried out in the laboratories of the Department of Applied Geology at the College of Science at the University of Babylon according to the modified Proctor test and according to the American standard (ASTM D 698.78).

![Fig. 2](image)

Fig. 2: shows the typical curve of the compaction and its relationship to the saturation line.

4- Atterberg Limits tests

Test of the Atterberg limits is an important physical test in the geotechnical evaluation, where the liquid limit (LL) is found, which represents the lowest water
content in which the sample is in a viscous liquid form and does not have any plasticity, and also the plasticity limit (PL) is found, which represents the water content in which the sample is transformed from the plastic to the semi-solid state and then compared to the limits of the required specifications to find out the suitability of the samples for the engineering and construction purposes for which they were tested for (Al-Hamdani, 2004). This test was carried out in the laboratories of the Department of Applied Geology at the College of Science at the University of Babylon, according to the American standard (ASTM D 4318-84).

5- Scraping ratio Test (Los Angeles Test)

According to (ASTM, 2004), this test includes knowledge of the extent of hardness and abrasion resistance and friction of the outer surface of the grains of natural aggregates, which is that qualitative evidence of the sources of aggregates different, which is similar in chemical composition, and this test carried out by using the Los Angeles device. This test was performed in the construction laboratory of Maysan Governorate and in accordance with the General Standard for Roads and Bridges (SORB / R6,1999).

B- Chemical tests:

The chemical tests of the sub-base samples were carried out by three samples from each of the four quarries. All the chemical tests of the samples were carried out in the laboratories of the Ministry of Science and Technology in Baghdad - Iraq as follows:

1- sulphate content (SO3 %)

From this test, the percentage of sulfur salts within the sub-base, gravel and sand is determined. This examination is one of the important chemical tests in the qualitative evaluation of construction materials, as sulfur salts have a negative and harmful effect that may lead to the failure of this aggregate and not to use it as a construction material if the percentage of sulfur salts is high and not within the standard specifications. And the British Standard (B.S 1377) was approved.

2- Gypsum content (CaSO4.2H2O %)

The gypsum mineral is considered to be one of the moist sulfuric salty minerals that are commonly found within the quarries of construction materials. Therefore, this test is to know the percentage of this mineral's presence in the aggregate of all kinds. The percentage of gypsum can be extracted mathematically by multiplying the sulfate percentage * (2.15%).

3- Total soluble salts %

Test of the content of total soluble salts is very important in the qualitative evaluation of construction materials. The presence of a high content of these salts
leads to the failure of these materials as construction materials, as these salts, after dissolving, leave large gaps, thus this affects the quality of these materials for construction uses. And this examination was done according to the American standard (ASTM - Earth Manual).

4- Organic Content %

The high percentage of organic impurities in the aggregates leads to a weakness in the mixture used in concrete, and because the basic material for the selected quarries is sub-base, which the various construction materials such as gravel (coarse aggregate) and sand (fine aggregate) are separated from it, and because these materials enter among the basic components within concrete, it was found that conducting this test is necessary within the study of the geotechnical properties of the samples taken from the quarries selected in this study, and according to the and on the basis of which this test was carried out, the organic impurities percentage should not increase more than 2%.

Results and discussion

Results and discussion of physical tests

1- Grain size analysis

The grain size analysis of the samples taken from the four selected quarries in the study area, was performed by (6) samples from each quarry, and the results of the analysis shown in Table (1) and also in Fig. (3) and Fig. (4). The gradation of grain size of the four quarries is clearly converging, as the four quarries can be included in Class (B) when compared with the limits of the required standard specification (SORB/R6, 1999).

2- Californian bearing ratio test (CBR)

The results of the (CBR) showed that the first, second and third quarries were close in results, but a relatively high was observed in the results of the fourth quarry, as shown in Table (2) and Fig (5). The results of all four quarry models fall within the acceptable limits depending on the general specification for roads and bridges (SORB/R6, 1999), where the minimum carrying value for the four quarry models was equal to 36% while the required specification limits require that the minimum bearing value is 35% for the class (B) and it is the class of false aggregate, under which most of the studied samples have been included according to the results of grain size analysis, and out of the total of all four samples of (24) only two of them fall into class (A), and these two samples according to this class are unnecessary to take this test on them.

3- Modified proctor compaction test

Table (3) shows the results of the Modified proctor compaction test of the four quarry models, where it can be observed that the highest dry bulk density is within the
fourth quarry and is estimated at \((2,273 \text{ g} / \text{cm}^3)\) and therefore the lowest optimum water content is for the same quarry with an estimated value of \((4.8 \%)\). While the lowest value of the maximum dry density was within the third quarry at a rate estimated at about \((2,257 \text{ g} / \text{cm}^3)\), and thus the highest value of the optimum water content of the same quarry corresponds to a value of about \((5.8\%)\). It is worth noting that the results of this test of the studied quarries (the first, second and third) are close due to the convergence of the volumetric gradient and the proportions of fine materials, but a slight deviation is observed in the values of the fourth quarry. Fig. (6) shows the curves of the maximum dry density and the optimum water content of some samples of the four quarries.

3- Atterberg Limits tests

Table (4) and Fig. (7) shows the results of examining the Atterberg limits for the samples of the studied quarries. It can be observed that the results values of the four quarries are very close to each other due to the convergence in the gradation of the grain size of the materials of those quarries, but a relative increase in the values of the limits of plasticity in the fourth quarry can be observed as it is estimated at \((3.6)\) It is the highest plasticity limit for all four quarries and this is due to the relative increase in the proportions of soft materials in that quarry. The results obtained were compared with the limits of the required American standard (ASTM D 4318-84). As it can be noted, the results values fall within the acceptable limits of the standard.

4- Scraping ratio Test (Los Angeles Test)

The results of the test shown in Table (5) showed that all the studied samples are within the acceptable limits of the General Standard for Roads and Bridges (SORB / R6,1999), and that the highest percentage of scraping ratio (abrasion) was recorded in the second quarry models and just \((34.83\%)\) and the lowest value of the scraping ratio (abrasion) was recorded in the fourth quarry at a rate of \((24.5\%)\) and the reason for this is due to the hardness of the outer surface of the grains of the samples in this quarry.

**Tab. 1:** Show grain size analysis results.

| Sieve size | Grain size results for each quarry (Average of the 6 samples of each quarry) | The required specification for the class (SORB/R6, 1999) |
|------------|--------------------------------------------------------------------------------|---------------------------------------------------------|
|            | Quarry 4 | Quarry 3 | Quarry 2 | Quarry 1 | B | A | inch | mm |
| 100        | 100      | 100      | 100      | ---      | 100 | --- | 100  | 75  |
| 100        | 100      | 100      | 100      | 100      | --- | 100 | 100 - 95 | 2  | 50  |
| 72.08      | 85.22    | 83.33    | 77.86    | 95 -75   | --- | 100 | 2    | 25  |
| 61.33      | 66.32    | 67.72    | 58.09    | 75 -40   | 65 -30 | 38  | 9.5 |
| 49.14      | 54.48    | 45.87    | 47.81    | 60 -30   | 55 -25 | No. 4 | 4.75 |
| 39.2       | 42.58    | 33.51    | 38.78    | 47 -21   | 42 -16 | No. 8 | 2.36 |
| 11.25      | 15.49    | 14.61    | 15.21    | 28 -14   | 18 -7  | No. 50 | 0.3 |
| 4.01       | 5.47     | 5.1      | 5.36     | 15 -5    | 8 -2   | No. 200 | 0.075 |
Fig. 3: Diagram representing the relationship between average grain sizes of the Sub-base samples of the studied quarries.

Fig. 4: Histogram representing the gradient curves of the Sub-base samples of the studied quarries.

Tab. 2: Show CBR test results.

| Quarry No. | Quarry 4 | Quarry 3 | Quarry 2 | Quarry 1 |
|------------|----------|----------|----------|----------|
| (CBR%)     | Sample No.| (CBR%)   | Sample No.| (CBR%)   | Sample No.| (CBR%)   | Sample No.|
| 44         | 1         | 39       | 1         | 37       | 1         | 37       | 1         |
| 45         | 2         | 40       | 2         | 36       | 2         | 37       | 2         |
| 45         | 3         | 40       | 3         | 36       | 3         | 38       | 3         |
| 45         | 4         | 39       | 4         | 37       | 4         | 37       | 4         |
| 44         | 5         | 40       | 5         | 36       | 5         | 38       | 5         |
| 45         | 6         | 39       | 6         | 36       | 6         | 37       | 6         |
| 44.66      | Aver.     | 39.5     | Aver.     | 36.33    | Aver.     | 37.33    | Aver.     |
Fig. 5: Diagram shows the relationship between the four quarries and CBR %.

Fig. 6: shows the curves of the maximum dry density and the optimum water content of some samples of the four quarries.

Tab. 3: Show the results of Modified proctor compaction test.

| Quarry No. | Sample No. | Maximum dry density (g/cm$^3$) | Optimum Water Content % |
|------------|------------|-------------------------------|-------------------------|
| 1          | 6 2.268    | 5.4                           |                         |
|            | 5 2.268    | 5.4                           |                         |
|            | 4 2.269    | 5.3                           |                         |
|            | 3 2.267    | 5.5                           |                         |
|            | 2 2.271    | 5.3                           |                         |
|            | 1 2.269    | 5.4                           |                         |
| 2          | 6 2.263    | 5.6                           |                         |
|            | 5 2.263    | 5.6                           |                         |
|            | 4 2.264    | 5.6                           |                         |
|            | 3 2.262    | 5.7                           |                         |
|            | 2 2.265    | 5.7                           |                         |
|            | 1 2.263    | 5.6                           |                         |
| 3          | 6 2.257    | 5.8                           |                         |
|            | 5 2.259    | 5.8                           |                         |
|            | 4 2.258    | 5.7                           |                         |
|            | 3 2.258    | 5.9                           |                         |
|            | 2 2.259    | 5.8                           |                         |
|            | 1 2.257    | 5.9                           |                         |
| 4          | 6 2.273    | 4.8                           |                         |
|            | 5 2.275    | 4.9                           |                         |
|            | 4 2.274    | 4.7                           |                         |
|            | 3 2.273    | 4.8                           |                         |
|            | 2 2.275    | 4.9                           |                         |
|            | 1 2.273    | 4.7                           |                         |
Tab. 4: Show the results of Atterberg limits (Liquid limit and plasticity limit).

| Quarry No. | Sample No. | Plasticity limit (P.L.) | Liquid limit (L.L.) | Sample No. | Plasticity limit (P.L.) | Liquid limit (L.L.) | Sample No. | Plasticity limit (P.L.) | Liquid limit (L.L.) | Sample No. | Plasticity limit (P.L.) | Liquid limit (L.L.) | Sample No. | Plasticity limit (P.L.) | Liquid limit (L.L.) |
|------------|------------|-------------------------|--------------------|------------|-------------------------|--------------------|------------|-------------------------|--------------------|------------|-------------------------|--------------------|------------|-------------------------|--------------------|
| 1          | 1          | 2                       | 22                 | 1          | 2                       | 2                  | 2          | 2                       | 22                 | 2          | 2                       | 22                 | 2          | 2                       | 22                 |
| 2          | 2          | 2                       | 23                 | 2          | 3                       | 2                  | 3          | 3                       | 23                 | 3          | 3                       | 23                 | 3          | 3                       | 23                 |
| 3          | 3          | 2                       | 24                 | 3          | 2                       | 2                  | 2          | 2                       | 24                 | 2          | 2                       | 24                 | 2          | 2                       | 24                 |
| 4          | 4          | 2                       | 25                 | 4          | 4                       | 4                  | 4          | 4                       | 24                 | 4          | 4                       | 24                 | 4          | 4                       | 24                 |
| 5          | 5          | 2                       | 26                 | 5          | 3                       | 3                  | 3          | 3                       | 23                 | 3          | 3                       | 23                 | 3          | 3                       | 23                 |
| 6          | 6          | 2                       | 27                 | 6          | 4                       | 4                  | 4          | 4                       | 22                 | 4          | 4                       | 22                 | 4          | 4                       | 22                 |
| 7          | 7          | 2                       | 28                 | 7          | 3                       | 3                  | 3          | 3                       | 21                 | 3          | 3                       | 21                 | 3          | 3                       | 21                 |
| 8          | 8          | 2                       | 29                 | 8          | 4                       | 4                  | 4          | 4                       | 21                 | 4          | 4                       | 21                 | 4          | 4                       | 21                 |
| 9          | 9          | 2                       | 30                 | 9          | 3                       | 3                  | 3          | 3                       | 22                 | 3          | 3                       | 22                 | 3          | 3                       | 22                 |
| 10         | 10         | 2                       | 31                 | 10         | 4                       | 4                  | 4          | 4                       | 22                 | 4          | 4                       | 22                 | 4          | 4                       | 22                 |

Fig. 7: Shows the results Atterberg limits tests for the samples of the studied quarries.
Tab.5 : Show the results of Scraping ratio Test for the samples of the studied quarries.

| Quarry No. | Acceptable standard limits |  |  |  |  |
|------------|----------------------------|---|---|---|---|
|            | Scarping rate % | Sample No. | Scarping rate % | Sample No. | Scarping rate % | Sample No. | Scarping rate % | Sample No. |
| 4          | 24 | 1 | 29 | 1 | 36 | 1 | 32 | 1 |
| 3          | 25 | 2 | 28 | 2 | 34 | 2 | 31 | 2 |
| 2          | 25 | 3 | 30 | 3 | 35 | 3 | 31 | 3 |
| 1          | 24 | 4 | 29 | 4 | 34 | 4 | 30 | 4 |
| 6          | 25 | 5 | 28 | 5 | 36 | 5 | 31 | 5 |
| 24.5       | Aver. | 28.83 | Aver. | 34.83 | Aver. | 31.16 | Aver. |

Results and discussion of chemical tests

1- Sulfate content S03% test

It appears in the results shown in Tab. (6) that the sulfate content S03% in the four quarry samples is excellent in terms of chemical evaluation, as it is considered small percentages, despite the relative increase in the sulfate content of the fourth quarry, but it is still within the limits of the required British standard (BS 1377), therefore, the samples are suitable for construction and engineering works.

2- Gypsum content CaSO4.2H2O% test

Tab. (6) shows that the results of examining the percentage of gypsum% CaSO4.2H2O in the studied models of the four quarries are good ratios in terms of chemical evaluation of the studied material, as they are considered very low, and if there is a slight increase in the percentage of gypsum in the fourth quarry, it is within the acceptable limits for construction work. Engineering.

3- Total soluble salts %

Tab. (6) which displays the results of the chemical tests, shows that the percentage of total soluble salts is a low and acceptable percentage as it falls within the permissible limits of the required American standard specification (ASTM - Earth Manual). Thus, the examined samples of the studied quarries are considered suitable for construction and engineering.

4- Organic materials content %

The results of the chemical tests of the studied quarry models shown in Tab. (5) show that the percentage of organic materials in these models is very low and meets the limits of the required British specification (BS 1377) and excellently as the highest percentage of organic materials was in the second quarry models. At a rate estimated at about (0.02%), which is almost negligible, so that the models are suitable for construction and engineering works.
Tab. 6 : Show the chemical tests of the studied quarry samples .

| Acceptable standard limits | Samples No. | Quarry No. | Chemical tests |
|----------------------------|-------------|------------|----------------|
|                            | Aver. | 3 | 2 | 1 |  |
| 5% is the maximum limit according to (BS 1377) | 0.27  | 0.26  | 0.28  | 0.29  | 1  |
|                            | 0.99  | 0.97  | 1.08  | 0.92  | 2  |
|                            | 0.65  | 0.63  | 0.67  | 0.65  | 3  |
|                            | 1.34  | 1.35  | 1.36  | 1.32  | 4  |
| 10.75% is the maximum limit according to (BS 1377) | 0.594 | 0.559 | 0.602 | 0.623 | 1  |
|                            | 2.128 | 2.085 | 2.322 | 1.978 | 2  |
|                            | 1.397 | 1.354 | 1.44  | 1.397 | 3  |
|                            | 2.888 | 2.902 | 2.924 | 2.838 | 4  |
| 10% is the maximum limit according to (ASTM - Earth Manual) | 4.48  | 4.47  | 4.53  | 4.45  | 1  |
|                            | 3.18  | 3.15  | 3.21  | 3.18  | 2  |
|                            | 5.31  | 5.34  | 5.29  | 5.31  | 3  |
|                            | 3.92  | 3.89  | 3.96  | 3.92  | 4  |
| 2% is the maximum limit according to (BS 1377) | 0.017 | 0.018 | 0.017 | 0.018 | 1  |
|                            | 0.020 | 0.020 | 0.019 | 0.021 | 2  |
|                            | 0.013 | 0.013 | 0.014 | 0.012 | 3  |
|                            | 0.016 | 0.015 | 0.017 | 0.016 | 4  |

Conclusions and recommendations

1 - It was concluded that the sub-base deposits in the studied quarries are well graded and fall into the class (B) according to the general standard for roads and bridges (SORB / R6/1999).

2- A convergence can be observed in the results of the chemical and physical tests. It can be said that this convergence is due to the absence of lateral measures in the layers of geological formations in the studied area.

3- Converging values can be observed in the results of the examination of mechanical abrasion in the deposits grains in the studied samples, and this is evidence that the origin of these deposits is from the same source.

4- The results of the chemical tests show very low percentages of harmful substances such as salts, sulfates, and organic materials and the percentage of gypsum, and thus they are chemically excellent from a geotechnical point of view.

5- It was concluded that the deposits of materials extracted from the quarries selected in this study are considered good and suitable for use in engineering and construction works and are very suitable for road works as well.

6- We recommend using the materials of these quarries them in the construction and engineering operations, as they are very good materials for these purposes, and also conducting detailed mineralogical studies to know the possibility of economically exploiting the minerals in these quarries and also studying the clay materials contained in these quarries.
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