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Research Article
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Investigation of Maghra Al Hadida Formation as Coarse Aggregate, Gabel Shabrawet, Northeastern Desert, Egypt

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Abstract

The increase in the development of the construction projects in Egypt during the last few years has increased the need for large quantities of concrete aggregates. The common types of aggregates such as natural and industrial gravel, which were widely used for a long time in many projects, became in severe shortage and were unavailable in many parts of our country. Moreover, the transport of high quality aggregates from far quarries was found impractical and costly. Many types of aggregates composed from carbonate or basaltic rocks became widely used.

In the present study, the physical, Geomechanical and chemical properties of Maghra Al Hadida Formation at Gabel Shabrawet were investigated. Bulk specific gravity (SSD), water absorption, sieve analysis, Los Angeles abrasion test, soundness, clay lump and friable particles, flakiness and elongation, XRD and DRF indices of coarse aggregate were evaluated and suitable for road construction and concrete industry. Nearly all the samples were found within the specified limits of ASTM specifications and are appropriate material for concrete, asphalt and suitable as dimension stone.

Keywords: Maghra al hadida; Aggregates; Physical; Geomechanical and chemical properties

Introduction

The Egyptian government and the private sectors have moved toward the new area by establishing lots of new road networks, different types of projects (industrial zones, new urbanization areas e.g. (New Cairo, 6th October) cities and agricultural activities). This will increase the ability of the country to advance and develop. However, these areas were the main source of the aggregate materials that represent a backbone for the infrastructures in the area (road construction and concrete industry). Accordingly, a decrease in the aggregate production could be a serious problem if there is no other source for these important materials have been detected and located. In Egypt, natural aggregates are widely distributed with a huge range of potential sources, that of low-cost products and they play an important role in the growth of the Egyptian economy. These aggregates were produced from quarries or from natural aggregate sources. More than 95% of asphalt pavement materials (by weight) consist of mineral aggregates and 60-70% of concrete ere from mineral aggregates. This paper focuses on suitability of aggregates of Magra El Hadida Formation at Gabel Shabrawet in asphaltic mixtures and concrete depending on their physical, mechanical, and mineralogical properties. This subject is a challenge in Egypt and needs intensive effort to end up with the Egyptian aggregate formulation.

This will help for managing Urban Development as most of the aggregates have been excavated and used in the last few decades.

Characters of selected formation

The present study deals with an area lies in the Northeastern Desert, between latitudes 29°48 and 30°17`N and longitudes 32°15`and 32°28`E (Figure 1).

A conspicuous relief in which the strata in its southern parts are highly tilted and rise abruptly with respect to the surrounding plateau characterizes Gabal Shabrawet. It is limited between latitudes 30°14`22`` and 30°17`N and longitudes 32°15` and 32°18`E (Figure 1). The highest peak has an elevation of about 226 m above sea level and is located in the central part of the area.

In the Eastern Desert, the Cretaceous has the widest extent from away the Mesozoic System. On the other hand, the Cretaceous is conformably overlain by the Lower Eocene (Quseir-Safaga area) or unconformably by Middle Eocene (Ataqa and Shabrawet areas).

This formation was named by El-Akkad and Abdallah [1]. Its name derives from Wadi Maghra El-Hadida at the southeastern corner of Eastern Desert (Gabal Shabrawet). This formation consists of 120.5 m thick mainly of hard dolomitic limestone and dolomite with alternating beds of white limestone, varicolored marls and sandstones. At Gabal Shabrawet, the Maghra El-Hadida Formation conformably overlies the Cenomanian “Galala Formation”. The contact is between the creamy, fine-grained dolomite of the uppermost Galala Formation and the creamy dolomitic limestone of the lowermost part of the Maghra El-Hadida Formation. The contact in some places is sharp while in other places is gradational (Figure 2).

Rocks of the Maghra El-Hadida Formation at Gabal Shabrawet areas are mostly unfossiliferous; hence, the age of this formation is assigned on the basis of its stratigraphic position. As the formation shows conformable contacts above the Cenomanian “Galala Formation” and below the Santonian-Campanian Maghra El-Bahari Formation. So the Maghra El-Hadida was attributed to belong to the Turonian age; this is in harmony with the opinion of El-Akkad and Abdallah [1].

Materials and Methods

The studied aggregate samples were subjected to several tests to determine their physical and mechanical properties. To study the

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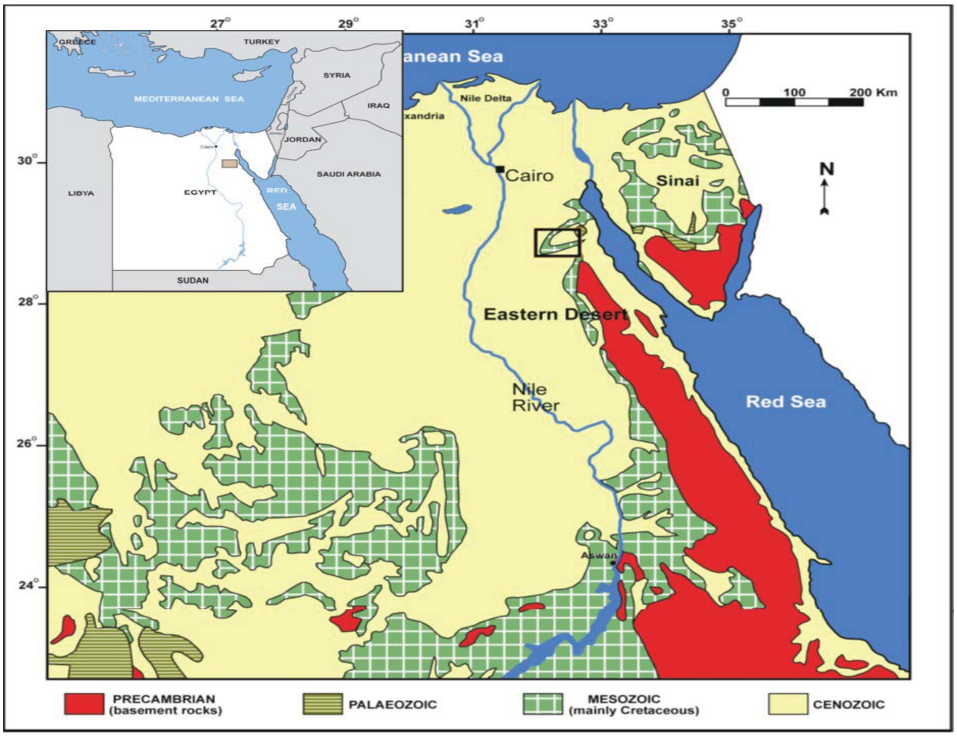

Figure 1: Geological map of Egypt [33]. The rectangle indicates the study area.

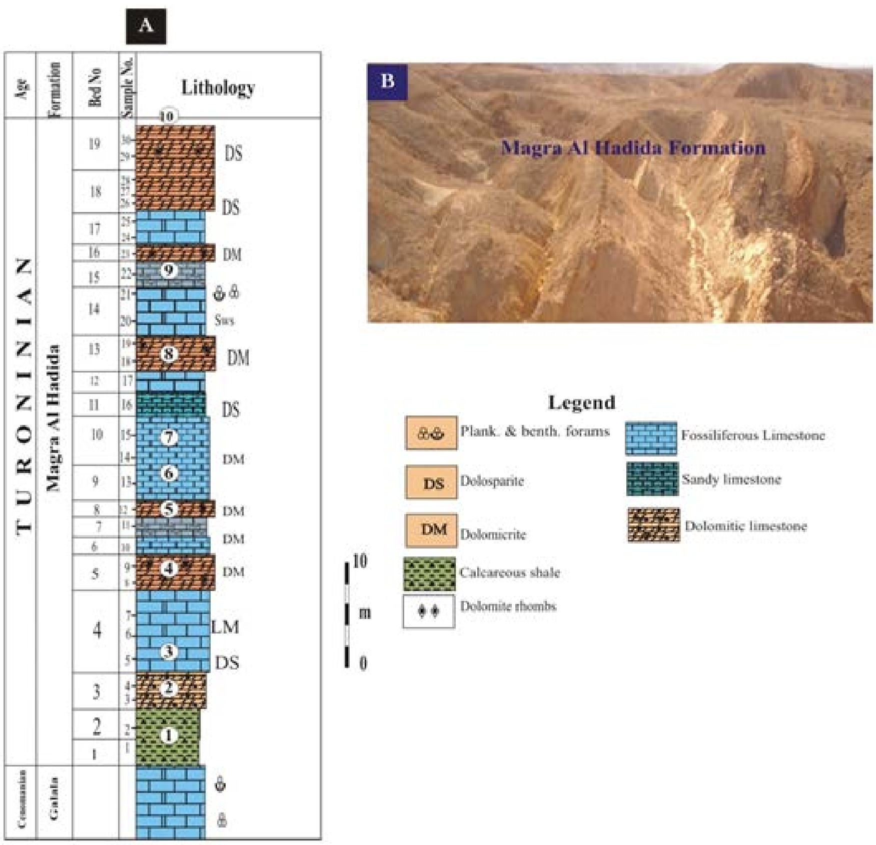

Figure 2: Stratigraphic columnar section of the Turonian Magra Al Hadida Formation (A) Field view of Magra Al Hadida formation (B) At G Shabrawet section.

properties of Maghra El-Hadida aggregates, samples were collected from Gabal Shabrawet area. Approximately 30 kg of fresh piece of rock samples were collected as per ASTM D 75 [2] specification. Specific standard methods of ASTM were adopted for the investigation of properties like bulk saturated surface dry (SSD), water absorption, sieve analysis, Los Angeles abrasion test, soundness, clay lump and friable particles, flakiness and elongation indices [3-9]. Flakiness and elongation Index of an aggregate can be estimated by measuring ratios between length, width and thickness. The Flakiness index is measured with the help of sieve while Elongation Index is assessed with the help of caliper devise [10-14].

Results and Discussion

Petrographic study

Petrography is the systematic study of rock specimens in thin-section. It is an integral part of material science, widely used to assess and classify aggregate for civil works, under ASTM C295 [15] specifications. The petrographic study plays a supportive role in order to assess the results and interpretation of other tests (New York State Department of Transportation Materials Bureau). It is a very essential parameter to infer about the composition of an aggregate. The study can be used to identify weak and reactive minerals, known to be linked with poor performance of aggregate [16]. During the petrographic study, examination of weathered and altered particles of the aggregate is also intended. Joints, cracks and other fracture are noticed during petrographical observations on microscopic level [17].

The petrographical examination of several representative gravel grains of the studied samples under the polarized light microscope illustrated that the studied gravel grains were mainly composed of very hard crystalline dolomitic limestone. The petrographic examinations and mineralogical tests showed that the particles, that looked different, had the same mineralogical composition such as Shabrawet aggregates.

Dolomicrite

The dolomicrite lithofacies has usually common occurrence in the Galala Formation at Shabrawet area with an average thickness of 3.9 m (Figure 3A). It also occurs in the Maghra El-Hadida Formation at Shabrawet areas and attains an average thickness of about 12.8 m (Figure 2). This lithofacies commonly overlies the lime mudstone, dolomitic marl and always underlies the dolosparite lithofacies with a gradational contact. Petrographically, the rock is essentially made up of dolomite rhombs (70-80%) with micritic to microsparite calcite crystals (8%) (Figure 3B). The rhombs are closely packed exhibiting xenotopic and hypidiotopic texture with an equigranular fabric. Most of the rhombs contain a dark core of opaque iron oxides with thin clear outer rim. Another type of dolomite rhombs is present usually coarser than the above. They have hypidiotopic texture with inequigranular fabric, the zoning is expressed by small dark core of iron oxide with clear outer rim.

Dolosparite: It represents the most abundant lithofacies that occurs at the Maghra El-Hadida Formations at Shabrawet areas. It always overlies the lime mudstone and dolomicrite lithofacies. This lithofacies has an average thickness of about 3.0 m at Shabrawet area.

In hand specimen, the rock is generally yellow to pale yellow in colour, massive, thin bedded, hard to medium hard and forming ledges. In thin-section, this lithofacies is composed essentially of dolomite (70-90%), blocky calcite (10-20%), quartz grains (1-3%), shell fragments <4%, and iron oxides (Figure 3C). The dolomite is hypidiotopic to idiotopic texture with inequigranular fabric. The zonal arrangement of dolomite rhombs consists of dark core iron oxide scattered with random orientation, and some of these rhombs show a cloudy surface without any core (Figure 3D).

The aggregate particles displayed weak to no effervescence upon application of dilute HCl which indicates that the sample is likely composed mostly of dolomite. Masses of anhedral to subhedral dolomite crystals are found with no original limestone textures and fossils preserved (Figure 3D and E).

XRF test results: The oxides contents for the series of considered aggregates were measured using XRF technique; the results are listed in Table 1. The XRF results were found consistent with those of the thin section findings and helped to verify the mineralogical composition for the tested aggregates.

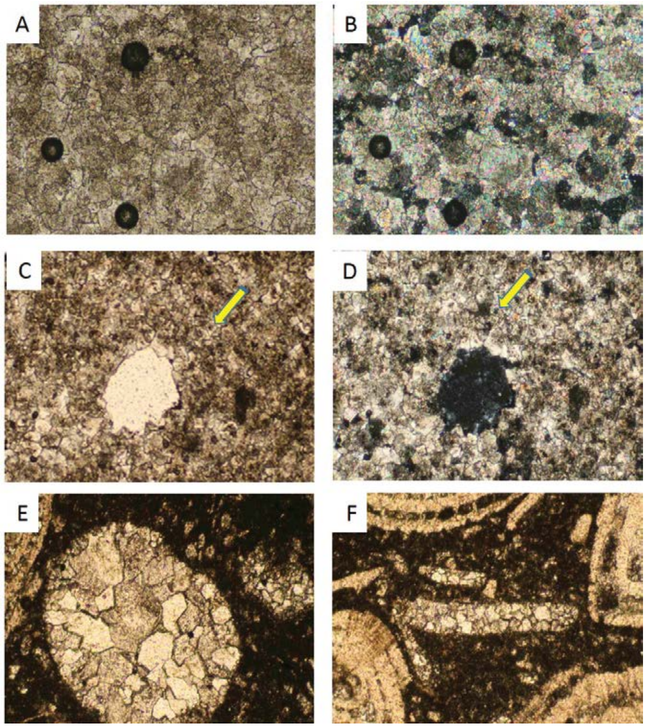

Figure 3: (A) Photomicrograph showing selective dolomitization of micrite into dolomicrite. (B) Dolomicrite microfacies under plane-polarized light. (C) Complete replacement of micrite to medium-grained dolomite (Dolosparite microfacies). (D) The dolosparite with small dark zone of dolomite rhombs under plane-polarized light. (E&F) Very coarse-grained and elongated fossils fragments which their internal chambers are filled with sparry calcite and dolosparite. Thin section views at 100X magnification.

Samples	Fe_2O_3	SiO_2	CaO	MgO	Na_2O	MnO	TiO_2	P_2O_5	Al_2O_3	L.O.I
1	0.08	0.6	31.06	20.33	<0.01	0.01	0.01	0.03	1.33	**46.32**
2	0.06	0.15	32.42	20.34	<0.01	0.01	0.01	0.01	0.31	**47.33**
3	0.07	0.27	31.33	20.89	<0.01	0.01	0.01	0.01	0.81	**47.44**
4	0.08	0.57	31.2	20.26	<0.01	0.01	0.01	0.02	2.21	**46.11**
5	0.06	0.16	32.06	20.51	<0.01	0.01	0.01	0.02	1.46	**46.83**
6	0.07	0.13	33.42	20.21	<0.01	0.01	0.01	0.01	0.44	**47.12**
7	0.08	0.26	31.45	20.35	<0.01	0.01	0.01	0.02	0.54	**47.35**
8	0.07	0.59	31.2	20.11	<0.01	0.01	0.01	0.02	2.32	**46.53**
9	0.06	0.5	31.06	20.12	<0.01	0.01	0.01	0.03	1.43	**46.83**
10	0.08	0.15	32.25	20.9	<0.01	0.01	0.01	0.01	0.31	**47.57**

Table 1: Chemical compositions (wt%)-aggregate materials from G. Shabrawet.

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Concerning the aggregate supplied from G. Shabrawet, the 10 samples had similar chemical composition with a high magnesium oxide. This was in accordance to the high dolomite content detected in the petrographic examination.

The chemical analysis results showed that the studied samples were composed of CaO (33.42%), SiO_2 (0.59%) and Fe_2O_3 (0.08%). The samples also ware contained MgO (20.90%) and Al_2O_3 (1.46%).

XRD test results: The XRD technique was employed in this study to identify the various crystalline phases of the aggregates investigated in this project. For each aggregate source, the samples tested in XRD were slight different from that examined in the thin section examination and XRF. The samples analyzed by means of XRD were prepared through mixing the aggregate fractions with similar oxide compositions and petrographic patterns, in the same ratios found in the original specimens. The X-ray diffraction patterns are shown in Figure 4. Because the XRF results and the petrographic examination showed that all samples were similar, only five samples were tested. The rock was composed of >95% dolomite. The X-ray diffraction results similar to the petrographic examination of this aggregate.

Sieve analysis

The Sieve analysis (gradation) of aggregates is one of the most important properties in estimating how they will carry out as a pavement material, especially in case of hot mix asphalt. In Portland cement and concrete (PCC), the proper gradation will help to assess workability, strength, durability and shrinkage; while it also facilitates to evaluate stiffness permeability, moisture susceptibility fractional and fatigue resistance in the hot mix design [14,18-20]. The aggregate size and gradation affect the strength, density, and cost of pavements. When particles are bound together by a bituminous binder, a variation in the gradation will change the amount binder needed to produce a mix of given stability and quality [13,20].

The studied coarse aggregate samples are predominantly with gravels (88 to 98.2%), sands (1 to 2.5%), and trace amounts of fine materials (silt and clays) around 1%.

Figure 5 represents a typical grading chart showing a well-graded distribution for both coarse and fine aggregates of the studied aggregates. A well-graded aggregate, which contains a wide range of particle sizes, generally produces a compacted layer with high unit

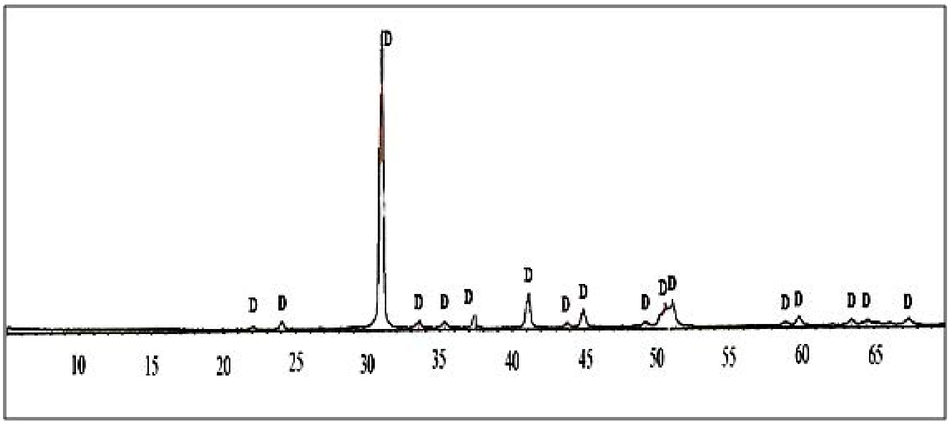

Figure 4: The X-ray diffraction patterns for Maghra Al Hadida Formation.

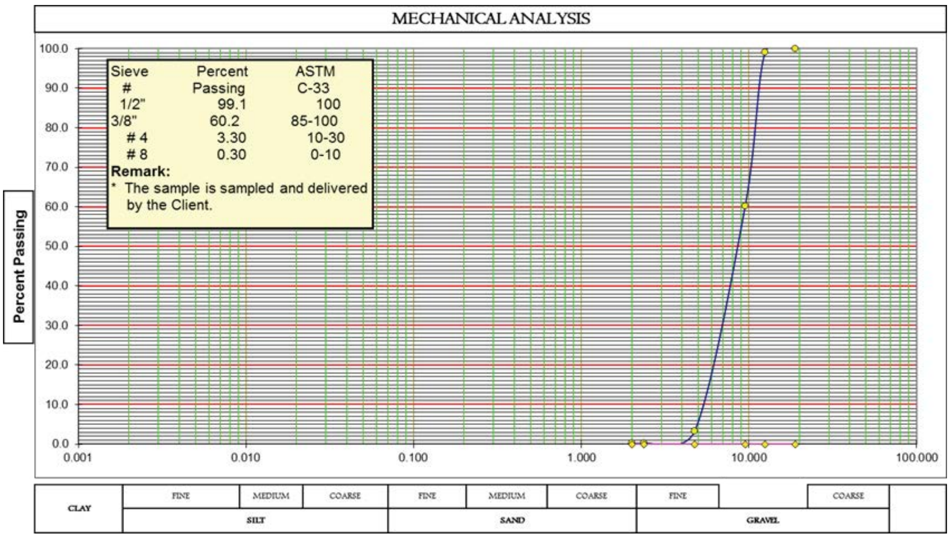

Figure 5: Grain size distribution chart for the studied aggregates.

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weight (low voids), low permeability, and good stability with good distribution of load/stress spreading out uniformly through the material to the road pavement layer and concrete infrastructures [21].

Specific gravity and water absorption (ASTM C 127, 128-84)

The specific gravity (SSD) of an aggregate is measured according to ASTM [5] specification. In this procedure, aggregate has been soaked and left overnight so water is absorbed into its pore spaces; then excess, free surface moisture has been removed so that the particles are still saturated, but surface of the particles is essentially dry. This is SSD specific gravity.

Bulk specific gravity, SSD=A / (A - B)

A=mass of saturated surface dry aggregate

B=weight of aggregate submerge in water

Bulk gravity (SSD) of sample collected is presented in Table 2 and shows minor difference in minimum, average and maximum values.

Water absorption of aggregate is very important. These properties affected its qualities for the bond between aggregate and cement. Affecting concrete strength and freezing and thawing. There are different sizes of pores some of them are big, but others are small. The small pores (4 microns) improve concrete freezing and thawing properties.

The content of absorbed water in the samples of study area is low, probably due to less porous nature of limestone (Table 3). All the samples have water absorption within 2% specified limits (National Highway Authority). Samples of Maghra El Hadida Formation have low water absorption capacity with little variation because all fractures and pores are filled-up by dolomite.

The results showed that the specific gravity values of the studied samples were ranging from 2.42 to 2.67 g/cm^3 with average 2.57 g/cm^3. The water absorption values were ranging from 2.70 to 3.91% with average 3.23%.

Los Angeles abrasion test (ASTM C C 131-66)

Los Angeles (LA) abrasion test provides a clear perception for abrasion, hardness, degradation and disintegration of the aggregate. Estimate of LA abrasion is essentially required to judge the firmness of either the concrete or asphalt to bear wear and tear right from their manufacturing and during their utilization for long time. In the present study, ASTM C131 [5] procedure is applied for estimation of LA abrasion.

ASTM method C 131-66 was used for the LA abrasion test. Test samples were oven-dried at 105–110°C for 24 h and then cooled to room temperature before they were tested. There are four aggregate sizes grading to choose from in the ASTM method. Grading D was used in the tests. Eight steel spheres were placed in a steel drum along with ~ 5000 g of aggregate sample and the drum was rotated for 500 revolutions at a rate of 30-33 rev/min. After the revolution was complete, the sample was sieved through the No. 12 sieve (1.7 mm). The amount of material passing the sieve, expressed as a percentage of the original weight, was the LA abrasion loss or percentage loss [22] (Figure 6A).

The calculation of LA abrasion loss or percentage loss as follows where:

Passing	Retained	A	B	C	D
1 1/2 IN	1 in	1250	0	0	0
1 in	3/4 in	1250	0	0	0
3/4 in	1/2 in	1250	2500	0	0
1/2 in	3/8 in	1250	2500	0	0
3/8 in	No.3	0	0	2500	0
No.3	No.4	0	0	2500	0
No.4	No.8	0	0	0	5000
Total		5000	5000	5000	5000
A) Weight of sample before test=5000 gm			5000		
B) Weight of sample after test (Retained on No.12 sieve)=			4298		
C) percentage of wear=A-BX100=			14.04		

Table 2: Example The percent of Les Angeles of the studied sample.

Samples	SSD (g/cm^3)	Water absorption (%)	Clay lumps and foreign materials (%)	Soundness	elongated	flatted	Les Angeles (%)
1	2.59	2.7	0.62	1.29	6.3	5	24.3
2	2.67	3.1	0.54	1.62	4.4	8.3	14.04
3	2.61	2.9	0.56	1.44	5.3	8.6	23.5
4	2.64	3.9	0.77	1.66	5.4	7.3	22.4
5	2.62	2.43	0.82	2.79	4.3	8.1	21.2
6	2.62	3	1.1	1.54	5.5	6.7	21.2
7	2.53	3.4	0.57	1.88	4.4	8.4	23.33
8	2.54	3.1	0.81	2.11	4.5	7.4	22.43
9	2.42	3.6	0.55	1.89	4.8	8.4	21.37
10	2.47	4.2	0.51	1.99	6.2	8.2	22.3
Ave	2.57	3.233	0.63	1.821	5.11	7.64	21.6
ASTM specification: Saturated specific gravity (g/cm^3) 2.70 Water absorption (%) <4% Les Angeles (%) <50% Soundness <12% Clay lumps and foreign materials (%)<3% flatted <15% elongated <15%							

Table 3: Physical and mechanical properties of aggregates in Magra El Hadida Formation at G. Shabrawet.

Figure 6: (A) Aggregates for flakiness and elongation index. (B) Samples for loss Angles abrasion test.

A=The weight of the sample in grams before testing.

B=The weight of the sample after testing (that portion retained on the 1.70 mm (#12) sieve).

Percent Loss=(A-B)/A*100

The percent of Los Angeles of the studied samples was ranging from 14.04 to 24.20% with an average 21.60% (Table 2).

Soundness (using sodium sulphate) (ASTM C 88-83)

Sulphate soundness is commonly employed to measure the freezing and thawing durability of aggregates. Freezing and thawing characters of an aggregate is assessed by repeatedly submerging the aggregate in a sulphate solution and oven drying. In the present work, $NaSO_4$ soundness method is opted for the studies, as per (**ASTM C 88-83**) specifications. The result of soundness is given in Table 1. It shows minimum value 1.29%, while 2.79% is the maximum. The average is found to be 1.80%. The present study indicates that the all samples are good, and have low soundness compared to (**ASTM C 88-83**) recommended value of 12%.

Clay lumps and friable particles (AASHTO T 112))

The clay lumps and friable particles is defined as any soft friable or clay like material, which can easily be removed when squeezed between the thumb and forefinger or will disintegrate into small pieces when aggregate is immersed in water for a short period. Coating clay which sticks on the surface of aggregate will hinder the bonding between cement and aggregate. If the quantity of clay in aggregate exceeds the maximum allowable limit (1.5%), it will harmfully influence durability and strength of concrete. Excessive clay lumps present in aggregate interfere with the bonding between asphalt and aggregate. This will cause stripping and pop-outs in the pavement [23].

The carbonate rocks of Maghra El Hadida Formation are relatively pure and clays are present in minor quantity (average 0.63%). Results of clay lumps and friable particles of current study given in Table 2 shows low amount of fine particles, thus it is good for asphalt and concrete.

Flakiness and elongation index

The particle is considered as elongated if its length is more than 1.8 times the mean sieve size of the size fraction to which the particle belongs. Similarly, the particle is considered as flaky if its thickness is less than 0.6 times the mean sieve size of the size fraction. Elongated and flaky particles have a large surface area relative to its small volume; hence it decreases the workability of concrete mix (Figure 6B). The flaky particles can affect the durability of concrete as they tend to be oriented in one plane, with water and voids forming underneath [24-26].

Shape of the aggregate is very crucial in the cement concrete. Proper shaped (equant) aggregates are needed for easy workability, deformation resistance and proper compaction. However, quantity and proportion of different shaped particles largely relies on the nature of civil work [27]. Poor strength of concrete is obtained in the presence of high amount of flat and elongated particles in the aggregate. Both of them are unable to bear heavy load and fracture more easily than the other aggregate particles [28]. Such flat and elongated particles also require more water for binding, which ultimately influence the mechanical characteristics of concrete. Furthermore, aggregate with high proportions of flat and elongated particles may also cause segregation in the fresh mix, which leads to low durability and strength of the concrete. In the pavement structure, proportion of aggregates is nearly 95% of the total volume of hot-mix asphalt (HMA). For this reason, shape of the aggregates; appreciably affect the overall quality and durability of the pavement [29]. The high quality of HMA mixture largely depends upon the presence of rough and angular aggregates [30]. Cubical shaped aggregates are most advantageous in HMA, while flat and elongated particles considered adverse because they tend to break during compaction and under heavy traffic [31]. The samples of the study area show an average of 5.11% elongated and 7.64% flat particles

The specified limit of 15% of flat and elongated particles in the sample largely depends upon the composition, nature of bedding, compactness, hardness and influence of tectonism prevailed in the area [32].

The Physical and mechanical properties of aggregates in Maghra El Hadida Formation at G. Shabrawet are illustrated in Table 3 [33-35].

Conclusion

The Maghra El Hadida Formation of Turonian age is exposed in the Gabal Shabrawet area; these rocks are widely used to fulfill the local demand for building and road constructions, which have good export potential abroad [36]. The average specific gravity (SSD) of carbonate rocks of Maghra El Hadida Formation is 2.57 g/cm^3, which classified it as normal-weight aggregate. It also has low water absorption capacity (av. 3.12%). The distribution of different sizes of the crushed material showed that the average gradation curve is within the ASTM specification and can be classified as open-dense graded. The size is good enough for durable and high strength concrete and convenient to bear freeze-thaw damages. The Los Angeles abrasion losses (21.5%) designate it as suitable material to bear load. The mean value of soundness test of present study is 1.80, much lower than ASTM recommended value (12%). It is safe to use it for cement concrete and asphalt with no hazard of expansion. Clay lumps and friable particles are very low (av. 0.69%). The amount of flat 7.6% and elongated particles is 5.17%. The petrographic study revealed dolomicrite and dolosprite type of texture with dolomitization of skeletal particles. All the above properties are within the ASTM specified limits and mark it as a suitable material for concrete and asphalt. For most economic design of mixtures use the limestone that available in many locations of Gabal Shabrawet area.

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