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# Geological and Geotechnical Assessment of Gabal Ataqa Dolostones, for Pavement Construction in Egypt

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**Abstract**

Aggregate is a collective term for the mineral materials such as sand, gravel and crushed stone. By weight, aggregate generally occupies about 92-96 percent of the hot mix asphalt (HMA), and about 79-85 percent of the Portland cement concrete (PCC). Aggregate is also used for Base and Sub-base courses for both flexible and rigid pavements. This research aims to investigate the geological and geotechnical properties of Gabal Ataqa dolostone for pavement construction projects in Egypt. A total of six dolomite microfacies were recognized and classified according to the dolomite rock classification. The X-Ray Diffraction (XRD) analysis showed that Ataqa dolostones consist mainly of dolomite (89.79%) and calcite (7.74%), while quartz (2.3 %) and halite (0.18 %) were found in small amounts in some samples. Generally Ataqa dolostone is around stoichiometric (50.96%), and may belong to dolomite of late diagentic coarse crystalline dolomite. The chemical investigation showed that the major elements of the investigated dolostone rocks are $SiO_2$ (1.72 %); CaO (32.03%), MgO (19.18%), $Fe_2O_3$ (0.22 %), $Na_2O$ (0.11%), and $Al_2O_3$ (0.05%) while the loss on ignition is about (46.19 %.). The trace elements consist of strontium (116 ppm), barium (14.0 ppm); and very low amount of zirconium (3 ppm). Petrographic, chemical, mineralogical, and compressive strength of Ataqa dolostone rocks beside, geotechnical properties of the produced coarse aggregates were investigated. Los Angeles abrasion, apparent specific gravity, water absorption, disintegration, and stripping were evaluated. The results of the conducted testing indicate that Ataqa dolostone rocks are suitable for road construction and concrete industry.

***Keywords:*** Gabal Ataqa; Dolostone; Aggregates; Mineralogical; chemical; Petrographic Geotechnical.

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## 1. Introduction

In the last few years, the demand for limestone as a building material in highway construction, general constructions, steel industry, and fertilizer industry and in cement manufacturing in Egypt has markedly increased. Therefore, it becomes a national need to satisfy the required specifications of the aggregate to ensure its best use [1].

The road construction industry is heavily dependent on the use of all sorts of aggregates including limestone. Aggregate is the main constituent of the Hot Mix Asphalt, bound / unbound granular base and sub-base materials.

There is an extensive literature dealing with the evaluation of the quality of aggregates generally used in road construction e.g., [2,3,4,5,6,7,8,9]. For example, Reference [7], listed six quality parameters required for an aggregate to be used as a surface course:

These parameters are toughness, hardness, resistance to polishing, stripping, weathering, and ability to contribute to strength and stiffness.

From the literature studies, it was reported that the problem is not the identification of poor quality aggregate, but is the determination of the boundary between the acceptable and unacceptable aggregates in terms of performance and cost [9].

The Egyptian code for urban and rural roads, American Association of State Highway and Transportation Officials (AASHTO ), Fedral Department of Transportation (FHWA )Texas Department of Transportation (TxDOT), other Departments of Transportions and other standards defined the following properties as important parameters for evaluating the quality of coarse aggregates:

Porosity or absorption, cleanliness and deleterious materials, toughness and abrasion resistance, and durability and soundness. Any relatively hard and durable rock is suitable for road construction e.g. basalt, granite or limestone.

The carbonate rocks are the most abundantly available and commonly used as unbound granular base/sub base material as well as HMA aggregate for pavement construction [9] .The carbonate rocks are usually exposed on the surface in sedimentary successions of large thicknesses and several varieties in Egypt of which Gabal Ataqa dolostone section is considered. Ideally, a quarry is located close to where crushed stone will be used. The haul distance of crushed stone plays a significant role in its actual cost.

This research aims to investigate the geological and geotechnical properties of Gabal Ataqa dolostones for pavement construction projects in Egypt. In the present study the Gabal Ataqa dolostone section, was measured, described and sampled (Table 1). The collected samples were crushed and chemically, mineralogically, and petrographically treated and their physical and mechanical properties were assessed for use in the pavement construction industry.

**Table 1:** Dolostone samples of Gabal Ataqa

| Area | | Age | Sample No. | Sample symbole | Sample location | Rock name |
|---|---|---|---|---|---|---|
| Gabal A taqa, West Gulf Of Suez | Cairo – Suez Road , near Km. 101 | Upper Cretaceous | 1 | D1 | Sharqia sons section | Dolomitic limestone |
| | | | 2 | D2 | | Dolomitic limestone |
| | | | 3 | D3 | | Dolomitic limestone |
| | | | 4 | D4 | 6-October section | Dolostone |
| | | | 5 | D5 | | Dolostone |
| | | | 6 | D6 | | Dolomitic limestone |
| | Gabal Ataqa | Upper cretaceous | 7 | D7 | Technogravil | Dolomitic limestone |
| | | | 8 | D8 | | Dolomitic limestone |
| | | | 9 | D9 | | Dolostone |
| | | | 10 | D10 | | Dolostone |
| | | Middle Eocene | 11 | D11 | Iron-Steel company | Dolostone |
| | | | 12 | D12 | | Dolostone |
| | | | 13 | D13 | | Dolostone |
| | | | 14 | D14 | Lafarge | Dolostone |
| | | | 15 | D15 | | Dolostone |
| | | | 16 | D16 | | Dolostone |
| | | | 17 | D17 | | Dolostone |

## 2. Geological setting

Gabal Ataqa form a topographic high that resulted from tectonic activity related to the Syrian Arc system [10]. Gabal Ataqa overlooks the junction of the Gulf of Suez and the Suez Canal. It is located between latitudes: 29º 47\ and 30º 00\ N, and longitudes: 32º 16\ and 32º 28\ E. The geological map of Gabal Ataqa is shown in Figure 1. Structurally Gabal Ataqa is a tilted fault block bounded by normal faults dipping in the northeasterly direction [11]. Eocene rock sharply overlie tilted cretaceous rocks with an obvious unconformable relationship that is mainly represented by the deposits of the Maghra El- Bahari formation, which were accumulated during the period from the end of the Late Cretaceous to the Early Middle Eocene [11].

The Maghra El-Bahri formation appears as massive and featureless which is subdivided into two informal lithostratigraphic parts. The lower part was recorded at both Gabal Ataqa and Gabal Shabrawet, whereas the upper part is absent at Gabal Shabrawet [12]. The lower part at Gabal Ataqa, comprises of unfossiliferous fine – grained sandstone, siltstone and silty claystone intercalated with beds of medium to coarse grained sandstone and calcium granule conglomerate. In addition, there are granules and pebbles, which are mainly calcareous in composition and occasionally ferruginous (Figure 2). The upper part of the Maghra El-Bahari formation consists of snow white carbonates and evaporites intercalated with grey siltstones, silty claystone and greyish marlstones. The carbonate and marlstone beds are poorly indurated, massive and have desiccation cracks [12].

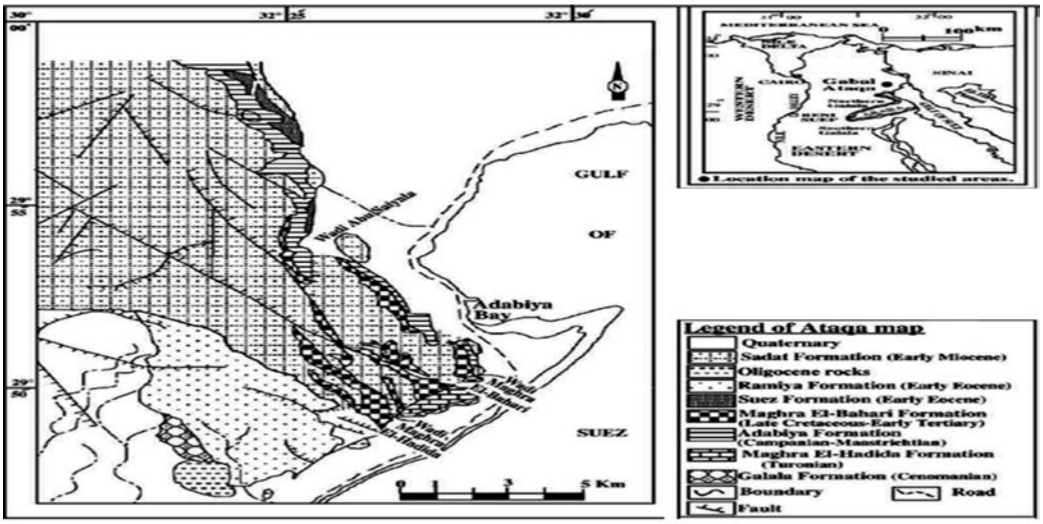


**Figure 1:** Geological map of Gabal Ataqa [modified after 11]

The exposed rock unit in Gabal Ataqa area is of the Cenomanian age. The oldest exposed rocks in the area are of early Cretaceous age, while the youngest rocks are of Quaternary age of synrift sedimentary sequence [13].

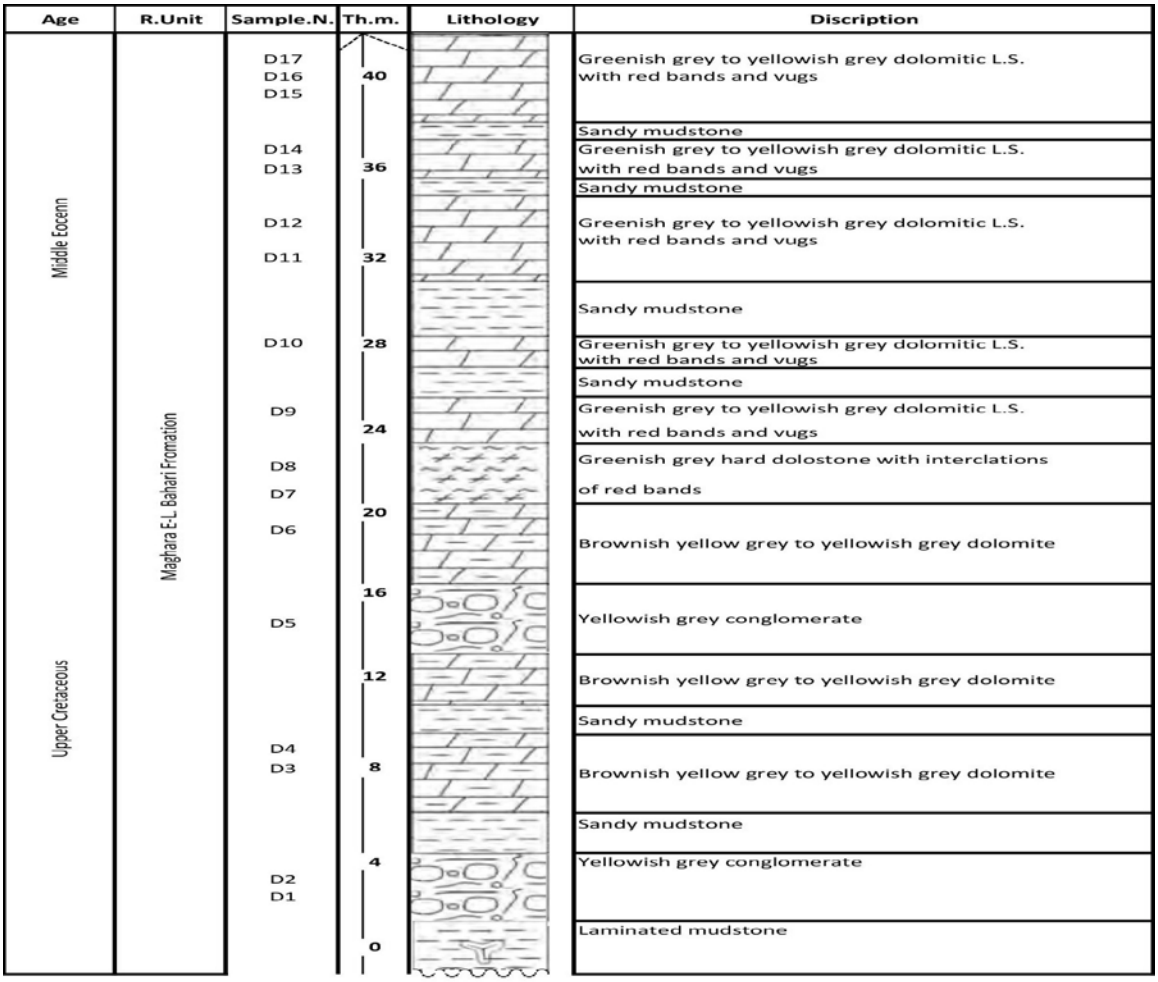


**Figure 2:** Composite lithological section at Gabal Ataqa

## 3. Materials and Techniques

The geologic succession at Gabal Ataqa (Figures 3A&3B, was investigated. Seventeen block samples (Table 1) with dimensions not less than 30 cm were collected. (Figures 3C&3D), and ten crushed aggregate samples (Figures 3E&3F) representing technological samples were collected.

### *3.1. Petrography*

The petrography of the collected samples was carried out using a polarizing microscope. The description of dolomite rock texture and the classification, given by [14], were here adopted.

### *3.2. Mineralogy*

X-ray diffraction techniques were used for the detailed mineralogical analysis. The whole rock powder samples were analyzed using Philips (PW 1840). The X-ray diffraction analysis were conducted in the X-ray laboratory of the Metallurgical Research Institute, Cairo, Egypt.

### *3.3. Chemistry*

The major chemical composition of the bulk dolostone powder samples was quantitively estimated by the recent X-Ray Refraction Fluorescence (XRF) . This was conducted using an AXIOS, WD-XRF-Sequential Spectrometer (PAN analytical, 2005), where chemical compositions are usually given in terms of oxides. The samples were analyzed in the Acme labs. Canada.

### *3.4. Insoluble residue*

The acid insoluble residue test [15] was used to determine the non- carbonate content of the dolostone samples.

### *3.5. Physical investigation of rock samples*

The physical properties of the rock blocks were determined on cylindrical core specimens obtained from the blocks using a thin wall diamond drill. The specimens were trimmed and ground into cylinders with a diameter of 100 mm ± 0.1 mm and a height of 150 mm ± 0.1 mm.

### *3.6. Mechanical investigation of rock samples*

The compressive strength of the rock core specimens was determined using a uniaxial compression testing according to the [16 ]. In this method, the stress was obtained from the recorded value of the axial load divided by the cross – sectional area of the specimen assuming that the deformation is homogeneous and no volume change occurred by axial stress. The ultimate compressive strength which is defined as the value of uniaxial compressive stress at failure was determined for each tested sample.

### *3.7. Physical investigation of coarse aggregate*

In addition, 10 samples representing the crushed aggregates from the selected locations were subjected to physical properties and gradation determinations. Approximately 30 kg of the crushed aggregates were collected from the fresh production of the working crushers according to [17] .These aggregates were divided into Cr.Agg.1 (10 mm – 4.75 mm) and Cr.Agg.2 (19 mm – 10 mm) classes according to the nominal size (Figures 3E & 3F). The bulk density, bulk, saturated surface dry and apparent specific gravities [18 ] and [19], gradation [20 ] and asphalt stripping [21 ], were determined .

### *3.8 Mechanical investigation of coarse aggregate*

Los Angeles abrasion according to [22] was determined, for both size #1 and #2.


**Figure 3:** Photomicrograph of Gabal Ataqa (A) General view of Gabal Ataqa, North West of Gulf of Suez. (B) Dolostone succession of Gabal Ataqa, Technogravil Section. (C) Different size of dolostone boulders at base of Gabal Ataqa, Technogravil section. (D) Nodules of Dolostone rocks near Km 101 of Cairo –Suez Road. (E) Crushed aggregates size #1. (F) Crushed aggregates size # 2.

## 4. Results and discussions

### *4.1. Petrography*

Six dolomite microfacies were recognized and classified according to the dolomite rock classification scheme of

[14]. The apparent maximum dimensions of the dolomite crystals were measured or estimated and subdivided using the subdivision of [23]; planar crystal boundaries develop when crystals undergo faceted growth and non-planar boundaries develop when crystals undergo non-faceted growth [24].

#### *4.1.1. Very fine crystalline dolomite*

This type of facies is characterized by very fine crystalline dolomite (Fig.4A&4B), planar euhedral to subhedral with homogeneous crystal distribution. Irregular- shaped; elongated in some cases are present. Vugs are rimmed or filled with calcite crystals, occasionally surrounded by iron oxide pigmentation (Figure 4B). Scattered pigmented patches were found in the rock matrix. The calcite crystals inside the vugs are coarser than the dolomite crystals, with subrounded to rounded and clear outlines.

#### *4.1.2. Very fine to fine crystalline dolomite in laminated silty dolomite*

Very fine to fine crystals in slightly cloudy rock, angular to subangular or irregular (serrated) and usually unzoned illsorted grains. Irregular patchy matrix is slightly pigmented by iron – oxides commonly along pedding planes (Figure 4C). Semitransparent layers were found to contain rare medium crystalline zoned of euhedral dolomite crystals. Quartz grains were clear, form about 1% of the rock, usually rounded. Rare fine irregular shaped vugs (Fig.4 D) were found.

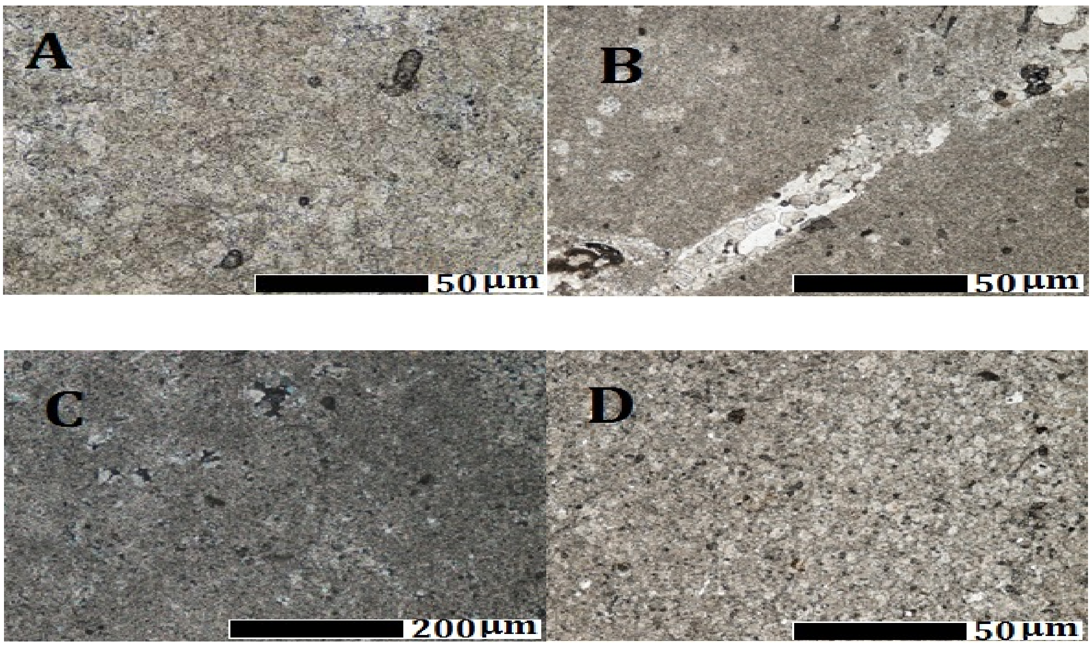


**Figure 4:** (A) Very fine crystalline dolomite, planar-e(euhedral), serrated grains floating in a very fine micritic matrix. (B) Very fine crystalline dolomite have fractures filled with calcite crystals. (C) Very fine to fine crystalline dolomite under polarizing light (D) Very fine to fine crystalline dolomite dominated by ferruginous grains .

#### *4.1.3. Fine to medium crystalline dolomite*

Fine to medium sized euhedral to subhedral, unimodal, planar crystals non-luminescent cloudy crystal cores of variable sizes and shapes, have a clear outer boundaries, surrounded by a clear moderately luminescent rims. Iron oxide of fine to medium, subrounded to rounded grains are scattered.

The core shape varies from a perfect rhombahedron to nearly round core and often matches the outline of the crystal. The rock is often penetrated by fractures and irregular angular to rounded vuge. In places a cloudy rim surrounds the vugs (Figures 5, A &B).

#### *4.1.4. Inequigranular dolomite*

This type contains dolomite grains of several sizes. The grains are planar, euhedral to subhedral (Fig.5 C ), often also anhedral with serrated or subrounded to rounded outlines.

Dolomite crystals have a semitransparent or cloudy core, surrounded by an indistinctly terminated iron rich level, rimmed by a clear outer cortex (Fig.5 D). In places rare, irregular- shaped angular vugs are found. Crystal deformation witnessed by wavy extinction.

#### *4.1.5. Concentric zoned dolomite*

Medium to coarse crystalline dolomite crystals are embedded in very fine crystalline dolomite cement (Fig.5E). The outlines of dolomite crystals are mainly planar, but some have slightly serrated outlines. Most of the dolomite crystals have a cloudy core, surrounded by a clear white rim with planar sides .These crystals are best seen under the polarized light ,but hardly seen under the crossed polarized light.Irregular - shaped voids often occur inside zoned crystals, mostly in the core, but also within the outer zones (Fig.5 F).

#### *4.1.6. Sucrosic dolomite*

Sucrosic dolomite represented by coarsely crystalline dolomite with planar euhedral to subhedral zoned crystals.This type of rock is strongly vuggy. The vugs have irregular shapes and irregular outlines, with large sizes ( Fig.6A) . In places wavy sutured planes penetrate the rock. The sutured planes have bright red color like the dolomite crystals on the pore surface.

Sucrosic dolomite crystals usually have cloudy centers and clear rims . The cloudiness arises from the presence of inclusions, mineral relics of the $CaCO_3$ precursor and empty of fluid-filled microcavities [25].

#### *4.1.7. Void-filling dolomite*

The studied dolomite rocks of Gabal Ataqa and Suez area contain numerous vugs and fractures ( Figures 6B &C &D ).Vugs and fractures are partly or completely filled with dolomite, some of them filled with calcite ( Fig.6B &C ). Vugs filling dolomite is composed of coarse transparent euhedral crystals with planar outline ( Fig.6D ) .The crystal size of void-filling calcite varies widely. In some cases large voids are filled with clear coarse grained calcite crystals with perfect crystal faces . Fine vugs are rimmed with clear subhedral and anhedral, often elongated, medium crystalline calcite.

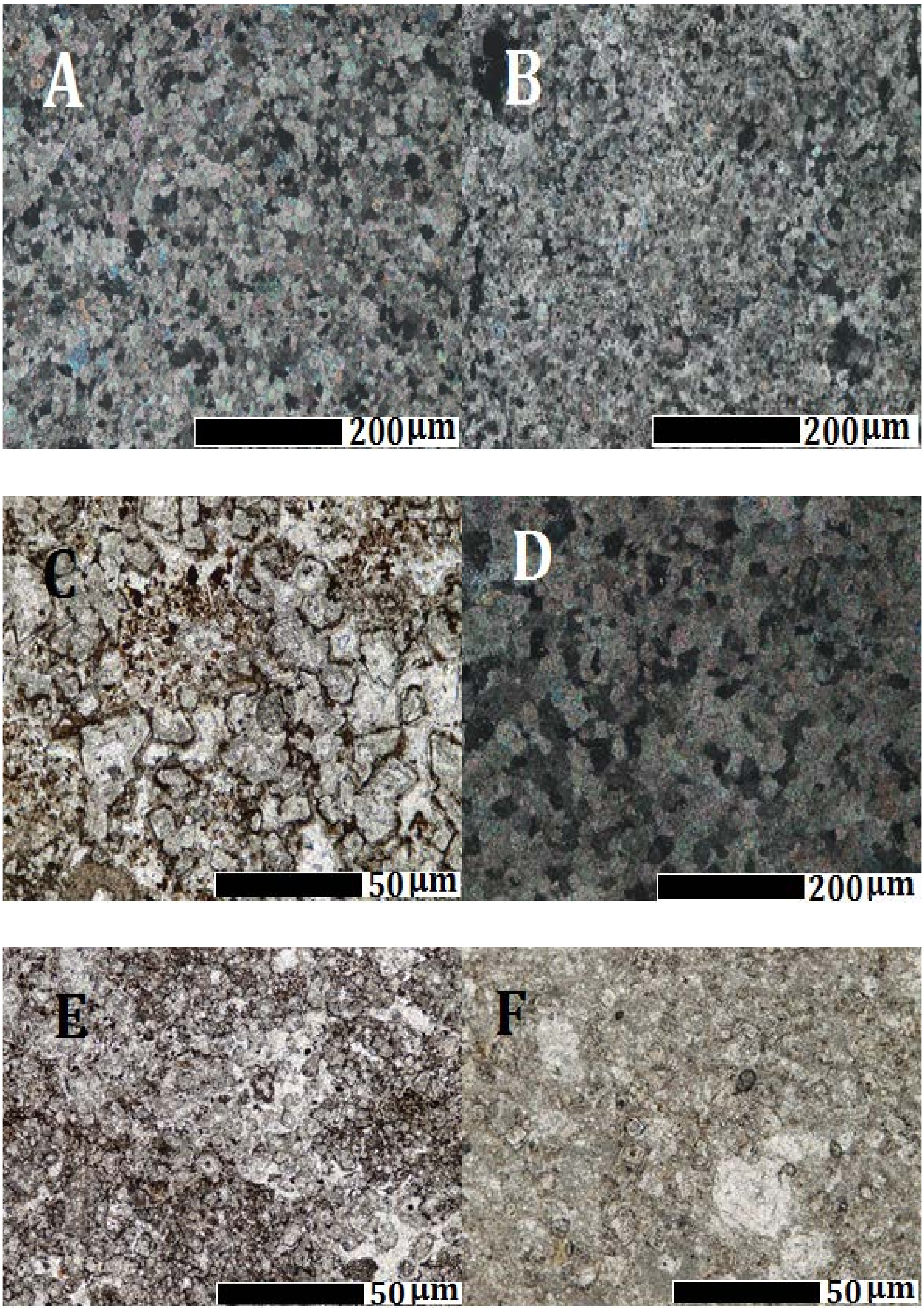


**Figure 5:** (A) Fine to medium crystalline dolomite ,xenotopic mosaic of anhedral dolomite crystals (B ) Fine to medium crystalline dolomite ,showing irregular crystal boundaries ( C ) Inequigranular dolomite, planar-e-(euhedral ),unimodal to polymodal, irregular boundaries with some vugs (D ) Subangular to subrounded ,planar-e-(euhedral ) ,fine to medium grains ; (E) Polymodal and concentric zoned dolomite ,showing zonation of calcite crystals replaced by dolomite (F ) Concentric zoned dolom

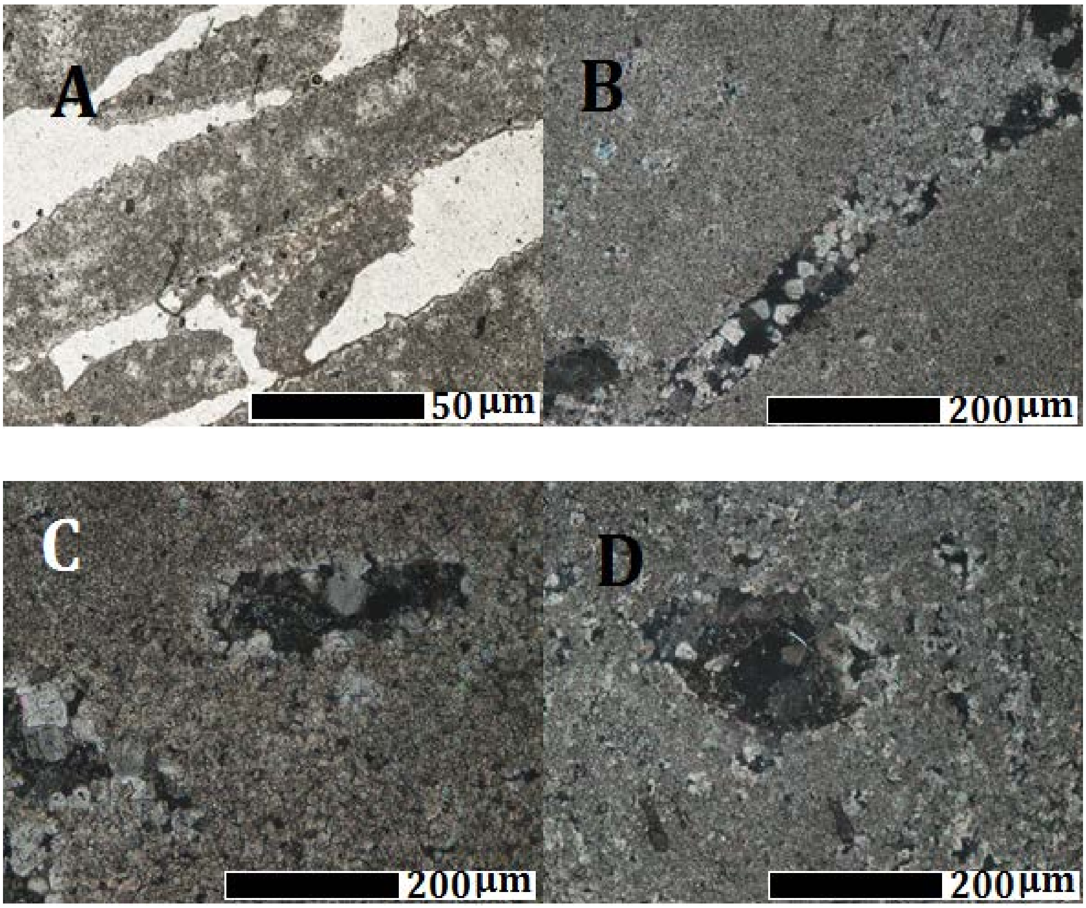


**Figure 6:** (A) Sucrosic dolomite ,large vugs have irregular shapes and irregular outlines (B) Fractures are partly filled with calcite (C) Voids are filled with clear coarse grained calcite crystals with perfect crystal faces (D )Voids partially filled with dolomite and calcite of coarse transparent euhedral crystals with planar outline.

***4.2. Mineralogy***

In road construction, mineralogy of an aggregate affects pavement performance of pavement. In HMA, certain aggregates are more susceptible to stripping due to the surface energy of the aggregate and the bond generated with the asphalt. Many studies have focused on testing engineering properties e.g. strength without considering the influence of the mineralogical and chemical composition of an aggregate [26 ] . According to [27] the bulk composition is an important factor in determining the strength of a rock and concluded that aggregates with significant carbonate minerals are weaker than aggregate with silicate minerals. The results of X-ray diffraction (XRD) of dolostone rocks of Gabal Ataqa are given in Table (2) and shown in Figures7 .Two main carbonate minerals were identified in the studied dolomite samples of Gabal Ataqa area. These minerals are dolomite and calcite,. The dolomite ranges from 28.5 % to 100 % with an average of 89.79%, whereas the calcite ranges from 0 % to 71.5 %, with an average of 7.74%. Quartz was found only in two samples with the percentages of 36.8 % and 2.3%, whereas halite was found only in one sample in a small percentage of 3%. Stoichiometry was used to outline three dolomite groups according to [28]: (1) Late diagentic, coarse crystalline dolomite, generally nearly stoichiometric; (2) Early diagenetic ,fine crystalline dolomite ,associated with evaporites and nearly stoichiometric , and (3) ) Early diagenetic ,fine crystalline dolomite ,not associated with evaporites and generally Ca-rich. The XRD patterns obtained exhibit sharp diffraction peaks and reveals minor remnants of the precursor mineral calcite in dolomite samples. The Stoichiometry of the studied samples of Gabal Ataqa ranges from 46.33 % to 55 % with an average of 50.96 %. The shift express deviation of composition from 1:1 molar $CaCO_3$: $MgCO_3$ to slightly Mg-rich. Generally, the dolomite in hand is around stoichiometric, having an average of 50.96 %. Thus Ataqa dolostone may be considered on the basis of obtained data as group (1), i.e., dolomite of late diagentic coarse crystalline dolomite, which are thought to result from slow crystal growth, possibly aided by elevated temperatures [29]. The sharpness of the peaks indicates an almost perfect and ordering of the crystalline lattice of the studied dolomites. The degree of cation order in the dolomite lattice can be derived from the ratio of the: d (105 ):d ( 110 ); super lattice reflection peaks [30]. The d(105) is a principle order reflection that is less pronounced for Ca-rich dolomites compared to ideal dolomites. The d (110) is not a dolomite ordering reflection; so it serves as a reference for change in order intensity [30] .As a result, d (105):d (110 ) ratios with higher values indicate dolomite with a higher degree of cation order . The cation order of the studied Ataqa dolostones ranges from 0.45 to 0.79 with an average of 0.578, ( Table 2). In general, the degree of cation order in dolomite samples increases with both percent dolomite and reaction time [29]. The degree of cation order increases as calcite is replaced by dolomite. The degree of dolomite cation order also continues to increase after all the calcite has been consumed [29] .The degree of cation order in dolomite is a function of reaction progress and independent of dolomite stoichiometry.

**Table 2:** X-Ray diffraction results of Gabal Ataqa dolostone samples

| ID | Calcite % | Dolomite % | Halite % | Quartz % | Stoichiometry % | I(105) | I(110 ) | Order |
|---|---|---|---|---|---|---|---|---|
| **D1** | 3.6 | 96.4 | 0 | 0 | 54.66 | 2.3 | 4.7 | 0.48 |
| **D2** | 18.9 | 44.3 | 0 | 36.8 | 53.33 | 4.9 | 7.2 | 0.68 |
| **D3** | 9.4 | 88.3 | 0 | 2.3 | 50.66 | 4.3 | 7.5 | 0.57 |
| **D4** | 0 | 100 | 0 | 0 | 50.00 | 3.6 | 6.6 | 0.54 |
| **D5** | 0 | 100 | 0 | 0 | 50.00 | 4.3 | 8.8 | 0.48 |
| **D6** | 71.5 | 28.5 | 0 | 0 | 55.00 | 1.3 | 2.5 | 0.52 |
| **D7** | 26.1 | 73.9 | 0 | 0 | 54.66 | 2.3 | 4.9 | 0.47 |
| **D8** | 2 | 98.0 | 0 | 0 | 50.66 | 2.9 | 4.2 | 0.69 |
| **D9** | 0 | 100 | 0 | 0 | 50.66 | 4.0 | 6.3 | 0.63 |
| **D10** | 0 | 100 | 0 | 0 | 51.00 | 2.5 | 4 | 0.62 |
| **D11** | 0 | 100 | 0 | 0 | 48.00 | 3.5 | 6 | 0.58 |
| **D12** | 0 | 100 | 0 | 0 | 49.66 | 2.7 | 3.4 | 0.79 |
| **D13** | 0 | 100 | 0 | 0 | 49.66 | 1.75 | 3.3 | 0.53 |
| **D14** | 0 | 100 | 0 | 0 | 47.66 | 3.7 | 5.5 | 0.67 |
| **D15** | 0 | 100 | 0 | 0 | 54.00 | 3.4 | 7.6 | 0.45 |
| **D16** | 0 | 97.0 | 3 | 0 | 46.33 | 4.0 | 7.8 | 0.51 |
| **D17** | 0 | 100 | 0 | 0 | 50.33 | 3.5 | 5.67 | 0.62 |
| **Ave.** | 7.74 | 89.79 | 0.18 | 2.3 | 50.96 | 3.23 | 5.65 | 0.578 |

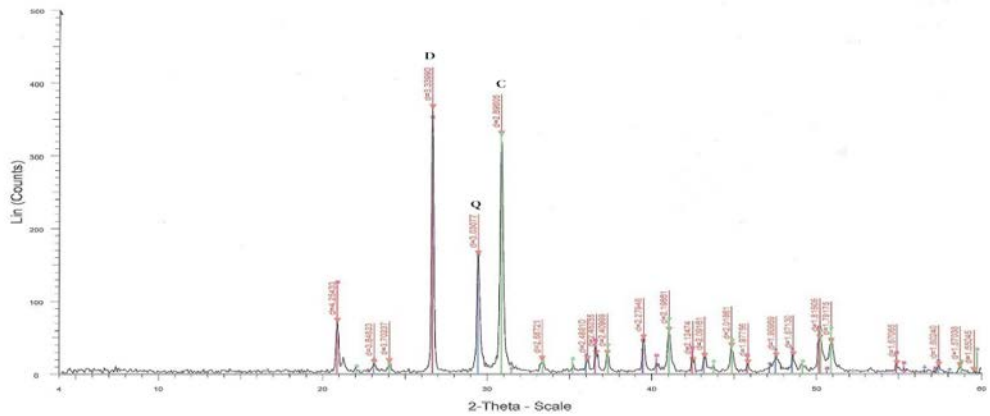


**Figure 7 a:** XRD pattern of the Quartz rich dolostone (Sample ID D2)

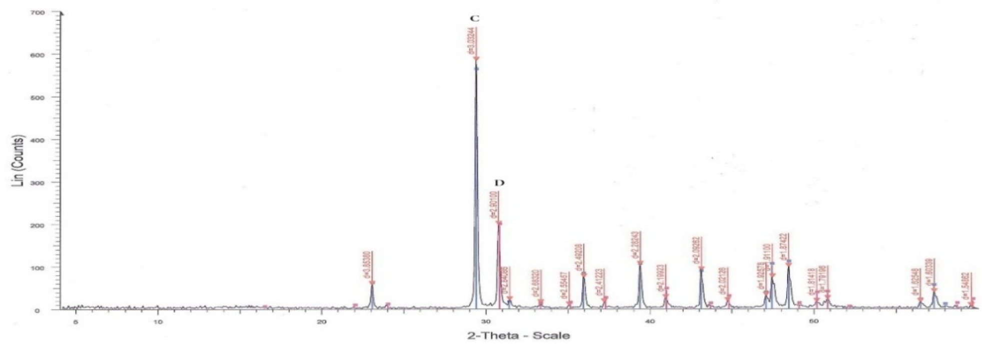


**Figure 7 b :** XRD pattern of the Calcite rich dolostone (Sample ID D6)

Note : D : dolomite ; C : calcite and Q : quartz

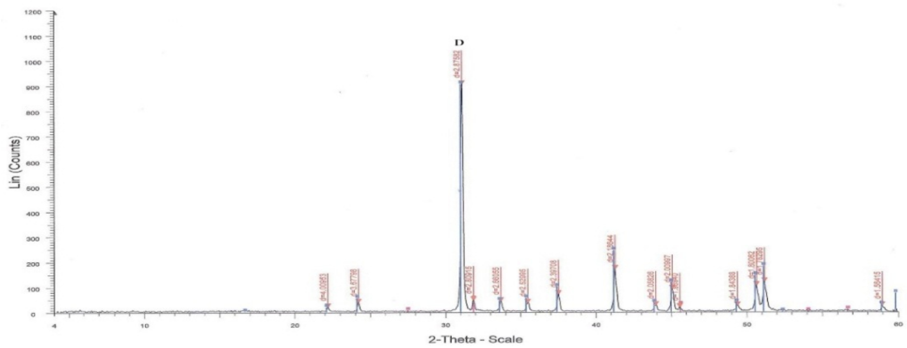


**Figure 7 c:** XRD pattern of Dolomite rich dolostone (Sample ID D 16)

### *4.3. Chemistry*

The oxide contents of the investigated dolostone rock samples of Gabal Ataqa were measured using the XRF technique. The results are listed in Tables (3 &4). The XRF results were found consistent with those of petrographic findings and helped to verify the XRD study and mineralogical composition of the tested dolostone samples.

#### *4.3.1. Major Elements*

Table (3), summaries the data of the major elements distributed in the studied dolostone rocks ..In particular the very high concentrations of LOI, CaO and MgO (Table 3) corroborate mineralogical observations that the carbonate phases are the dominating phases in the investigated rocks .The data clearly fall within the limiting values known for carbonate rocks, which agree with the broad classification of the carbonate rocks. Dolomite is clearly the dominating phase, with calcite as subordinate, while quartz and halite constitute the accessory phase of the rock .

#### *4.3.2. Trace elements*

The trace element distributions in the studied dolostone rocks show that , the average values are as follows: Strontium (Sr) is 116 ppm; Barium (Ba) is 14.0 ppm; very low amounts of Zirconium (Zr) 3 ppm and yttrium (Y) is.0.71 % only. The Sc, Ni and Nb on the other hand are insignificant and not detected.

### *4.4. Geotechnical properties*

Geotechnical properties especially the physical properties are the most readily apparent aggregate properties. They have the most direct effect on how an aggregate performs as either a pavement material constituent or by itself as a base or sub base material. The geotechnical characteristics measured on the core rock samples were bulk density, absorption, porosity and compressive strength. In addition to the bulk specific gravity, saturated specific gravity, apparent specific gravity, Los Angeles abrasion (LAA), disintegration, absorption, and stripping of the crushed aggregates were also determined.

#### *4.4.1. Physical and mechanical properties of Ataqa dolostones*

Table (4) summarizes the physical and strength properties, beside the percentages of insoluble residue of the studied dolostone samples. From Table 4, it can be concluded that the properties vary from sample to sample with the greatest variability in the compressive strength which was found to be in the range of 37 kg/cm$^2$ to 670 kg/cm$^2$ with an average of 217 kg/cm$^{2,}$ . Only one sample (D16) showed the lowest compressive strength value 37 kg/cm$^2$ , which also have very low density ( 1.940 kg/cm$^3$) and very high porosity ( 7.64 % ) and the highest value of water absorption ( 8.79 % ) . While sample (D4) showed the highest compressive value 670 kg/cm$^2$ ,which also have the highest value of density ( 2.714 kg/cm$^3$) and very low porosity ( 0.075 % ) and very low water absorption value ( 0.11 % ). This indicate the inverse relationship between compressive strength and porosity, which affects the water absorption and density. It clear that the clay content in the studied dolostones, sample (D4) have the highest clay content (5.67% ) , not effect on the compressive strength, may be due to the clay particles fill the pore spaces and vugs.While samples D11 and D17 ,showed low compressive values may be due to the presence of some vugs or cracks and fissures in the core samples .

**Table 3:** Major element distributions in the studied dolostone rock samples of Gabal Ataqa

| Sample No. | $SiO_2$ % | $AL_2O_3$ % | $Fe_2O_3$ % | MgO % | CaO % | Na2O % | $K_2O$ % | $TiO_2$ % | $P_2O_5$ % | MnO % | $Cr_2O_3$ % | LOI % | Sum % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D1 | 0.11 | 0.03 | 0.05 | 19.57 | 32.71 | 0.07 | <0.01 | <0.01 | 0.01 | <0.01 | <0.002 | 47.1 | 99.68 |
| D2 | 26.81 | 0.02 | 3.27 | 10.47 | 26.32 | 0.05 | <0.01 | <0.01 | 0.03 | 0.19 | <0.002 | 32.6 | 99.81 |
| D3 | 1.25 | 0.02 | 0.12 | 19.22 | 32.07 | 0.08 | 0.03 | 0.02 | 0.01 | <0.01 | <0.002 | 46.6 | 99.67 |
| D4 | 0.01 | 0.02 | <0.04 | 21.75 | 30.41 | 0.07 | <0.01 | <0.01 | <0.01 | <0.01 | <0.002 | 47.4 | 99.63 |
| D5 | 0.21 | 0.04 | 0.05 | 21.67 | 30.37 | 0.04 | <0.01 | <0.01 | 0.02 | <0.01 | 0.002 | 47.2 | 99.63 |
| D6 | 0.16 | 0.02 | 0.13 | 5.16 | 49.73 | 0.03 | <0.01 | <0.01 | <0.01 | 0.02 | <0.002 | 44.6 | 99.90 |
| D7 | 0.02 | <0.01 | <0.04 | 14.19 | 39.16 | 0.08 | <0.01 | <0.01 | 0.02 | <0.01 | <0.002 | 46.2 | 99.75 |
| D8 | <0.01 | <0.01 | <0.04 | 21.62 | 30.61 | 0.04 | <0.01 | <0.01 | 0.05 | <0.01 | <0.002 | 47.3 | 99.63 |
| D9 | <0.01 | <0.01 | <0.04 | 21.96 | 30.47 | 0.02 | <0.01 | <0.01 | 0.02 | <0.01 | <0.002 | 47.2 | 99.63 |
| D10 | 0.03 | <0.01 | <0.04 | 21.47 | 30.60 | 0.08 | <0.01 | <0.01 | <0.01 | <0.01 | <0.002 | 47.4 | 99.63 |
| D11 | <0.01 | <0.01 | <0.04 | 21.92 | 30.54 | 0.04 | <0.01 | <0.01 | 0.02 | <0.01 | <0.002 | 47.1 | 99.63 |
| D12 | 1.23 | 0.02 | 0.09 | 21.19 | 29.67 | 0.16 | 0.02 | 0.02 | 0.03 | <0.01 | <0.002 | 46.7 | 99.64 |
| D13 | <0.01 | 0.02 | <0.04 | 21.93 | 30.47 | 0.05 | <0.01 | <0.01 | 0.05 | <0.01 | <0.002 | 47.1 | 99.63 |
| D14 | 0.23 | 0.02 | <0.04 | 21.82 | 30.38 | 0.05 | <0.01 | <0.01 | 0.02 | <0.01 | <0.002 | 47.1 | 99.63 |
| D15 | 0.12 | 0.04 | <0.04 | 19.88 | 31.74 | 0.22 | 0.02 | <0.01 | <0.01 | <0.01 | <0.002 | 47.6 | 99.66 |
| D16 | 0.31 | 0.14 | 0.07 | 20.76 | 29.12 | 0.78 | 0.06 | <0.01 | 0.02 | <0.01 | <0.002 | 48.4 | 99.65 |
| D17 | 0.04 | 0.03 | <0.04 | 21.56 | 30.29 | 0.07 | 0.01 | <0.01 | 0.01 | <0.01 | <0.002 | 47.6 | 99.63 |
| Av. | 1.72 | 0.05 | 0.22 | 19.18 | 32.03 | 0.11 | 0.01 | | | | | 46.19 | 99.63 |

### *4.4.2. Physical properties of dolostones coarse aggregate*

Ten coarse aggregate represent the aggregate production of the current crushers located at the studied sites. Samples from these crushers were collected to evaluate the final aggregate product of these crushers which is used in concrete and pavement construction. The produced crushed aggregate is divided into to two sizes. The crushed aggregate size # 2 which ranges in size from 19 mm to 10 mm and crushed aggregate size # 1 which ranges in size from 10 mm to 4.75 mm. The physical Properties of the crushed dolomite coarse aggregate are listed in Table (5). Specific gravity of a particular aggregate helps in determining the amount of asphalt needed in the hot mix asphalt. There is no specific limits for specific gravity. Water absorption of aggregate is very important property. This property affects the bond between aggregate and asphalt cement. The studied crushed aggregate size # 2, has an average absorption value of 1.13%., while the average absorption value of the aggregate size # 1, is 1.5% achieving the required specifications of 5% maximum absorption according to the Egyptian code of highways. Absorption above 5% tend to make HMA mixtures uneconomical, because extra binder is required to account for the high aggregate absorption. The water absorption values of the crushed aggregates, generally are lower than that of the core rock samples due to the weak particles in the rock removed during crushing and sieving processes. The average value of disintegration of coarse aggregate size # 2, is 0.71%, while the coarse aggregate size #1, have an average disintegration of 1.06 %. Generally, the disintegration values of the coarse aggregate size #2 are lower, compared to the coarse aggregate size #1. Los Angeles abrasion (LAA) test provides a clear perception for abrasion, hardness, degradation and disintegration of the aggregate.

The average LAA of coarse aggregate size # 1 is slightly higher than that of coarse aggregate size #2 (25.14%. and 22.3%.) respectively . Aggregate in HMA must be durable enough to stand up to production, transportation and construction processes, as well as the long-term effects of load and environmental stresses.

Therefore, LAA of the studied samples indicates that the studied aggregate is tough and have good resistant to abrasion. The test results of LAA for the investigated samples falls within the accepted limits according to Egyptian code of highways not more than 40% for HMA and 50 % for base and sub base layers. Stripping is a major problem in pavement construction, especially in countries with wet climate.

**Table 4:** Physical & strength properties of Ataqa rock Samples

| **Core No.** | **Sample ID** | **I.R %** | **Carbonate %** | **Sand%** | **Clay%** | **Compressive Strength Kg/cm$^3$** | **Density gm/cm$^3$** | **Porosity %** | **Absorption %** |
|---|---|---|---|---|---|---|---|---|---|
| 1 | D1 | 1.614 | 98.39 | 1.04 | 0.51 | 207 | 2.395 | 0.540 | 1.03 |
| 2 | D2 | 1.819 | 98.18 | 1.24 | 0.55 | 359 | 2.516 | 0.079 | 0.52 |
| 3 | D3 | 2.001 | 97.99 | 1.36 | 0.62 | 159 | 2.341 | 2.137 | 2.33 |
| 4 | D4 | 10.35 | 89.65 | 4.68 | 5.67 | 670 | 2.714 | 0.075 | 0.11 |
| 5 | D5 | 0.207 | 99.79 | N.d | N.d | 186 | 2.304 | 1.619 | 3.33 |
| 6 | D6 | 0.561 | 99.44 | N.d | N.d | 152 | 2.358 | 0.556 | 2.22 |
| 7 | D7 | 3.064 | 96.94 | 1.35 | 1.38 | 138 | 2.292 | 0.431 | 2.23 |
| 8 | D8 | 5.321 | 94.68 | 2.42 | 2.90 | 138 | 2.397 | 1.265 | 1.26 |
| 9 | D9 | 3.585 | 96.42 | 1.56 | 2.02 | 240 | 2.539 | 0.344 | 1.15 |
| 10 | D10 | 6.735 | 93.27 | 3.12 | 3.61 | 110 | 2.637 | 0.039 | 0.04 |
| 11 | D11 | 4.861 | 95.14 | 2.08 | 2.78 | 83 | 2.594 | 0.437 | 0.56 |
| 12 | D12 | 3.982 | 96.02 | 1.74 | 2.24 | 352 | 2.646 | 0.074 | 0.45 |
| 13 | D13 | 3.874 | 96.13 | 1.62 | 2.25 | 339 | 2.706 | 0.137 | 0.61 |
| 14 | D14 | 3.618 | 96.38 | 1.64 | 1.98 | 173 | 2.604 | 0.434 | 0.26 |
| 15 | D15 | 5.608 | 94.39 | 2.44 | 3.17 | 270 | 2.287 | 3.874 | 4.51 |
| 16 | D16 | 0.757 | 99.24 | N.d. | N.d | 37 | 1.940 | 7.641 | 8.79 |
| 17 | D17 | 3.626 | 96.37 | 1.58 | 2.04 | 74 | 2.470 | 0.291 | 0.73 |
| Avg. | | 3.623 | 96.38 | 1.64 | 1.87 | 217 | 2.455 | 1.174 | 1.77 |

Note : I.R. Insoluble residue N.d. : Not determined

Different mechanisms contribute to the stripping phenomenon, but one of the key parameters is the adhesion between aggregate and binder. In many countries tests on loose coated aggregates, generally referred to as immersion or bonding tests are preferred.

The asphalt-stripping test according to [21], was conducted for the present study. Results showed that the dolomite coarse aggregate samples had stripping values ranging from 1.0% to 26.0%, with an average of 12.40%. The test was only conducted on the crushed aggregate size #2,as it is a visual test .

**Table 5:** Average and range values of physical properties of studied crushed aggregate size #2 & 1

| | | **Bulk sp. gravity gm/cm3** | **saturated sp. gravity gm/cm** | **Apparent sp. gravity gm/cm** | **los-Angeles Abrasion%** | **Disintegration %** | **Absorption %** | **Stripping %** |
|---|---|---|---|---|---|---|---|---|
| | Av. | 2.552 | 2.572 | 2.588 | 22.3 | 0.71 | 1.13 | 12.4 |
| Cr.Agg.2 | Min. | 2.42 | 2.45 | 2.51 | 19.7 | 0.20 | 0.6 | 1 |
| | Max. | 2.61 | 2.64 | 2.69 | 26.2 | 2.33 | 1.63 | 26 |
| | Av. | 2.54 | 2.57 | 2.61 | 25.14 | 1.06 | 1.50 | n.d. |
| Cr.Agg.1 | Min. | 2.34 | 2.40 | 2.50 | 22.0 | 0.1 | 0.80 | n.d. |
| | Max. | 2.62 | 2.65 | 2.68 | 31.0 | 3.9 | 2.82 | n.d. |

### *4.5 Summary and Conclusions*

Petrographic, mineralogical chemical, and compressive strength of Ataqa dolostone rocks beside, geotechnical properties of the produced coarse aggregates were investigated. Los Angeles Abrasion, apparent specific gravity, water absorption, disintegration, and stripping were evaluated. On the basis of the geological and geotechnical scheme , the petrograhical , mineralogical ,chemical and engineering properties ,the dolostones rocks of gabal Ataqa,Egypt are judged adequate for pavement,concrete and engineering works.

- The dolostone rocks of Gabal Ataqa are massive, durable and unfossilferious .
- The mineral composition of the studied dolomite rocks consists mainly of 89.79 % dolomite, 7.74 % calcite and traces of quartz and halite.
- The investigated dolostone rocks are around stoichiometric having value ranging between 50.33 and 55.00 percent CaCO3,thus the Ataqa dolostone may be considered belonging to dolomite of late diagentic.
- The average value of CaO of the tested dolostone rocks is 32.03 %, while the average MgO is 19.18%, whereas the average loss on ignition is 46.19 % with a very low content of $Al_2O_3$ .This indicates that the clay mineral in dolomite is not significant.
- The compressive strength of dolostone rocks increase with the increasing of density and reduction in porosity.
- Los Angeles abrasion values and the physical properties of dolostone coarse aggregate are acceptable. The studied dolostone samples have good affinity to bituminous materials.

The above properties match within the ASTM specification and the Egyptian code of highways limits and mark the dolomite coarse aggregate of Gabal Ataqa as a suitable source for concrete and asphalt.

### *4. 6. Recommendations*

- Petrographic, mineralogical chemical, and compressive strength investigations is very important and must be carried out on the rocks for evaluating it for construction purposes before starting coarse aggregate production.
- Geotechnical properties of the produced coarse aggregates must be carried out in regular basis by qualified and competent persons .
- The crushers and production scheme must be followed by third party to review the crushers products especially coarse aggregates.

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