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Geotechnical properties of Galala Limestone Tiles, Eocene rocks, Ain El Sukhna, Red Sea Coast, Egypt

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Abstract: Galalalimestone has been increasingly popular for building and ornamental applications and very famous in the world by many commercial names, Galala White, Galala Golden, GalalaCreama and Galala Classic. In this study the effect of petrographical aspects on the physical and mechanical properties of different types of the Galala limestone will be elaborated.

The physical and the mechanical behavior of the studied rocks have been outlined by measuring some physico-mechanical properties, such as apparent density, open porosity, water absorption,abrasion resistance, compressive strength, and slip resistance. The rocks also have been investigated by XRD and XRF.
Keywords: Mechanical properties; Galalalimestone; Dolomite, Middle Eocene, Porosity, Abrasion resistance.

1. Introduction

Natural stone is one of the most common construction materials, to be used for interior and exterior walls of buildings. Natural stone must satisfy standardized physical and mechanical requirements Yagiz[1].The Galala Eocene rocks and its units have been described and classified by many Authors including Sadek[2],Moon and Sadek[3], Abu El-Enain[4].

The Galala plateau is a high plateau and located in the North Eastern Desert of Egypt (Fig.1).The quarry under investigation (Galala quarry) is located in the central part of El-Galala El-Baharriyaplateau and bounded by latitude29°32'Nand longitudes 31°54'Eand is accessible by asphaltic road of Sukhna –Suez road (Fig.1).

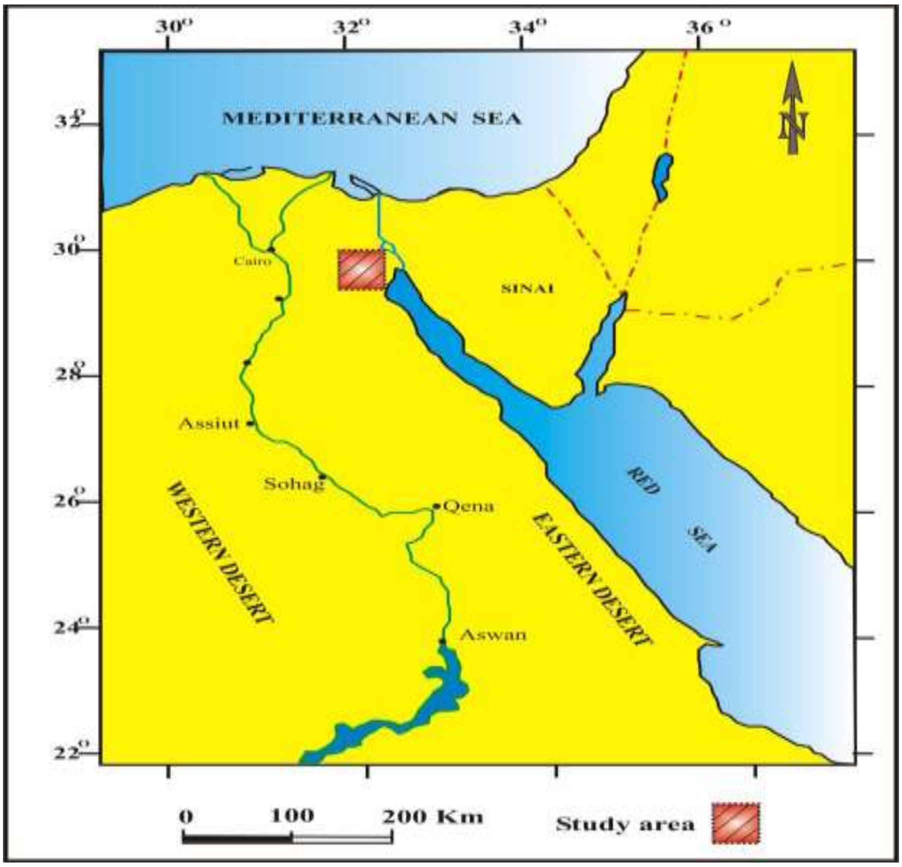

Fig.1.Locationmap of the of the study area (Gebel Galala El-Bahariya)

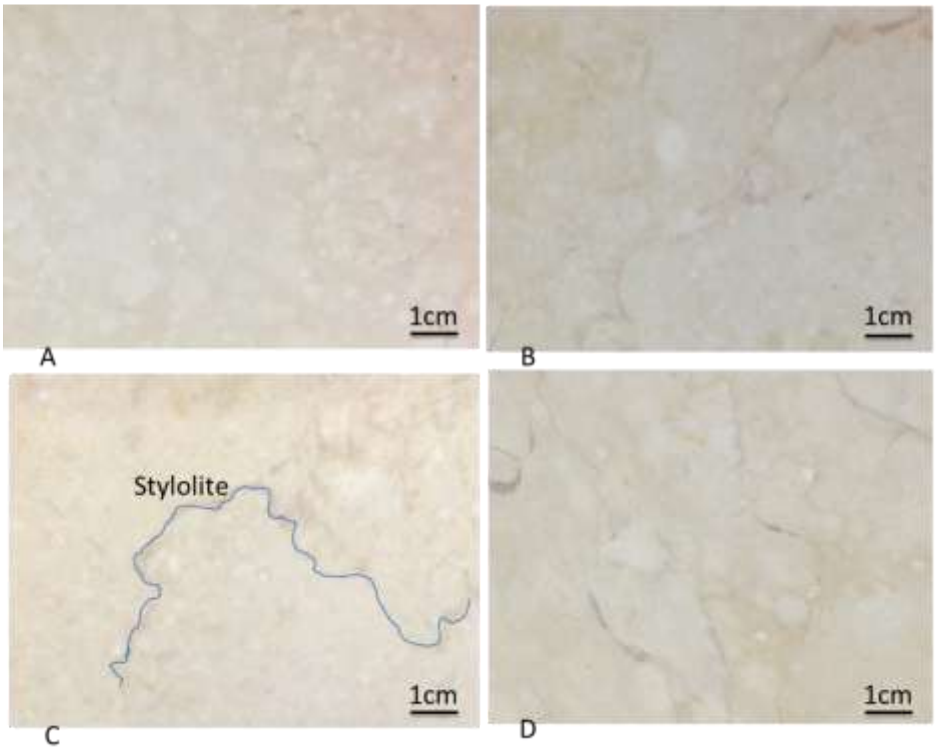

Fig.2.Photographs showing different types of Galalal limestone tiles and megascopic features of stylolite.

Stratigraphically, the sedimentary succession of the Galala quarry is belonging to Thebes Formation Middle Eocene age which introduced by many authors in many places. In the study area, the exposed stratigraphic section is composed of thick beds of varied colored crystalline hard, massive, compact, jointed, and highly fossiliferous limestone rich in nummulites and pelecypodes. The carbonate beds in the studied quarry vary in colors and they are characterized by stylolite seams which extend across the bedding planes.

Four main Galalalimestone varieties are produced from the quarry (Fig.2) and they are known commercially as:

A-Galala White
B- Galala Golden
C- GalalaCreama
D-Galala Classic

The present work aims to provide new geotechnical data for the different types of Galala limestone and its suitability to be used as tiles and an assessment of their quality as building stones through field, geotechnical and geochemical investigations.

2. Lithostratigraphy

2.1. Thebes Formation

At Gebel El Galala El Baharriya (Northern Galala quarry), the Thebes Formation occurs as isolated conical hill with steep slopes and rounded to nearly flat-topped crest with maximum thickness (about 715 m thick). On the basis of its lithological characteristics, the Thebes Formation is subdivided into five microfacies. The lithological column of the section represents a certain horizon of the Thebes Formation in a Galala quarry is shown in Fig.3.

2.2. Petrography

Petrographic study for 40 rock samples has been carried out in order to assess the importance of the main mineralogical composition and comparing to the physical and mechanical properties of the envisaged rock tiles. The recognized microfacies types according to Dunham's[5]classification is as following from top to bottom:

Age	formation	Thickness (from top to bottom) m	Bed No.	Description
Eocene	Thebes formation	5	A	Limestone: white to yellow color, massive, with chertnodulus.
		7	B	Limestone: white to yellow color, massive, and clayey.
		10	C	Limestone: beige to pink color, hard, massive, with highly stylolite.
		17	D	Limestone: yellowish brown, moderately hard,compact with pink patches.

Fig.3. Lithological column of the investigated quarry in the study area

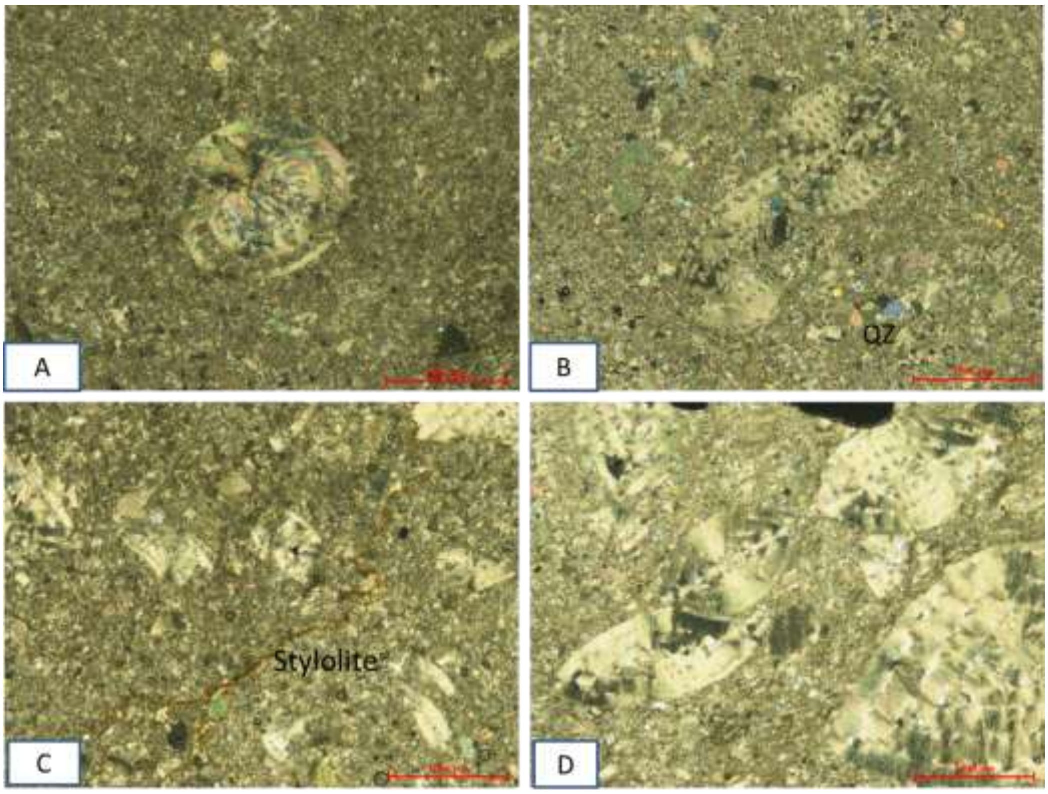

Fig.4.Photomicrographs of Eocene carbonate

A: Packstone (Galala White)showingnummulitiestestswith its original radial texturesembedded in a micrite matrix (CN).

B:Shelly oyster packstone (Galala Golden) showing nummulites fragments embedded in a micrite matrix showing aggrading neomorphism with quartz grains which indicated by XRF test as a high content of Sio_2 (CN).

C:Nummuliticpackstone to wackstone (GalalaCreama) showing nummulites fragments embedded in a micrite matrix with stylolite deformation (CN).

D: Nummuliticpackstone(Galala Classic) showing allochems of plankatonic foraminifera, pelecypodes fragments, echinoids, stylolite and nummulities(CN).

2.2.1. Wackstone to Packstone

The rock consists of massive, compact and whitish to creamy yellowlimestone. Petrographically, the rock is composed of pelecypodes, sponge fragments, echinoids and nummulities are partly recrystallized.The matrix is micrite converted to sparite as aggrading neomorphism(Fig. 4A).

2.2.2. Shelly Oyster Packstone

It consists mainly of fossiliferous limestone,beige to reddish, massive, and moderately hard .This microfacies consists of mainly of oyster shell fragments (85 %) , gastropods (2 %),nummulites (4%) and echinoids (3%). The skeletal particles and echinoids particles are altered completely into coarsely crystalline calcite. The matrix represented mainly by a dense micrite(Fig. 4B).

2.2.3. NummuliticPackstone to Wackstone

The rock composed of white nummmulitic chalky limestone. Petrographically, this microfacies consists mainly of oyster shell fragments, pelecypods, nummulites and echinoids embedded in a dark dense micrite. Stylolite are commonly exist that result from mechanical stress which cause brittle failure of the rock components (Fig. 4C).

2.2.4. NummuliticPackstone

This microfacies consists of allochems of larger benthic foraminifera and bioclasts that embedded in a sparymicrite groundmass containing few scattered, fine-grained quartz grains. Petrographically, it is consists of plankatonic foraminifera , pelecypodes fragments , echinoids , oyster fragments, bryozoan remains and the walls of zooids replaced by quartz grains and chambers are filled with micrite , ferrugination and secondary silica filling (Fig. 4D).

3. Materials and methods

Four different types of the Galala limestone were collected from theGalala quarry. The stones were sawed to appropriate dimensions and analyzed according to the European standards at laboratoryofthe Ministry of Trade and Industry -Mining Industry and Marble Technology Center.

3.2. Laboratory tests

A total of 388 samples were collected from the highest level of the quarry for further laboratory testing.

3.2.1. Apparent density

Apparent density was carried out accordance with EN1936[6]on specimens approximately 50*50*50 mm, and can be defined as the ratio between the mass of a dry specimen and its apparent volume. It is reflects the degree of compaction of the stone.

3.2.2. Open porosity

The open porosity is directly related with important stone characteristics, such as the mechanical strength and the behavior in presence of liquids. When porosity is higher, the mechanical strength is lower and liquids can be more easily absorbed by the stone. For determining open porosity 50*50*50 mm cubes were tested in accordance with EN1936[6]

3.2.3. Water absorption

Absorption reflects the ability of a stone to take up liquids and gases. The test was carried out on specimens 50*50*50 mm according to EN 13755[7]

3.2.4. Abrasion resistance

Abrasion is defined as the wear caused by fine solid particles. The test is carried out by abrading the face of a sample, with an abrasive material (Corundum powder) in accordance with EN14157[8]on specimens 150*100*50 mm.

3.2.5. Compressive strength

The uniaxial compressive strength is the load per unit area, under which a block fails by shear. The test carried out in accordance with EN1926[9]on specimens 50*50*50 mm.

3.2.6. Flexural strength

Flexural strength represents mainly the resistance to flexure deformation. The samples, with standardized dimensions 150*75*25 mm, are placed and centered on two bars and carried out according to EN12372[10]

3.2.7. Dynamic modulus of elasticity

The dynamic modulus of elasticity is a measure for the stone strength. The test was carried out in accordance with EN 14146[11]on specimens 100*100*200 mm.

3.2.8. Frost resistance

Freeze-thaw resistance is certainly the most important property to consider when specifying a stone type for external use, because if frost damage occurs, it is so destructive. The samples undergo 48 cycles of frost in air and defrost in water, followed by a compression or flexure test. The test was carried out in accordance with EN 12371[12]

3.2.9. Resistance to thermal shocks

Thermal shock refers to the stress that a stone undergoes when it is subjected to abrupt temperature changes, inside as well as outside. All the composing minerals will expand in relation with their thermal expansion coefficient. This test was carried out in accordance with EN 14066[13]on specimens 200*200*20 mm.

The result obtained from the analysis of the physical and mechanical values of the Galala limestone are summerized in Table 1.

Table 1: Average values of physical and mechanical parameters of the different types of the Galala limestone tiles.

Tests	Galala White(I)	Galala Golden(II)	Galala Creama(III)	Galala Classic(IV)
Apparent density (Kg/m3)	2649.7	2633	2642.3	2622.8
Open Porosity (%)	1.9	2.5	2.2	2.7
Water Absorption (%)	0.9	0.8	0.8	0.6
Abrasion Resistance (mm)	22.8	23.3	23.5	25.1
Slip Resistance (C Scale)	64.2	63.5	63.0	57.3
Dowel Hole (N)	1786.9	1812.7	1989.0	2033.0
Thermal Expansion (C Scale)	3.69E-06	3.77E-06	3.90E-06	4.00E-06
	X Direction			
	Y Direction			
	3.60E-06	3.69E-06	3.73E-06	3.90E-06
Compressive Strength (MPa)	Load Perpendicular			
	101.1	105.2	121.7	138.0
	Parallel Load			
	93.0	108.2	96.4	126.5
Flexural Strength (MPa)	15.8	15.6	14.0	12.2
Compressive Strength after freezing (MPa)	Load Perpendicular			
	95.3	99.5	124.6	132.1
	Parallel Load			
	80.5	86.3	128.6	134.7
Flexural Strength after freezing (MPa)	10.6	10.5	11.0	10.9
Dynamic Modulus %	7.2(EXT.), 4 (FL.)	11(EXT.), 6.3 (FL.)	14 (EXT.), 110 (FL.)	28 (EXT.), 34 (FL.)

3.3. Mineralogy and Geochemistry

As much as 12 representative samples of the studied tiles were analyzed using XRF technique in the laboratories of the Geological Sciences Department, National Research Center, Egypt (Table 2).

1. The main major oxides (such as CaO, MgO, FeO, SiO_2, Al_2O_3, Na_2O, and K_2O), minor oxides (such as P_2O_5, SO_3,), and the trace elements (such as Sr, Ba, Zr, Zn, Ni, Mn, and Cu) were analyzed.
2. Loss on ignition (LOI) was determined by igniting one gram of the sample in a weighed crucible at 1000◦C in the Muffle Furnace for 2 hours.
3. The main major minerals such as calcite were detected using XRD technique in the laboratories of the El Tabbin Institute for Metallurgical Researches, Egypt (Fig.5).

Table 2: Chemical analysis of major and minor elements of the GalalaLimestonetypes

Concentration of main constituents	Galala White	Galala Golden	Galala Creama	Galala Classic
SiO_2	0.85	1.55	0.78	0.68
Al_2O_3	0.16	0.13	0.15	0.10
Fe_2O_3	0.04	0.03	0.04	0.02
MgO	0.23	0.21	0.20	0.24
CaO	55.82	55.31	55.98	55.96
Na_2O	0.06	0.07	0.055	0.04
P_2O_5	0.05	0.03	0.04	0.02
SO_3	0.04	0.03	0.03	0.03
L.O.I	42.71	42.59	42.68	42.85
Cl	0.015	0.011	0.004	0.014
CuO	--	0.004	0.006	0.004
SrO	0.030	0.031	0.028	0.037

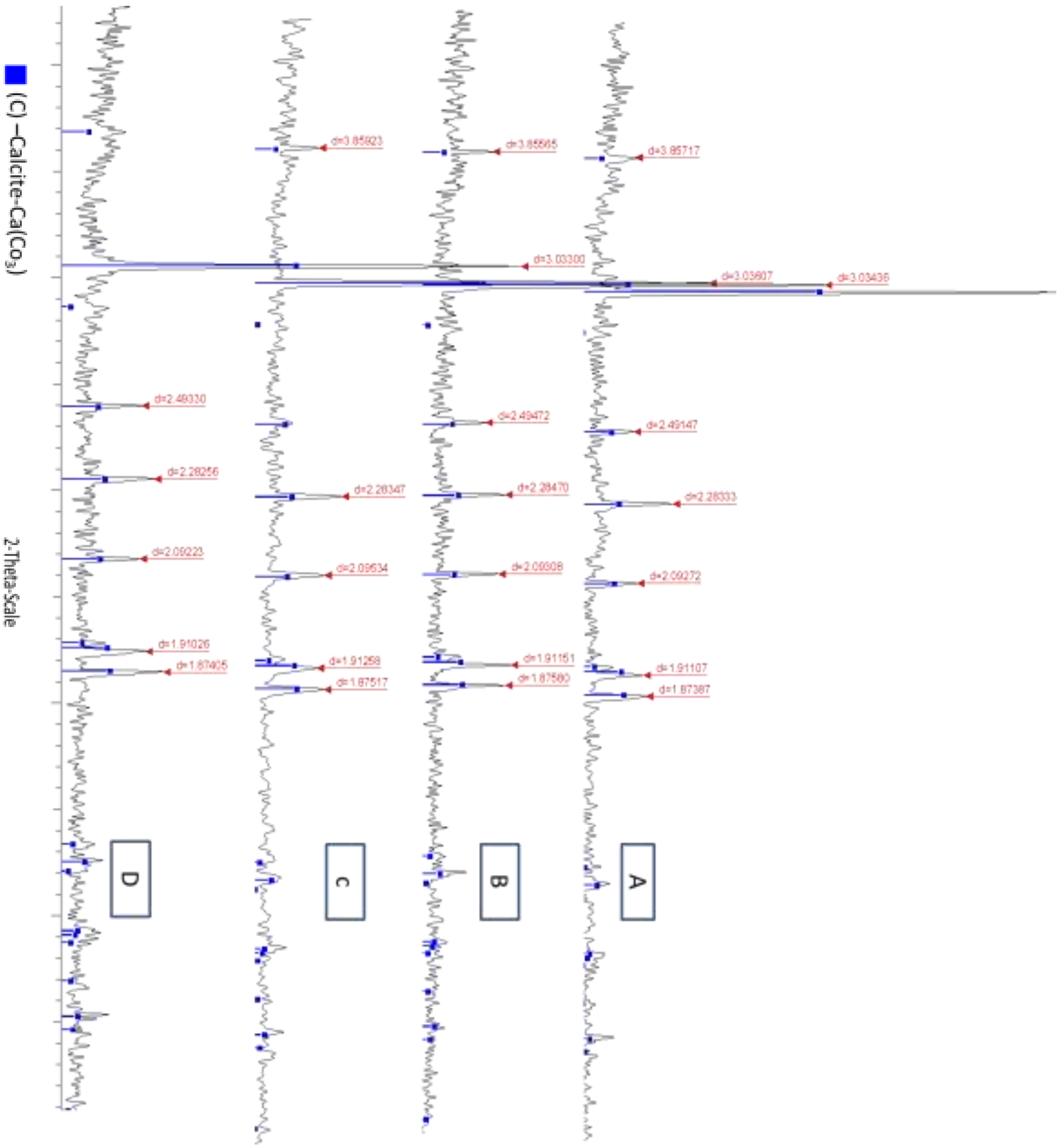

Fig.5. XRD analysis of the Galala Limestone Tiles, (A) Galala White ,(B) Galala Golden ,(C) GalalaCreama , (D) Galala Classic

4. Result and discussion

(1) The studied Galala limestone types are characterized by high CaO content and low MgO content. CaO content varies from 55.98 to 55.31 % while the MgO content ranges from 0.24 to 0.20%

However, due to its high mobility, Na in original carbonates can be modified greatly during diagenesis. Scoffin[14]reported that, Na occurs in modern carbonate sediments to levels of about 3,000 ppm and progressively drops with diagenesis to 200 ppm in the ancient limestone. Ernest[15]concluded that the concentration of Na higher than 0.3% indicates marine influence, while a very low concentration less than 0.05% indicates contribution of freshwater, which is the case of the studied carbonates.

From the above data, it is clear that the studied limestones did not display a significant variation in their chemical composition. These limestones are characterized by very high $CaCO_3$ content and relatively low Mg content. No dolomite has been recorded neither petrographically nor chemically.

4.1 Influence of textural properties on the physical properties

The relationships between apparent density and open porosity shows a general trend of increasing density with decreasing porosity and also water absorption

Decreases by decreasesopen porosity (Figs.6A and 6D).

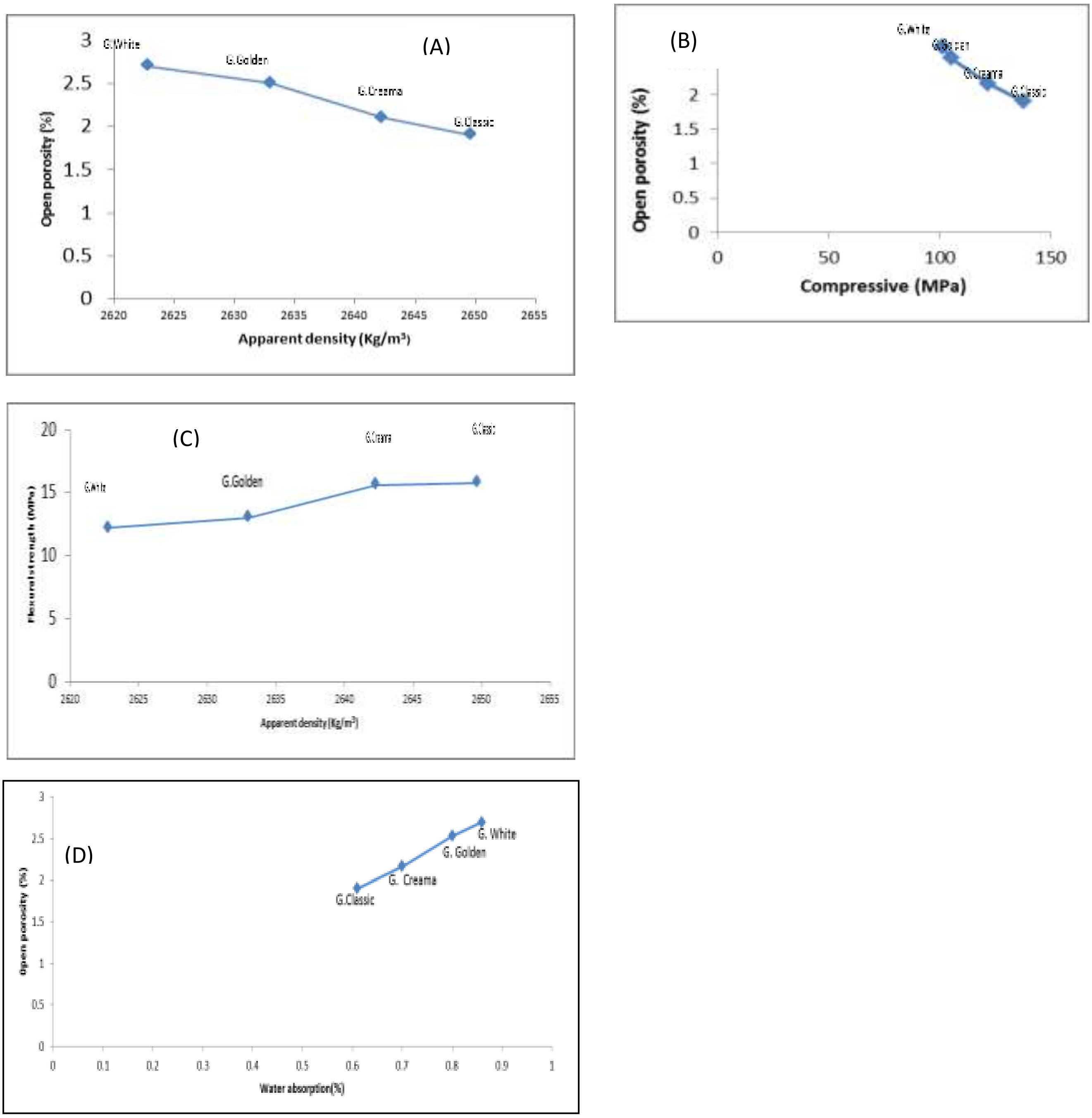

Fig.6 . Binary Diagrams of different parameters
(A) Relation between apparent density and Open porosity, (B) Relation between open porosity and compressive strength, (C) Relationships between apparent density and flexural strength,(D) Relationships between open porosity and water absorption.

As shown in (Fig.6B), as open porosity increases, compressive strength of the rock decreases, astheGalalaClassic type shows anincrease in the compressive strength .As apparent density increases, flexural strength of the rock increases where there is no stylolite (Fig.6C).

4.2. Physical and mechanical properties of the Galala tiles

The apparent density of a rock is influenced by the density of the minerals, their content and amount of void space inside the rock Bell and Lindsay[16]

In the investigated samples, the apparent density showed little variation due to the presence of clay as a matrix in all the samples, but the Galala Classic type displayed the highest value as it contains large amount of fossils which were filled by sparite (Fig. 4D). Also the open porosity varied slightly and show low value at the Galala Classic type. The obtained value of water absorption (from 0.6 to 0.9 %) indicates low water absorption; also the GalalaClassic type displayed the lowest value due to the low content of clay as a matrix. The abrasion test displayed its highest value at the GalalaClassic type;it is influenced by the presence of fossils content more than the other types. The Breaking load at dowel hole influenced the presence of fracturing, compaction and cementation. The Galala Creama and GalalaClassic types have the highest values, which give an indication to the good compaction. The dry unconfined compressive strength values vary between 138 and 121.7.The highest value is possessed by the Galala Classic type, in both directions of planes of anisotropy (load perpendicular and parallel to the planes), that is influenced by the percentage of fossils filled by spary calcite, Compaction, the percentage of water absorption and the percentage of clay. While flexural strength increases with the increase of the apparent density, so that the GalalaClassic possessed the highest values.

5. Conclusion

This study emphasized four lithological types of Galala limestone. The values of physical and mechanical properties indicate the good quality of Galala Classic.The petrological, textural and structural characteristics have an impact on the numerical values of its physical and mechanical properties.

Relationship between physic-mechanical properties showed eminent variation in important mechanical parameters. The result of the relations suggests that as the apparent density increases the open porosity decreaseswhichhave an important role in determining the suitable application of the stone. Also as open porosity increases, compressive strength of the rock decreases. The low value of water absorption is in agreement with that value of the porosity. As in samples of Galala Classic with a porosity value of 1.9 %, the water absorption was very lowor micro-cracks unable to receive and retain water. The low values of water absorption indirectly imply limestone resistance to frost.

The mechanical properties results of the Galalatiles point to their quality which are in accordance with the petrological characteristics to reflect their ability to be used in floor tiles, interior and exterior cladding, production of paving material and mosaics. Galala Classic is strong regarding the unconfined compressive strength. Simultaneously, it is hard concerning its wear abrasive. Samples with high value of strength and lower value of abrasive resistance correspond to micrite, and fossiliferousmicrite. On other hand, samples with low value of strength and poor resistance to wear related to the clay content.

References

1. Yagiz, S. (2010): Geomechanical properties of construction stones quarried in south-western Turkey. Scientific research and essays, 750–757.
2. Sadek, H. (1926): the geography and geology of the district between Gebel Ataqa and El Galala El Bahariya (Gulf of Suez). Geological Survey of Egypt, p. 1-120.
3. Moon, F. Sadek, H. (1923): Preliminary geological record on WadiGharandel area. Petroleum Research Bulletin, 12: 1-42.
4. Abu El-Enain, F. M.; Ali, M.M., and Ismail, A.S. (1995): Petrography, geochemistry and depositional history of the Eocene rocks in the area between northenGalala and GabalAtaqa, Western Gulf of Suez, Egypt. Annals Geol. Surv. Egypt, V.XX, 551-576.
5. Dunham,R.,J.(1962):classification of carbonate rocks according to depositional texture, classification of carbonate rocks, American Association of petroleum Geologists Memoir.1, pp.108-121.
6. Natural stone test methods, BS EN (1936:2006): Determination of real density and apparent density, and of total and open porosity.

7. Natural stone test methods, BS EN (13755:2006): Determination of water absorption at atmospheric pressure.
8. Natural stone test methods, BS EN (14157:2004): Determination of abrasion resistance.
9. Natural stone test methods, BS EN (1926:2006): Determination of compressive strength.
10. Natural stone test methods, BS EN (12372:2006): Determination of flexural strength under concentrated load.
11. Natural stone test methods, BS EN(14146:2004): Determination of Dynamic modulus of elasticity.
12. Natural stone test methods, BSEN (12371:2001):Determination of frost resistance.
13. Natural stone test methods, BSEN (14066:2003):Determination of thermal shock
14. Scoffin, T.P. (1987): An introduction to carbonate sediments and rocks. Chapman and Hall, New York.
15. Ernest, W. (1970): Geochemical facies analysis. In: Methods in geochemistry and geophysics. Elsevier Publ. Co., Amsterdam
16. Bell, F.G.,Llindsay, P. (1999): the petrographic and geomechanical Properties of some sandstone from the Newspaper Member of the Natal Group near, Durban, South Africa. Engineering Geology, 53: 57–81.

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