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Evaluation of the Waras Serpentinite Rocks for Dimension Stone, Mawat Ophiolite Complex, Kurdistan Region, NE Iraq

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ABSTRACT

The Mawat ophiolite complex (MOC) is a part of the Zagros Suture Zone, which extends of about 2000 km from southeastern Turkey through northern Syria and Iraq to western and southern Iran. The serpentinite rocks are exposed at Waras area near Betwat village. Serpentinite rocks from this area have been studied to assess their suitability for use as dimension stone. Ten samples were collected in the studied area to establish their physical and mechanical properties. Petrographic studies indicate that the serpentinite rocks in the studied area are composed mostly of serpentine minerals so the results of the color measurement show multiple colors of the studied samples after polishing which are grayish green, greenish black, brownish black, olive brown and dark yellowish green. Physical properties for the studied samples were determined they show low bulk density while the water absorption for all the studied samples except sample (10) show suitability for the interior uses, as well as only the samples (4, 6, 7, 8 and 9) exhibit suitable range of interior and exterior uses. The results of the compressive strength and modulus of rupture of the studied samples are below the requirement. According to the American Standard for Testing and Materials, ASTM C1526-02(2002) the serpentinite rocks from Waras area is not suitable for the use as dimension stone.

Introduction

Dimension stone includes different kind of naturally occurring stones utilized in the outside and inside enhancement of buildings (e.g. marble, granite, gabbro, serpentine, gneiss, limestone, and sandstone) [1]. The reasonableness of various rock types was evaluated based on the opportunity of extracting huge pieces, the appearance of the stone when cut and polished, the accessibility of the site and the mechanical properties of the stone [2]. The extreme success in marketing a dimension stone includes firstly its appearance and secondly within the opportunity of manufacturing rectangular squares of reasonable dimensions [3]. Indeed, the United School of Business Management (USBM) defines dimension stone as "naturally occurring rock material cut, formed or selected for use in blocks, sheets, slabs or other construction units of specialized shape and sizes"[4]. Hence some authors select the term "ornamental stone" for the term dimension stone [5]. The Mawat ophiolite complex MOC is of Cretaceous period as a residue of oceanic crust covers approximately 200 km², Northeastern Iraq [6]. Serpentinites are rocks composed mainly of serpentine minerals; lizardite, chrysotile and antigorite with accessory magnetite, brucite and Mg and Ca-Al silicates. Serpentinites are usually formed by low-temperature hydrothermal metamorphism of peridotite, pyroxenite, gabbro, marble and silicate dolomite [7]. Serpentinites are very heterogeneous rocks due to their mineralogical and structural variability; they were utilized as construction substance on the grounds that historic times; many historical buildings and monuments are made of those vital history stone [8,9]. So [10], characterize

serpentinites, among other stones determining their diverse behavior related to the degree of alteration. Other authors [11] have evaluated the serpentinites from Macael (South of Spain) utilized as dimension stone, obtaining different consequence with regard to their mechanical residences, because of the mineralogical differences between samples. Hence the main aim of this study is to assess the serpentinite rocks of the Waras vicinity near Betwat village from the MOC as dimension stone.

To avoid unexpected behavior of serpentinites as well as to understand the behavior of serpentinites utilized as dimension stones, a complete characterization of the rock, with respect to their mechanical properties, geochemistry and mineralogy data should be available.

The geology of MOC has been studied by some earlier researcher [12 - 32] all of them focused on petrography, geochemical investigation, origin, structural and tectonic setting of rocks. This work is attempted to study the serpentinite rock for dimension stone which cover extensive area from MOC at Waras area near Betwat village. Other authors [33] have evaluated the carbonate rocks from Pilaspi Formation at Qara Dagh area for dimension stone indicated that the rocks are acceptable for use as dimension stone.

Geological Setting

Waras is a part of MOC located at the intersection of latitude (35° 47' 31" N) and longitude (45° 30' 66" E), which composed of different type of rock such as serpentinite, gabbro, meta gabbro, meta basalt and meta diabase (**Fig.1**) The sampling is from the outcrop of the serpentinites at Betwat village, which is far from Sulamania city by about 25 km southeast of Mawat area (**Fig.2**).

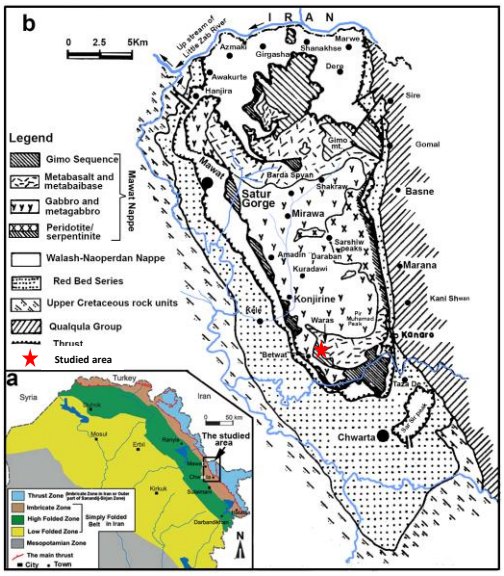

Fig. 1: (a) Tectonic and location map of the study area, (b) Geological map of Mawat- Chwarta area [34].

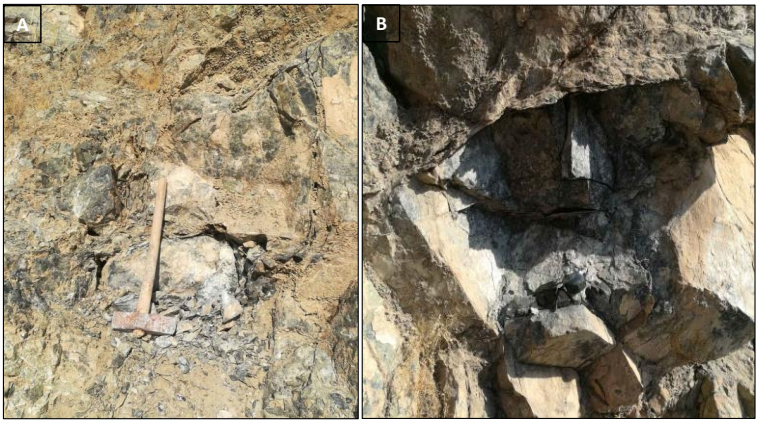

Fig. 2: (A) Massive serpentinite rocks of Betwat village. (B) Fresh surface color of serpentinite showing dark green to black color.

The MOC is a part of the Zagros Suture Zone, which extends of about 2000 km from southeastern Turkey through northern Syria and Iraq to western and southern Iran [35]. The importance of the ophiolite complex come from its distribution and its situation within the orogenic belts related to the plate tectonics. Geologically, Mawat nappe as one of the structures in the area is composed of metamorphosed igneous rocks (Mawat ophiolite complex) and metasedimentary rocks (Gimo sequence) which situated on the top of Walash-Naoperdan rocks. Lithologically, the MOC from bottom to top is composed of tectonic peridotite, gabbro, dykes, metamorphic pillow lava that was affected by silicitization and radiolarian chert of marine sediment [36].

Materials and Methods

For this study, ten serpentinite rock samples from Waras area were collected, the samples were randomly collected depending on the physical appearance especially color.

Two thin sections of ten serpentinite samples were prepared for petrographical study using polarized microscopes which are samples 1 and 9. The specimens tested were prepared as cubes roughly 50 mm in all dimensions to measure the physical properties which include porosity, water absorption and bulk density based on the [37]. The mechanical

study (compressive strength and modulus of rapture) were carried out at the Department of Geology/University of Sulaimani using [38] and [39] respectively. The colors were determined using Geological Rock-Color Chart with genuine Munsell color chips (2009). The color of the studied samples is determined by polishing the surface of the rock by sand paper to appear the color of the constituent minerals and comparing the color of a standard Rock Color Chart, that prepared by Munsell color X-rite (2009).

Results and Discussion

Petrography

Based on the petrographic investigation, the rocks of the study area are homogenous and mostly are serpentinite rock which almost are composed of the serpentine minerals and pyroxene (**Fig.3A**) generally having green to black color after polishing. Except sample No.9 which differ in property with other samples, mostly composed of serpentine minerals, sillimanite, opaque minerals such as iron oxide with some grain of quartz (**Fig.3B**) which represents serpentinized meta gabbro.

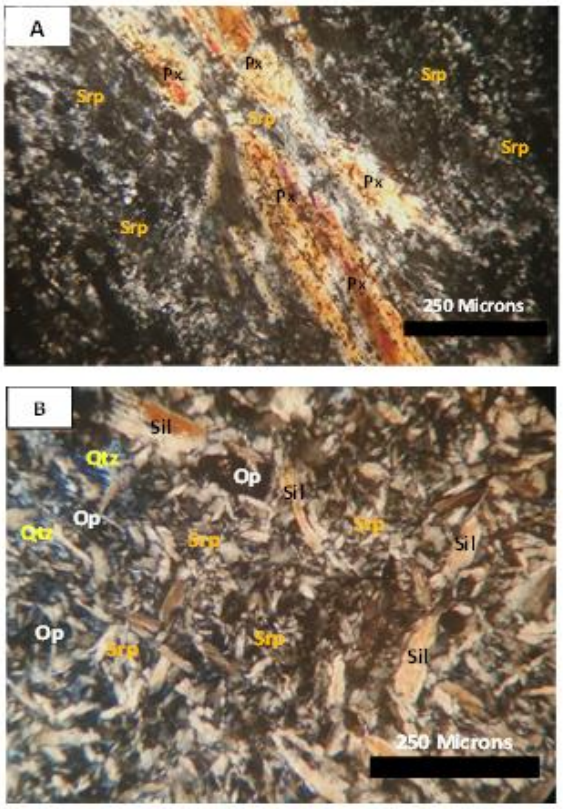

Fig. 3: (A) Serpentinized ultramafic rock composed of serpentine minerals and pyroxene. (B) Sample No.9 which shows that this sample is serpentinized meta gabbro. [Srp: Serpentine, Px: Pyroxene , Op: Opaque minerals , Sil: Sillimanite and Qtz: Quartz]

Geotechnical Properties

The desirable properties of a good dimension stone are: **1)** attractive appearance (colors and textures), **2)** durability (physical and chemical stability, **3)** strength, **4)** other factors such as cost of quarrying, transportation, processing and the availability of alternative sources of supply [40].

The physical properties of serpentinite rock collected from the Waras area to be assessed as dimension stone; are compared with [41] which cover the physical properties of serpentinite rock such as water absorption, bulk density, compressive strength and modulus of rapture. This standard indicates the mininum requirements for a serpentinite to be utilized as dimension stone, either for inside or outside utilization.

Color

Color is an important character of the rock used as a construction material such as building stone and monumental which is mainly related to the mineralogical and chemical composition. It would be alluring to incorporate the right petrological title in any depiction or classification, counting serpentinites within marbles (‘green marble’) can lead to their incorrect utilize as dimension stones, because it shows off all the beauty of the colors, the problems with polishing can be overcome by knowing the correct mineralogy of the rock [42]. Serpentinites show a wide range of colors (light–dull green to nearly dark) and pattern that results from modification of rock types of different bulk rock compositions and structures. The color of serpentinite also changes with the degree of hydration of the protolith and with the degree of distortion [42]. The results of color measurement for the studied samples

indicated that the colors vary from grayish green to greenish black, moderate olive brown and dark yellowish green(**Fig.4**) (**Table.1**).

Table 1: Color measurements of the studied samples using Geological Rock Color Chart with genuine Munsell color chips version 2009

Sample No.	Color Code	Color Name according to the Geological Rock Color Chart
1	5G 2/1	Greenish Black
2	5YR 2/1	Brownish Black
3	10GY 5/2	Grayish Green
4	5G 2/1	Greenish Black
5	5Y 4/4	Moderate Olive Brown
6	10GY5/2	Grayish Green
7	10GY 5/2	Grayish Green
8	10GY 5/2	Grayish Green
9	N3	Dark Gray
10	10GY 4/4	Dark Yellowish Green

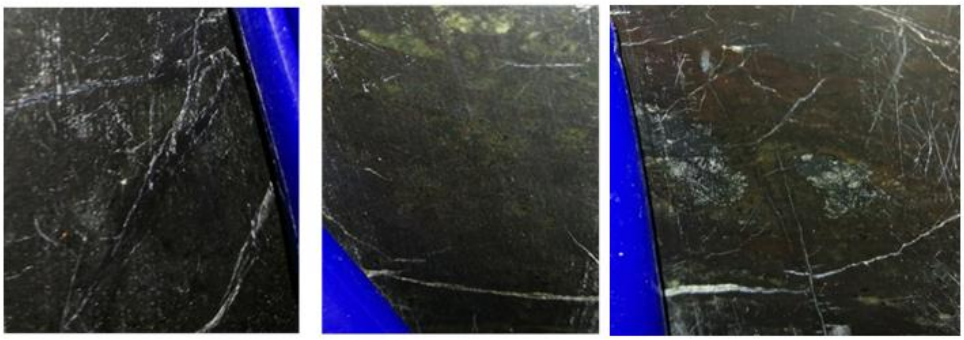

Fig. 4: Multiple color of serpentinite rock samples after polishing their surface.

Porosity, Water Absorption, and Bulk Density

The main characteristics for suitable ornamental stone are: significant exposure, lithological consistency, toughness, low density of joint and breaks, absence of pernicious materials and attractiveness [43]. Generally, rocks with low water absorption or porosity values indicate that are more durable; Water is one of the most operator of weathering so water would be less able to penetrate non-porous rock types and less able to cause distortion [1]. The porosity refers to the volume of pore space, and water absorption refers to the sum of fluid that a stone will retain upon submersion, the bulk density of a specimen is the quotient of its dry weight divided by the exterior volume including pores (bulk volume) [44]. Bulk density is vital for transportation and calculating the weight of walling, flooring or cladding panels utilize within the plan of foundations and buildings [2].

Results of porosity, water absorption, and bulk density of the studied samples are listed in **Table.2**. The results show that the average porosity of the studied samples is 0.46% and the average water absorption is 0.29%, the water absorption for all of the studied samples except sample (10) show suitability of the interior uses as well as only the samples (4, 6, 7, 8 and 9) exhibit suitable range of interior and exterior uses according to the [37] (**Table.4**). On the other hand the average results of bulk density of the studied samples is 1601 kg/m^3 which do not meet the requirement value of [37] (**Table.4**). Using the method of correlation coefficient (R^2), correlation equations were determined to correlate between bulk density and apparent porosity for the studied samples (**Figs.5A and B**). It can be seen that there is a weak correlation between porosity and density as R^2 is nearly 0.1.

Table 2: Apparent porosity, water absorption and bulk density of the studied samples

Sample No.	Apparent Porosity %	Water Absorption %	Bulk Density (Kg/m^3)
1	0.64	0.40	1617
2	0.59	0.38	1550
3	0.63	0.39	1610
4	0.20	0.12	1625
5	0.61	0.39	1574
6	0.28	0.17	1682
7	0.19	0.12	1584
8	0.30	0.19	1572
9	0.08	0.05	1539
10	1.11	0.67	1656

Average	0.46	0.29	1601

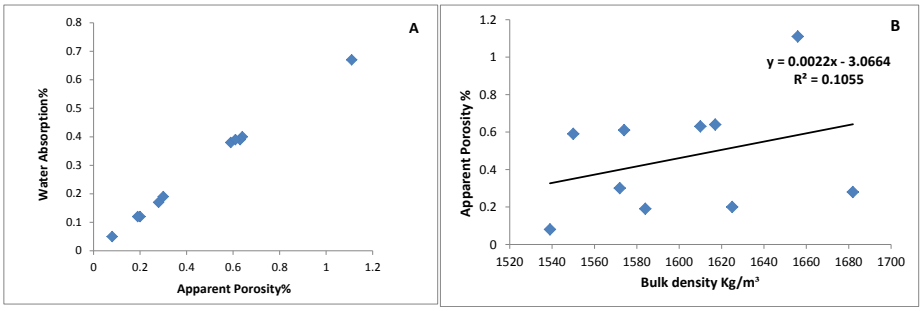

Fig. 5: A) The relationship between apparent porosity and water absorption of the studied samples, B) the relationship between apparent porosity and bulk density of the studied samples.

Compressive Strength

The compressive strength is the measure of the stone ability to sustain a load [45]. Compressive strength values, utilized with rock mass data such as fracture information, are utilized to distinguish the foremost fitting strategies to extricate building stone [2]. [46] Evaluated serpentinites from the point of view of rock mass, report that the value of the Geological Index Strength (GSI) significantly varies depending on the petrographic and basic varieties of serpentinites.

The averages compressive strength of the serpentinite rocks of the study area in case of dry and wet are 52.2 MPa and 17.1 MPa, respectively (**Table 3**), according to [38], the collected samples from the serpentinite rock of Waras area shows the low compressive strength values, clearly do not meet the requirement values of ASTM, this confirms that they are not suitable to be used as dimension stone (**Table 4**). Serpentinites are influenced by late shearing, which created veins filled by calcite, these veins act with diverse reactions to weathering, being weaker than the host rock [42]. Serpentinites can endure a range of changes when affected by atmospheric conditions [8]. So the degree of modification and the structure or foliation influencing the rock affected the behavior of serpentinized rock masses.

Modulus of Rupture (MOR):

Tests for modulus of rupture have a more substantial value than those for compressive strength since they degree the flexural strength of stones set in positions of unequal pressure or bending, such as caps and sills for doors and windows [47]. The average modulus of rupture of the serpentinite rock of the studied area in case of dry and wet are 2.49 MPa and 1.63 MPa respectively (**Table 3**). According to [39] the collected samples from the serpentinite rock of Waras area shows the low modulus of rapture values, clearly do not meet the requirement values of ASTM, this confirms that they are not suitable to be used as dimension stone (**Table 4**).

Table 3: Results of the compressive strength and modulus of rapture of the studied samples

Sample No.	Uniaxial Compressive Strength (MPa)		Modulus of Rapture (MPa)	
	Dry	Wet	Dry	Wet
1	26	17	1.23	0.83
2	29	10	1.40	0.46
3	38	7	1.83	0.33
4	78	50	3.70	2.37
5	32	_	1.55	_
6	45	_	2.13	_
7	52	_	2.49	_
8	76	_	3.63	_
9	103	87	4.90	4.16
10	43	_	2.03	_
Average	52.2	17.1	2.49	1.63

[-] ((not prepared))

Table 4: The values of physical and mechanical properties of Serpentinite as a dimension stone according to [41]

Physical Properties	Test Requirement	Test Methods
Water absorption (%) outside/inside	0.2max. /0.6max.	C 97
Density(kg/m³)	2560 (min)	C 97
Compressive strength (MPa)	69 (min)	C 170
Modulus of rapture (MPa)	6.9 (min)	C 99

Conclusion

- According to the petrographic study the rock from MOC at Waras area are mostly serpentinite rocks which generally composed of serpentine minerals with some pyroxene. Only one rock sample is differ from the other samples is composed of serpentine minerals, sillimanite, opaque minerals such as iron oxide and magnetite, and some grain of quartz which represent serpentinized meta gabbro.

- The serpentinite rock from MOC at Waras area are heterogeneous in color and their color after polishing are grayish green, greenish black, brownish black, moderate olive brown and dark yellowish green which is resulted from different degree of serpentinization.
- Physical properties, namely porosity, water absorption and bulk density, for the studied rock samples ,they exhibited a low bulk density, while the water absorption for all of the studied samples except sample (10) show the suitability of the interior uses , as well as only the samples (4, 6, 7, 8 and 9) exhibit suitable range of interior and exterior uses .
- The average value of compressive strength and average modulus of rapture of the studied samples are below the requirements of the [38] and [39] respectively, which commonly related to highly micro fracture and joint in serepentinite rocks.
- The comparison of the measured values of the physical and mechanical properties of the studied samples with those specified in [41] shows that the serpentinite rock from Waras area near Betwat village are not suitable to be used as dimension stone.

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قسم الجيولوجي ، كلية العلوم ، جامعة السليمانية ، ألسليمانية ، ألعراق

الملخص

معقد اوفيولايت ماوت (MOC) هو جزء من نطاق درز زاغروس، التي تمتد حوالي ٢٠٠٠ كم من جنوب شرق تركيا عبر شمال سوريا والعراق إلى غرب وجنوب إيران. ان الصخور السربنتينية تظهر في منطقة وراس بالقرب من قرية بتوات. تمت دراسة صخور السربنتينية من هذه المنطقة لتقييم مدى ملاءمتها للاستخدام كأحجار تغليف. تم جمع عشر عينات من منطقة الدراسة لتحديد خواصها الفيزيائية والميكانيكية. اظهرت الدراسات البتروغرافية إلى أن صخور السربنتينات في منطقة الدراسة تتكون في الغالب من معادن السربنتين لذا تظهر نتائج قياس اللون ألوانًا متعددة للعينات المدروسة بعد التلميع وهي الأخضر الرمادي والأسود المخضر والأسود البني والبني الزيتي والأخضر المصفر الغامق. تم تحديد الخواص الفيزيائية للعينات المدروسة حيث أظهرت كثافة حجمية منخفضة بينما أظهر امتصاص الماء لجميع العينات المدروسة ما عدا العينة رقم (١٠) وهي ملائمة للاستخدامات الداخلية كما وان العينات (٤، ٦، ٧، ٨ و٩) هي مجموعة مناسبة للاستخدامات الداخلية والخارجية. كانت نتائج جهد الانضغاط ومعامل التكسر للعينات المدروسة أقل من المطلوب. وفقًا للمعيار الأمريكي للاختبار والمواد، (2002) ASTM C1526-02، فإن صخور السربنتينات لمنطقة وراس ليست مناسبة لاستخدامها كحجر تغليف.