Evaluation of the Validity of the rocks of the Pila Spi Limestone Formation in in the Northeastern limb of Dohuk Anticline / Northern Iraq for Building Stones

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Abstracts:

The research aims to evaluate the validity of the rocks of the Pila Spi limestone formation in the Duhok fold / northern of Iraq for building stones. The Pila Spi, Fatha and Injana formations are exposed, together along with the deposits of the Quaternary period. Five stations were selected in the northeastern limb of the anticline Duhok fold, in which the limestone layers belonging to the Pila Spi formation are exposed. The engineering geological survey in the study area showed that the limestone rocks are yellowish in color. And layers are medium, thick to very thick, with wide spaced between joints to very wide, moderately strong strength, and slightly weathering.

Petrophysical tests showed that the absorption ratio ranges between (3.15-10.90%) and the dry density ranged between (2.08-2.46) g/cm3. While mechanical tests showed that the compressive strength values range between (21.60-40.03) MPa and the flexural strength values between (3.06-12.44) MPa, and when comparing these properties with (ASTM-C, 568 – 99., 2004) It was found that the limestone rocks in the study area are within the limits of the standard and that they are valid suitable for building stone in all stations.

Keywords:(Pilaspi formation, Dohuk anticline , geological survey, Engineering geology, Building stone)

تقييم صلاحية صخور الحجر الجيري لتكوين بلاسبي في الجناح الشمالي الشرقي لطية دهوك/ شمال العراق لاغراض البناء

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الملخص:

يهدف البحث إلى تقييم صلاحية صخور الحجر الجيري لتكوين بلاسبي في طية دهوك/ شمال العراق كأحجار بناء إذ تتكشف تكوينات بلاسبي والفتحة وانجانه إضافة إلى ترسبات العصر الرباعي وتم اختيار خمسة محطات في الجناح الشمالي الشرقي لطية دهوك المحدبة المنكشفة فيها طبقات الحجر الجيري العائدة لتكوين البلاسبي الجيري. اظهر المسح الجيولوجي الهندسي في منطقة الدراسة بأن صخور الحجر الجيري ذات لون اصفر فاتح . وطبقات متوسطة، وسميكة الى سميكة جداً، وذات مسافات واسعة بين الفواصل الى واسعة جداً، ومقاومة قوية باعتدال، وقليلة التجوية. و أظهرت الفحوصات البتروفيزيائية إن نسبة الإمتصاص تتراوح ما بين (3.15–10.90 %) والكثافة الجافة الحقيقية تراوحت ما بين (2.08–2.46) غم\سم^{3}. في حين أظهرت الفحوصات الميكانيكية إن قيم المقاومة الانضغاطية تتراوح ما بين (21.60–40.03)ميكاباسكال وقيم مقاومة الانثناء ما بين(3.06–12.44)ميكاباسكال، وعند مقارنة هذه الخواص الميكانيكية والفيزيائية مع المواصفة (ASTM–C, 568 – 99., 2004) وجد بأنها ضمن حدود المواصفة وأن صخور الحجر الجيري في منطقة الدراسة صالحة لأغراض البناء في جميع المحطات.

الكلمات المفتاحية: (تكوين بلاسبي، طية دهوك، الجيولوجيا الهندسية، احجار بناء، المسح الجيولوجي).

Introduction

The building stone industry is a large-scale market in the world and has shown promising trends for expansion in recent years. Building stones can be defined as natural stones that have been selected and extracted to produce stones of precise size and shape. Building stones were used in construction engineering and many other decorative objects (Kavinda, et al. 2022).

Building stone includes different types of natural stones used in exterior and interior improvements of buildings such as: marble, granite, limestone and sandstone, and the types of building stones are evaluated based on the opportunity to extract large pieces, the appearance of the stone when cut and polished, the accessibility of the site and the

mechanical properties of the stone (Mirza,and Rashid,2019**)**. Rock masses vary in types, qualities and features from one region to another, where these rocks were formed in different conditions and ages (Gaber et, al. 2020)

Limestone rocks are one of the most widespread sedimentary rocks in the stratigraphic column in Iraq. In the Kurdistan region, there are a huge number of different units of carbonate rocks, which are different in their geological age, depositional environment, The limestone rocks has a wide range of uses and applications such as: building stone, paving stones, and others since ancient times **(**Faraj**,**2022).

Limestone rocks are estimated to account for about (20-25%) of the total number of sedimentary rocks in the world (Pettijohn,1975).Sales of limestone such as pavement, façades, and ornamental stones constitute the second largest type of stone traded in the Brazilian market, and about (35%) of the total global reserve mass(Dolley,2007).

Location of the Studied Area

The study area is located in northern of Iraq within the administrative boundaries of Duhok Governorate, between longitudes (43°0'52")-(43°1'18") east and latitudes(36°50'02)-(36°50'26) north. The study area is located on the northeastern limb of the fold, where the length of the fold is about 15Km, and its width is about 3-5 km Fig.1.

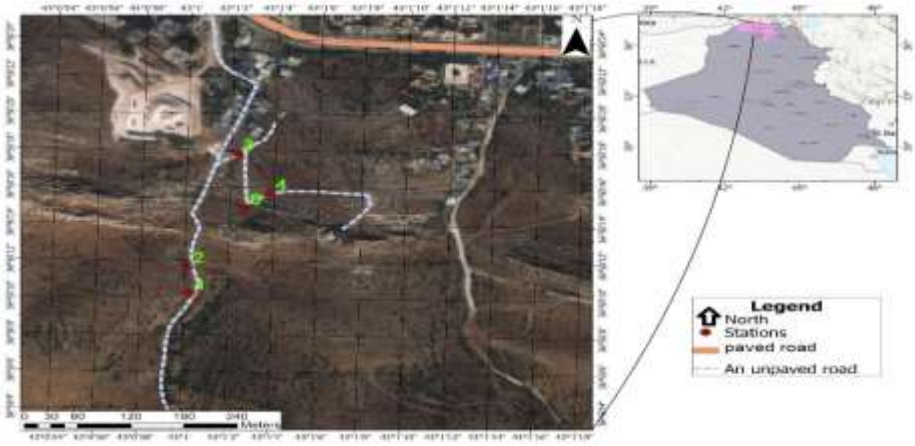

Fig.1. Site map of the study area

The aim of the study

The study aims to find out the validity of limestone rocks in the Duhok anticline for building stone purposes by studying their geotechnical properties that are related to building stone after comparing them with the engineering specification related to their validity as building stones.

Stratigraphy of the Studied Area

The Pila Spi, Fat'ha and Injana formations are exposed in the study area, in addition to the deposits of the Quaternary period. The Pila Spi formation is one of the prominent formations that form continuous ridges in the Kurdistan region, and the thickness of the formation ranges from 15 to 110 meter. The Pila Spi Formation is one of the main formations in northern of Iraq (Middle-Upper Eocene) and it forms the structure of the most folds (Varoujan, et al.2020),and controls the geological and geomorphological structure of the region. Its typical section is located in the village of Pila Spi, southeast of Sulaymaniyah, and as a result of the disappearance of this section in the lake of the Darbandikhan Dam, an additional section was chosen for it in the Kashti area near the original section. The lower contact of this formation with the formation of Avana is sometimes overlapping and other times separated by the basal conglomerate(Bellen,et al, 1959**)** and the upper contact of the pila Spi formation is unconformable determined by appearance of basal conglomerate bed of different thickness, and these conglomerate may disappear in some areas. The pila Spi formation is deposited in a lagon environment (Sardar and Kurdistan,2021), and consists of a sequence of layers of limestone and marley limestone and interspersed with layers of marl and dolomitic limestone and nodulas of Chert (Irfan,2022), at the top of the formation where this part is in the form high rideges and the presence of joints is observed on the surfaces of this part.

Plate 1. Limestone Rocks for Pilaspi Formation at Study Area Stations

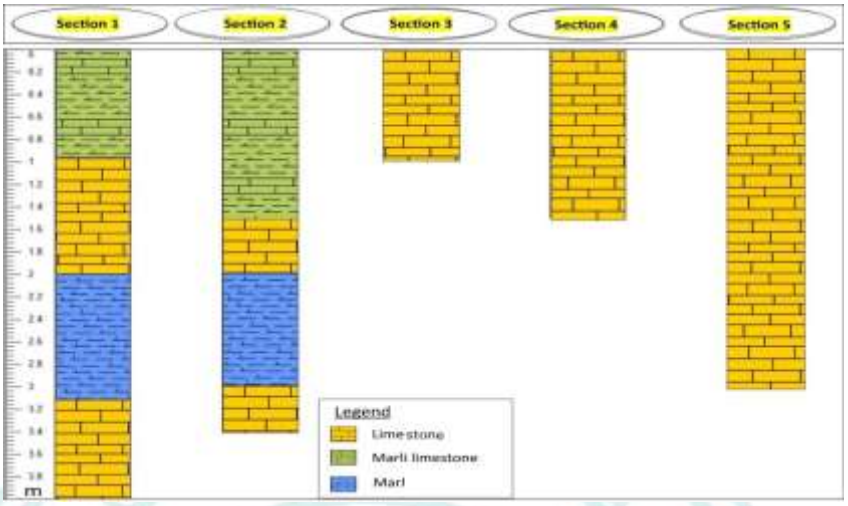

Fig.2. Stratigraphic sequences of limestone Pilaspi formation rocks in the study area

Structure and tectonics of the Studied Area

Duhok Fold is structurally defined as an asymmetrical anticline fold, as the northeast limb is des about (80 degrees), and it is one of the large geological structures and its axis extends towards (northwest - southeast) and its length is about 15 km and its width is about 3 km (Al-Kadhim,2009).

The study area is located tectonic within the zone of high folds according to the modern division of (Jassim and Goeff,2006),which they dealt with based on the theory of plate tectonic, they divided Iraq into three main parts, namely the stable shelf and the unstable shelf (high folded zone and low folded zone) and the zone of the Zakrus sature, and the fold was formed in the second phase of the alpine movement in the Pliocene as a result of the collision of the Arabian plate with the Turkish and Iranian plates and the formation of the folds of its axes in a northwest-southeast direction, including the fold of the study area, which returns to the direction of The folds of Zakros, as for the folds whose axes are east-west resultin from the collision of the Arabian plate with the Turkish plate(Buday and Jassim,1987), and mentioned (Fouad,2012), a division of Iraq based on modern concepts of tectonic plate ,Fig. 3.

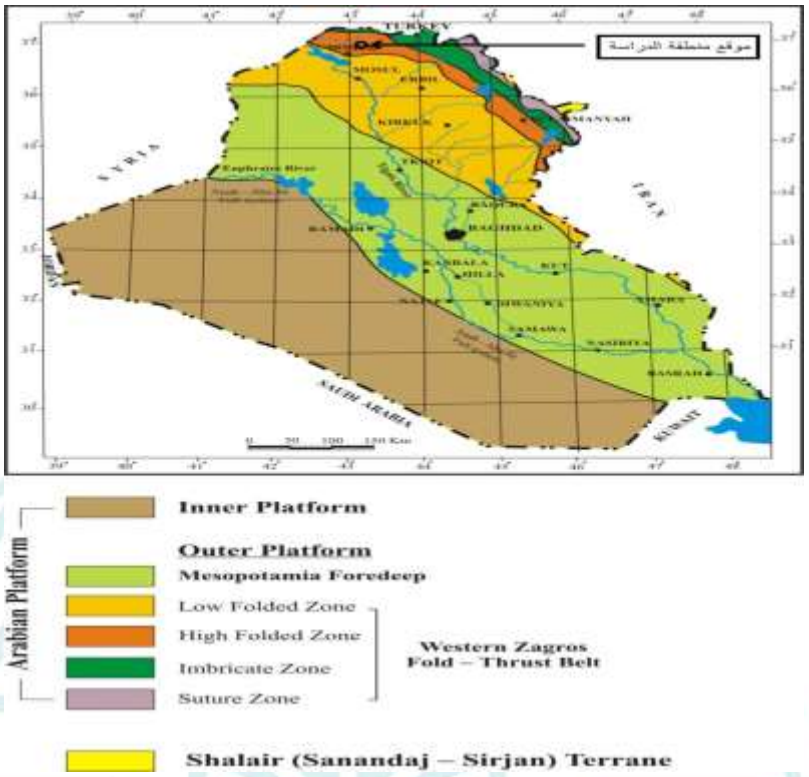

Fig. 3. Tectonic map of study area. (Fouad,2012)

Geomorphology of the Studied Area

The study area is characterized by a variety of topographical and geomorphological features with high, medium and low altitude terrain. The terrain with high and medium altitude is characterized by its resistance to weathering, while the low terrain is almost even due to its low resistance to erosion, and the geomorphological phenomena observed in the field are: (Hogback ridges) and transverse valleys that are perpendicular to the strike line, and the toppling and rock fall resulting from the erosion of limestone rocks and their fall down the slope, plate(2).

Plate.2. geomorphological features,1–Toppling, 2–Rock fall, 3–valley, 4–Ridge.

Engineering Geological Survey

The engineering geological survey is very important in the classification of rock masses and their suitability for various engineering purposes through the diagnosis of the field properties of rocks, a comprehensive engineering geological survey of limestone rocks in the study area was conducted and engineering description according to the description of the Geological Society Committee of London(Anon,1972,1977). Which states that the name of the rock alone without description is not useful for engineering and stratigraphic purposes and that there must be an accurate description of the rock, and that the proposal of the Committee of the Geological Society of London that the system of description of the rocks according to: color, spaced between joints, field rock strength, thickness of bedding, according to (Anon,1972,1977)and description of the weathering condition by(Hawkins,1986), Table (1).

Table 1: shows the engineering field description of the limestone rocks belonging to the Pila Spi Formation in the study area(Anon,1972),(Anon,1977), and (Hawkins,1986).

No.	Attitude bedded Dip direction Dip amount	The color (Anon, 1972)	Spaced between joints (Anon,1972)	Weathering (Hawkins, 1986)	Rock strength (Anon,1977)	Bedding (Anon, 1972)
1	010\80	Yellowish	Moderately wide spaced	Slightly weathering	Moderately strong	Thickly bedded
2	031\84	Yellowish	Moderately widely spaced	Slightly weathering	Moderately strong	Medium bedded
3	010\86	Yellowish	Widely spaced	Slightly weathering	Moderately strong	Medium bedded
4	016\75	Yellowish	Moderately wide spaced	Slightly weathering	Moderately strong	Thickly bedded
5	010\78	Yellowish	Very widely spaced	Slightly weathering	Moderately strong	Very thickly bedded

Sampling

Five stations representing the study area in the northeastern limb of the Duhok anticline were selected and GPS was used to locate the stations and were sampled so that the samples are representative of the calcareous rocks in the area, and sufficient to conduct all required tests.

Properties of Building stone

The specification (ASTM-C, 568 – 99., 2004) specifies the physical and engineering requirements and their classification of building limestone as in Table 2, which is used for building purposes, and these requirements are necessary when evaluating the suitability of natural stones for building purposes, namely: absorption ratio, true dry density and compressive strength, while flexural strength is one of the most important coefficients for calculating the tensile strength of rocks for building and is determined according to the specification (ASTM-C, 99-09.,2010). An important step to consider when choosing any type of stone for façade cladding is the aesthetic appearance (ASTM–C,1528 -02.,2004).

Laboratory tests

The geotechnical tests required to find the properties related to the validity of limestone rocks for building stone were carried out by(ASTM-C, 568 – 99.,2004), namely:

dry density, absorption ratio, compressive strength, flexural strength, the tests were carried out in the rock labortory, Department of Geology Applied College of Sciences / University of Tikrit, and the following is a brief explanation of the properties:-

1- Dry density(ρdry) is defined as the mass of a unit volume and its units (g / cm3)(ASTM- C, 127- 01.,2004), and depends on porosity, and mineral composition, and the mass of the unit volume of the samples was measured by the method of three weights (dry, saturated, and submerged) by (**ASTM- C, 97-09., 2010),** and the true dry density is calculated the following equation:-

$$Bulk\ Density(\boldsymbol{\rho} dry) = \frac{Mdry}{Msat - Msub} . \boldsymbol{\rho w}$$

2-Water absorpation ratio (W.ab.) It is the ratio of the mass of water in the voids (Mw) absorbed within 48 hours to the total dry mass of the rock (Mdry), which is a percentage (ASTM- C, 127- 01.,2004), and the absorption ratio was calculated according to the following equation:

W.abs.=$\frac{Mw}{Mdry}$ *100

3-Uniaxial Compressive Strength is defined as strength of a rock to the normal pressure applied to it at the failure point. According to (ASTM- D, 2938-95.,2004), it is calculated according to the following formula: σc= P/A

where: σc: uniaxial compressive strength calculated. P : force at failure, A : cross-sectional area perpendicular to the direction of force The following equation was used to obtain the compressive strength value at the diameter/length ratio (1:1) to overcome the effect caused by differences in lengths of core samples (ASTM-C, 170-09.,2010) and (Jaeger, and Cook,1976). Cc = σc/ [0.778+0.222 (D/L)]

since Cc: corrected compressive strength, :D sample diameter, L: sample length.

4-Flexural Strength(R) is the strength of the rock to bending or bending, and is an important characteristic in building applications when using rock in the upper beams of doors and windows (Grisafe,1976). According to(ASTM-C, 99-09.,2010) It is calculated according to the following equation.

R = 3Wl/2bd2 as: R:flexural strength, W:force at failure (N), l:distance between loading supports (mm), b:sample width (mm), d: sample thickness (mm)

Assessment Suitability of Pilaspi limestone rocks for building stone

The validity of limestone rocks in the five stations of the study area for building stone purposes was evaluated by comparing the results of the geotechnical properties of these rocks with the values fixed in the American standard (ASTM-C, 568 – 99.,2004), which classifies limestone as building stones into three categories: according to density, absorption ratio, compressive strength in addition to flexural strength as in Table 2. The first class is accepted, the second class is recommended, and the third class is highly recommended for construction building.

Table 2: Specifications of Building Stones by (ASTM-C, 568 – 99.,2004).

Class	Petrophysical tests		mechanical tests	
	Dry density (g/ cm^3)	Water absorpation ratio %	Uniaxial Compressive Strength (Mpa)	Flexural Strength (Mpa)
I	2.16> - 1.76	>12	28> - 12	3.4>-2.9
II	2.56 - 2.16	12->7.5	55 -28	6.9-3.4
III	>2.56	7.5-3.0	>55	>6.9

Table 3: shows the values of petrophysical and mechanical tests of limestone rock samples belonging to the Pilaspi Formation in the study area.

No.	Lithology	Petrophysical tests		mechanical tests	
		Dry density (g/cm^3)	Water absorpation ratio (%)	Uniaxial Compressive Strength (Mpa)	Flexural Strength (Mpa)
1	Limestone	2.46	3.15	40.03	12.44
2	Limestone	2.40	4.77	34.80	10.31
3	Limestone	2.30	6.61	30.09	8.11
4	Limestone	2.17	8.30	25.19	3.60
5	Limestone	2.08	10.90	21.60	3.06

The results of the geotechnical properties of limestone rocks of the study area were evaluated with the required specifications and found to be suitable for building stone purposes, Table 4.

Table 4: shows the final evaluation of limestone rocks in the area and their conformity (+) according to(ASTM-C, 568 – 99.,2004) and(−) non−conformity.

No.	Dry density (g/cm^3)	Water absorpation ratio (%)	Uniaxial Compressive Strength (Mpa)	Flexural Strength (Mpa)	Evaluation
1	(II)+	(III)+	(II)+	(III)+	**Acceptable**
2	(II)+	(III)+	(II)+	(III)+	**Acceptable**
3	(II)+	(III)+	(II)+	(III)+	**Acceptable**
4	(II)+	(II)+	(I)+	(II)+	**Acceptable**
5	(I)+	(II)+	(I)+	(I)+	**Acceptable**

Conclusions

1. The geological formations exposed in the study area are the Pila Spi, Fat'ha and Injana formations as well as the Quaternary deposits.

2- The engineering geological survey in the study area showed that the limestone rocks are yellowish in color. And layers are medium, thick to very thick, with wide spaced between joints to very wide, moderately strong strength, and slightly weathering.
3- Petrophysical tests showed that the absorption rate ranged between (3.15-10.90%), indicating the high porosity of limestone rocks. The dry density values ranged between (2.46-2.08) g/cm3 and this indicates the variation in the porosity values.
4- Uniaxial compressive strength tests for limestone rock samples showed values ranging between (40.03-21.60) MPa and described as moderately strong according, and the flexural strength test showed values ranging between (12.44-3.06) MPa.

5.The limestone rocks of the Pila Spi Formation in the study area were found to be suitable for building stone purposes according to the standard.

Recommendations

1. Calculation of the reserve of limestone rocks in the study area for use in various engineering purposes.

2- When exploitation these rocks, it is preferable to use the method of mining with terraces in the extraction process..

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