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The suitability of Sinjar and Pila spi rocks for building and as railway ballast stone for the Bazian anticline fold in the Sulaymaniyah governorate

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ABSTRACT

The research aims to find the suitability of limestone rocks belonging to the Sinjar and Pila Spi Formations in the southwestern part of the Bazian fold in Sulaymaniyah Governorate for building purposes and as a railway ballast stone by conducting some important geotechnical laboratory tests and comparing them with the required standard specifications for building stones and railway ballast stone. Through these tests, it was found that the values of the dry density of the studied samples ranged from (1.87-2.31) (g/cm³), while the values of the water absorption coefficient ranged from (1.84-9.87)%, and the specific weight values ranged from (2.16-2.25), while the values of The unconfined compressive strength ranged between (31-55) MPa in its natural state, and the Flexural strength values ranged from (5.5-11.9) MPa, and the mechanical abrasion percentage values ranged between (24.4%-61.6%). After comparing the values of these properties with the specifications required for building stones and the specifications required for railway ballast stones, it was found that the limestone rocks in the study area are suitable for building purposes, but they are not valid as a railway ballast stone.

Introduction

Limestone rocks are used for engineering purposes, including building and railway ballast stone. In building, they are used after cutting it into pieces of suitable sizes and dimensions for building and covering walls from the outside. They are good thermal and sound insulation. They are also used in building terraces and doorsteps. Natural building stones have good advantages as they give an aesthetic harmonious with nature and maintain a more suitable and healthy thermal environment, thus reducing the costs of energy that is used for heating and cooling purposes. In railway ballast stone is used after crushing to suitable sizes. The rail consists of two main parts, the upper part and the lower part. The upper part consists of rails, struts and a system for fixing rails to the struts. As for the lower part, it is a part of the aggregate consisting of three layers, namely the sub-grade and the sub-ballast layer, which separates the upper and the base aggregates with grades softer than the first and coarser than the second. As for the upper layer, it is ballast: it is crushed granular materials that are paved between the supports to the ends of the supports fixed in the bottom layer of the rubble, and it is the most important component because it works to restrict the rails and prevent their movement [1]. The projects of construction, development or maintenance of railways in the country were the main motive for conducting this study to provide large quantities of ballast stone in different regions of the country to facilitate its transportation from the areas of its presence to the proposed railway tracks and thus reduce the costs of transporting stones. Because transporting large quantities of stones to remote areas requires large and large transport vehicles and consumes a lot of fuel and time, and thus high labor costs.

The study area is located within the administrative borders of the Sulaymaniyah Governorate in northeastern Iraq and is about 25 km southwest of the city of Sulaymaniyah. The study area is located between coordinates square (517500 , 520000) and (3928000 , 3932000).Figure (1).

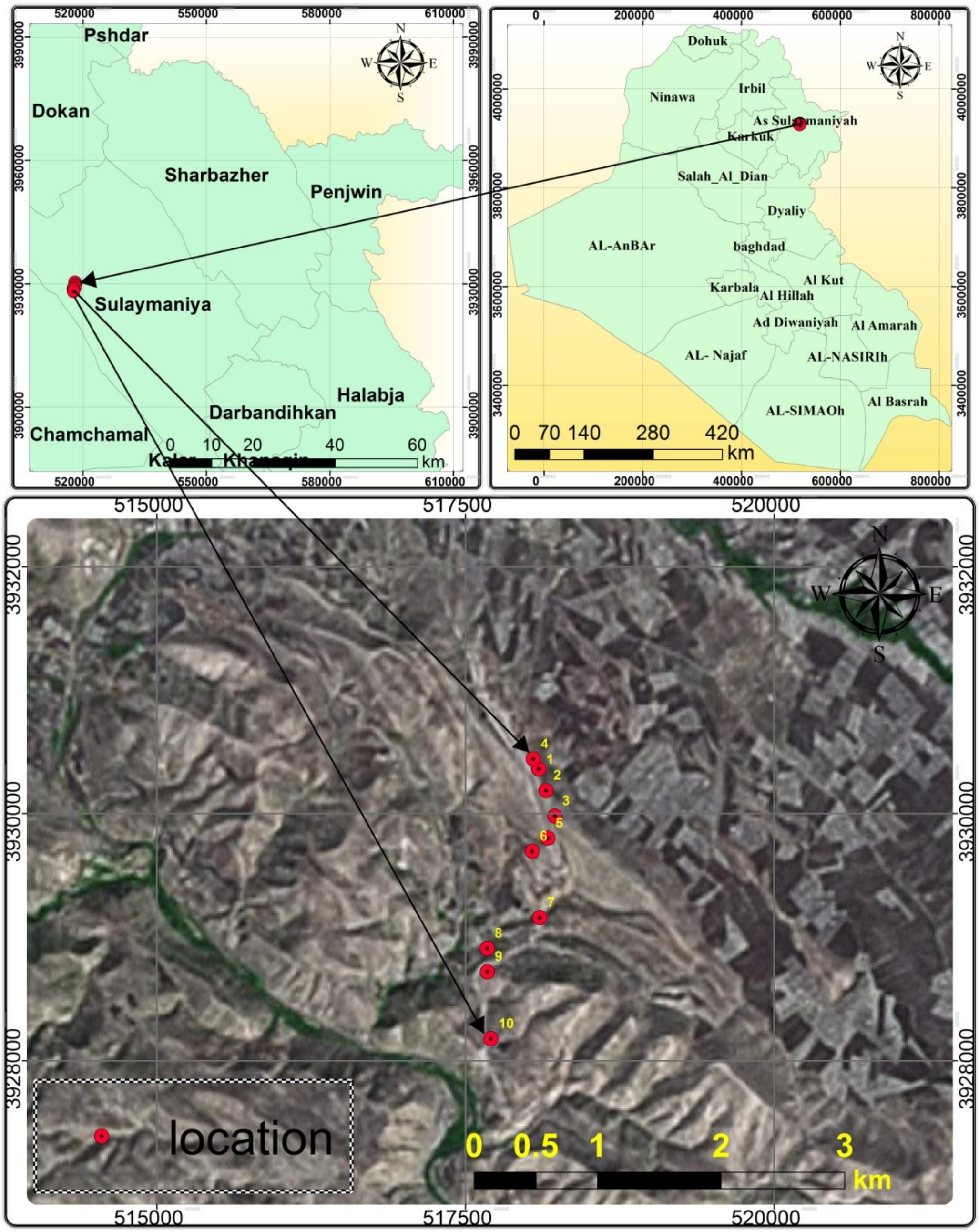

Fig. 1: is a image showing the locations of the studied stations

Tectonically, the region lies within the southwestern boundary of the high fold zone, where characterized by high anticlines and intense folds, which resulted from the Alpine orogeny. The intense folding that the region had experienced resulted in the formation of complex structural features. In general the anticlines are asymmetric,the Bazian anticline has an axis north west-south east which follows the direction of Zagros.

Stratigraphically the formations of Pila Spi, Gercus and Sinjar are exposed. The Sinjar Formation consists of thick to massive layers of yellowish-gray limestone, clayey-limestone, sandy limestone and conglomeratic limestone. The upper contact unconformable with Gercus Formation which is indicated by colour and lithological variation into red clasts with a weak conglomerate bed at this boundary.

The Pila Spi Formation consists of well layers of highly fractured limestone, dolomitic limestone, dolostone and chalky limestone. The upper contact of the Pila Spi Formation with the Fat'ha Formation is unconformable which is indicated by the basal conglomerate [2].

Geomorphologically cuesta hills and the various drainage systems are spread that are determined by the characteristics of rocks and geological structures. In addition to that, one of the clear geomorphological features in the study area is the toppling failure also the topography of the dissolution, especially the caves, was found in the rocks of the Sinjar and Pila Spi Formations. There is also depositional terrain in the study area such as flood fans at the bottom of mountain valleys.

Laboratory tests

The American Standard was used to determine the suitability limestone rockes in the Sinjar and Pila Spi Formation for building purposes. Several required geotechnical tests were performed in the evaluation of limestone for building and railway ballaststone purposes. some them are physical tests, included dry mass density, absorption ratio, and some of the mechanical tests included unconfined compressive strength, flexural strength, and mechanical abrasion rate.

Density is one of the most important physical properties affecting the mechanical properties of rock. It was calculated according to [3] by the method of three weights. According to the following equation $\rho dry = \frac{M_{dry}}{M_{sat} - M_{sub}} \times \rho w$ ….(1) with one sample from each station. Table(1)

As for the property of the stone water absorption, it is also an important physical property in the evaluation of the suitability of a rock for engineering purposes because the rock has a low ratio of water absorption to be more tolerant and less affected by freezing and thawing, and changes in drought and humidity [4]. The absorption ratio was calculated according to [3] from the following equation **W.ab=**$\left\{\frac{Msat-Md}{Md}\right\} \times$ **100% ……**(2) with one sample from each station table(1)**.**

The unconfined compressive strength test, it was carried out in the laboratory by preparing a sample in a cylindrical or cubic shape so that the ratio of **2** ≥ length/diameter ≥ **1/3** for the cylindrical sample, and the two ends of the sample preparation for testing must be flat and perpendicular to the longitudinal axis of the sample to a limit of **(±1°)**. Then the cylindrical or cubic rock sample is subjected to the impact of a compressive load at a rate of (0.75MPa⁄(sec) increasing from zero until it failure employing a compressive strength tester, provided that failure occurs in the rock sample within (5-10) minutes [5]. After that, the unconfined compressive strength is calculated from the following equation

σc = P/A ….(3) which is the basic equation.

P is the compressive force, **A** is the area of the sample base, **σc** is the compressive strength. The accuracy of the calculations is greatly affected by the ratio of the length of the sample to its diameter, even if the ratio is within the rate **[1/3-2].**

The ratio of the sample length to its diameter when it is **1:1** gives the most accurate results.

To overcome the effect of this ratio, [6] proposed another equation to correct the unconfined compressive strength values calculated from the basic equation and make the values identical to the values calculated at a 1:1 ratio for the same sample. The equation is

$\sigma corrected = \frac{\sigma calculated}{0.778+0.222D/L}$……(4) table(1)

σcorrected unconfined compressive strength, **L** rock sample length, **D** rock sample diameter.

Flexural strength is also important when rocks are used in the upper thresholds of doors and windows [7]. The dimensions of the sample preparation for testing (length x width x thickness) should be **(**203x101x57**)** mm or close to that, and cut the rocks in a position that makes the length and width parallel to the level of stratification according to [8]. This test was conducted according to[9]. Then the equation **R=3WL/2bd²** …..(5) was used to calculate the flexural strength **(R)** with one sample from each station. table(1)

R is the flexural strength in megapascal (MPa) **b** is the width of the sample in (**mm**)

W represents the load at the breakdown in units of newtons (**N**)

L represents the distance between the suppository armrests in (**mm**)

d represents the thickness of the pattern in mm plates (**mm**)

The mechanical abrasion resistance test is also very important because through it, it is possible to know good aggregates that are resistant to crushing and corrosion processes, especially when using this aggregate in railway ballast stone. Perhaps the best mechanical corrosion test for aggregates is the Los Angeles test, which depends on calculating the weight percentage of aggregate lost by abrasion using the Los Angeles device.

The test was conducted according to [10] and calculate the percentage of mechanical abrasion (Ab) from the following equation **Ab=**$\frac{W1-W2}{W1} \times$ **100%** …..(6)

W1 Total dry weight of the sample (gm) before testing

W2 Dry weight of the sample remaining on the sieve is 1.7 (gm)

Table 1: shows the values of petrophysical and mechanical tests for limestone samples

formation	station number	Density in units g/cm³	Absorption%	Compressive Strength in units MPa	Flexural Strength In units MPa	Abrasion
Sinjar	**1**	**2.084**	**1.848**	**31.54**	**9.5**	**33.6%**
	4	**2.341**	**1.626**	**36.27**	**8.3**	_
	5	**2.148**	**2.231**	**55.54**	**11.9**	_
	6	**2.311**	**2.344**	**41.35**	**10.3**	_
	7	**2.292**	**2.100**	**41.59**	-	_
Pila Spi	**8**	**1.857**	**8.931**	**24.05**	**5.5**	**24.4%**
	9	**2.225**	**4.181**	**35.17**	-	**61.6%**
	10	**1.946**	**9.876**	**27.1**	**8.2**	**37.4%**

Discussion

It is known that the petrographic properties of rocks have an impact on their qeotechnical properties and this was evident for the rocks of the study area as the slight dissolusion of the Sinjar formation rocks and cementation led to an increase the values of mechanical properties such as uniaxial compressive strength , flexural strength and mechanical abrasion in the rocks of Sinjar formation compared to its value in rocks of Pila Spi formation, like wise the petrophysical properties of the Sinjar formation rocks showed ahigher density and lower absorption ratio compared to the Pila Spi formation rokcs.

Evaluation of the suitability of limestone rocks for building purposes:

Table 2: specifications of limestone used for construction purposes according to [11]

class	Physical Requirements		Engineering Requirements	
	absorption %	Density in units kg/m³	Compressive Strength in units MPa	Flexural Strength In units MPa
I	>12	1760 – 2160>	<12-28>	2.9 – 3.4>
II	12 –7.5	2160 – 2560>	28 -< 55	3.4 – 6.9>
III	7.5> - 3	≥2560	55≥	≥6.9

This standard classifies limestone as building stones into three classes: first (I) low density, second (II) medium density, and third (III) high density, the first is desirable, the second is acceptable, and the third is good for building purposes.

After comparing the results of the geotechnical tests of the studied rock samples with the [11], their validity was evaluated for building purposes, and it was found that the rocks of the study area in general, belong to the third class (III) as in Table (3)

Table 3

formation	station number	Density	absorption	Compressive Strength	Flexural Strength	Final evaluation
Sinjar	1	(I)+	(III)+	(II)+	(III)+	successful
	4	(II)+	(III)+	(II)+	(III)+	successful
	5	(I)+	(III)+	(III)+	(III)+	successful
	6	(II)+	(III)+	(II)+	(III)+	successful
	7	(II)+	(III)+	(II)+	not tested	successful
Pila Spi	8	(I)+	(II)+	(I)+	(III)+	successful
	9	(II)+	(III)+	(II)+	not tested	successful
	10	(I)+	(II)+	(I)+	(III)+	successful

Evaluation of the suitability of limestone rocks as a railway ballast stone:

In order to know the suitability of rocks for use as railway ballast, they must possess certain mechanical and physical specifications such as those specified by [12] Table (4). In the current study**,** a comparison was made between the results of mechanical and physical tests for limestone rocks shown in Table (1) with the required specifications specified by [12] shown in Table (4) and it was found that the rocks of the study area are not suitable as a railway ballast stone Table (5).

Table 4: Specifications of rocks used as a railway ballast stone according to[12]

Mechanical and physical specifications of aggregates	Allowed Ranges
True dry density	Not less than 2.4 g/cm3
water absorption ratio	no more than 3%
The abrasion resistance value of aggregate	no more than 25-30%
Unconfined compressive Strength	Not less than 80 MPa

Table 5: shows the suitability of the rocks of the study area as ballast stone for the railways.

Formation	station number	Density	absorption	Compressive Strength	Abrasion	Final evaluation
Sinjar	1	-	+	-	-	X
	4	-	+	-	not tested	X
	5	-	+	-	not tested	X
	6	-	+	-	not tested	X
	7	-	+	-	not tested	X
Pila Spi	8	-	-	-	+	X
	9	-	-	-	-	X
	10	-	-	-	-	X

(X) means failed, (-) means not conforming to the specification, (+) means conforming to the specification

Conclusions

1. The exposed Formations in the study area are the Sinjar, Gercus and Pila Spi Formations in addition to Quarteanary deposits.

.The suitability of the limestone rocks in the study area for building purposes in all stations.2

The limestone rocks in the study area are not suitable for use as railway aggregates..3

Recommendations

1. Studying the limestone reserves in the study area to use them for various engineering or industrial purposes after studying their suitability for each purpose.
2. Use appropriate mining methods when investing these rocks
3. Carrying out a similar study for the areas adjacent to the study area to obtain other arbitration rocks that meet the specifications required for building purposes and the railways ballast stone.
4. To study the viability of the rocks of the study area for other purposes, such as the cement industry.
5. When approving a project to build railways, sources of arbitration stone are sought in nearby areas along the railway, where this proximity is an economic factor mainly.

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صلاحية صخور تكويني سنجار وبلاسبي الجيرية في طية بازيان في محافظة السليمانية للأغراض البناء وتحكيم السكك الحديدية

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الملخص

يهدف البحث إلى بيان مدى صلاحية صخور الحجر الجيري العائدة لتكويني سنجار وبيلاسبي في الجزء الجنوبي الغربي من طية بازيان في محافظة السليمانية لأغراض البناء وكحجر تحكيم للسكك الحديدية وذلك بأجراء بعض الفحوصات المختبرية الجيوتكنيكية المهمة ومقارنتها مع المواصفات القياسية المطلوبة الخاصة بأحجار البناء وأحجار تحكيم السكك الحديدية. تبين من خلال هذه الفحوصات ان قيم الكثافة الجافة للعينات المدروسة تتراوح من (2.31−1.87) $\frac{\text{غم}}{\text{سم}^3}$ بينما تراوحت قيم معامل امتصاص الماء من (1.84 −9.87)% وتراوحت قيم الوزن النوعي من (2.16−2.25) فيما تراوحت قيم المقاومة الانضغاطية الغير محصورة بين (31−55) ميكا باسكال في حالتها الطبيعية. وتراوحت قيم مقاومة الانثناء من (5.5−11.9) ميكاباسكال وتراوحت قيم نسبة التآكل الميكانيكي بين (24.4%−61.6%). وبعد مقارنة قيم هذه الخواص مع المواصفات المطلوبة بأحجار البناء والمواصفات المطلوبة بأحجار تحكيم السكك الحديدية تبين إن صخور الحجر الجيري في منطقة الدراسة تصلح لأغراض البناء لكنها غير صالحة كحجر تحكيم للسكك الحديدية.