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Evaluation of lithological and mechanical characteristics of Ilam Formation

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Abstract

The Ilam Formation has a special place in the oil industry as one of the most important oil reservoirs and as a construction site in projects, so knowing its engineering geological characteristics is very important.

In order to comprehensively investigation of the Ilam formation, the type section of the formation was studied in Ilam, Lorestan and Kermanshah provinces. Based on the studies of 110 samples, 7 types of microfacies were identified and were classified in 4 groups Mudstone, Wackestone, Wackestone-Packstone and Packstone by Dunham method. The physical properties of rocks including density, porosity, water absorption and p-wave velocity and mechanical properties including uniaxial compressive strength and point load index were measured.

The results show that the average porosity and water absorption of mudstone samples are higher than the other types of rocks tested, which is due to the finer grain of the texture. P-wave velocity, point load index and uniaxial compressive strength in Packstone samples are higher than other types of samples, which is due to the presence of more grains in the texture and as a result its higher strength.

The results of the statistical tests show that there is a statistically significant relationship between the independent variables and the dependent variable. In addition, the relationship between point load index and uniaxial compressive strength was linear. The correlation coefficient of uniaxial compressive strength with porosity and point load index is higher than other parameters, and as a result, they provide a suitable estimation of the strength of Ilam limestones.

Keywords: *Ilam Formation, Engineering geological characteristics, Physical and Mechanical properties, statistical analysis*

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Extended Abstract:

1. Introduction

Limestone are place of construction of projects such as dams and tunnels and the place of concentration of mineral deposits, oil and gas resources and underground water resources. Therefore, knowing their geological engineering characteristics is very important. In fact, not knowing the mechanical properties of structures before implementing engineering projects will lead to many problems during or after the construction of such structures (Wanniarachchi et al, 2017; Sun et al, 2017; Sari, 2018). Based on this, various researchers tried to investigate the engineering geological characteristics of rocks and using different methods to develop relationships between textural, physical and mechanical parameters of different rocks. In many of these studies, through statistical methods such as regression analysis, experimental relationships of various parameters have been presented (Singh and Singh, 1993; Katz et al, 2000; Kahraman, 2001; Yılmaz and Sendır, 2002; Quane and Russell, 2003; Tsiambaos and Sabatakakis, 2004; Kahraman et al, 2005; Basu and Aydin, 2006; Prikryl, 2006; Agustawijaya, 2007; Sharma and Singh, 2007; Sabatakakis et al, 2008; Zorlu et al, 2008; Gupta, 2009; Altindag and Guney, 2010; Tahir et al, 2011; Khandelwal, 2012; Gupta and Sharma, 2012; Sharma and Gupta, 2013; Nazir et al, 2013; Kahraman, 2014; Madhubabu et al, 2016; Jahed Armaghani et al, 2017; Wang et al, 2017; Kong and Shang, 2018).

In this study, the lithological, physical and mechanical properties of the Ilam formation have been investigated. The large expansion of this formation has caused many dam construction and tunnel excavation projects to be carried out on this formation. On the other hand, this formation, together with the Sarvak Formation and its equivalent units in other countries (such as the Mishrif Formation of Iraq), is considered one of the most important reservoir rocks among the oil fields of Iran and the Middle East (Motiei, 1993; Aqrawi et al, 1998; Adabi and Asadi-Mehmandosti, 2008).

2. Materials and methods

2.1 Study area:

The Ilam formation was introduced for the first time by James and Wynd (James and Wynd, 1965) in Kabirkooh in Ilam province. The type section of this formation was selected at the northwestern end of Kabirkoh, 12 km from Ilam city. The age of this formation is Santonian-Campanian. In order to collect the samples, 3 places were visited in Ilam and Lorestan and Kermanshah provinces and sampling was done. Each block sample was examined for macroscopic defects so that the collected samples were free of fractures and cracks. Then, cylindrical samples with standard dimensions and microscopic thin sections were prepared from the samples.

2.2 Microscopic and petrographic studies:

In order to name the rocks and identify the microfacies, 110 thin sections were prepared. Dunham's method (1962) was used to name the rocks. The methods of Wilson (1975) and Flügel (2004) have been used to describe the microfacies and determine their sedimentary environment.

2.3 Microfacies and sedimentary environment

Based on microscopic studies, 7 types of microfacies related to the deep parts of the basin and the outer ramp environment have been identified and their types are as follows:

Heterhelix, Hedbergella Mudstone, Heterhelix, Globotroncana Wackestone, Hedbergella Wackestone, Hedbergella, Heterhelix Wackestone Packstone, Heterhelix, Hedbergella Packstone, Oligostegina, Heterhelix Packstone and Bioclast Packstone Grainstone.

3. Results and discussion

3.1 Determination of physical and mechanical properties

In this study, 110 samples of Ilam Formation were examined to determine their physical and mechanical characteristics. The physical characteristics of the samples including density (ρ), porosity (n), water absorption (Wa) and P-wave velocity (Vp) were measured according to the standard (ASTM D2845, 2017). In order to determine the mechanical characteristics of the samples, the uniaxial compressive strength (UCS) test was performed based on the standard (ASTM D7012, 2014). Also, the test of point load index (Is) based on the standard (ASTM D5731, 2008) was performed on all samples.

The results of physical and mechanical tests of the samples are shown in Table 1. This table shows that the porosity of the samples varies between 3.72% and 10.93%. The average porosity of mudstone samples is higher than other types of tested rocks, which is due to the presence of a higher percentage of carbonate mud and finer texture. The density of the samples is between 2.08 and 2.44 grams per cubic meter, and the average density of all 4 types of samples are very close to each other. The water absorption percentage of the samples varies between 0.29 and 4.34%. The average value of water absorption percentage of mudstone samples is higher than other types of samples tested, which is due to the presence of a higher percentage of carbonate mud.

P-wave velocity varies between 3.97 and 5.82 km/s, and the average speed in packstone samples is more than other types of rocks. Uniaxial compressive strength and point load index varies in the range of 29.68 to 124.99 and 2.21 to 4.80 MPa, respectively. packstone samples show a higher average strength than other types of samples, which is due to the presence of more grains in the texture and as a result its higher strength. According to the classification of Deere and Miller (Deere and Miller 1966), packstone samples belong to category (B) and mudstone samples belong to category (C).

Table 1. physical and mechanical properties

Group	N (sample)	index	ρ (g/cm3)	n (%)	Wa (%)	Vp (km/s)	UCS (Mpa)	Is (Mpa)
A	23	Mean	2.26	7.14	2.85	4.78	90.48	3.36
B	28	Mean	2.28	6.36	2.53	4.98	94.32	3.52
C	33	Mean	2.31	5.95	2.33	5.08	97.21	3.69
D	26	Mean	2.32	5.48	1.90	5.23	101.94	3.93
total	110	Mean	2.30	6.18	2.39	5.03	96.18	3.63
		Min	2.08	3.72	0.29	3.97	68.29	2.21
		Max	2.44	10.93	4.34	5.82	124.99	4.80
		Std. Deviation	0.09	1.54	0.93	0.39	11.37	0.56
		Std. Error of Mean	0.01	0.15	0.09	0.04	1.14	0.06

3.2 Statistical analyses

The results of ANOVA and correlation coefficient tests showed that there is a statistically significant relationship between the independent variables (n, ρ, Wa, Vp) and the dependent variable (UCS). In order to determine the relationship between these variables, various regression models were examined and the regression model with the correlation coefficient was chosen as the relationship between the variables. Based on this, the relationship between density, porosity, water absorption and P-wave velocity with uniaxial compressive strength was linear, power, exponential and power, respectively. In addition, the relationship between Is and UCS was also linear (Table 2).

By examining the correlation of parameters based on rock type, the highest correlation of density and uniaxial compressive strength is related to mudstone with a correlation coefficient of 0.81 and the lowest is related to wackestone-packstone with a correlation coefficient of 0.64. The highest correlation of porosity and uniaxial compressive strength is related to wackestone with a correlation coefficient of 0.84 and the lowest is related to mudstone with a correlation coefficient of 0.74. In addition, the highest correlation of water absorption and uniaxial compressive strength is related to packstone with a correlation coefficient of 0.83 and the lowest is related to mudstone with a correlation coefficient of 0.61. The highest correlation of P-wave velocity is related to wackestone with a correlation coefficient of 0.85 and the lowest is related to mudstone with a correlation coefficient of 0.64.

Table 2. The results of ANOVA and correlation coefficient tests

parameter	Equation	R^2	Adjusted R^2	P-value
UCS-ρ	UCS = 105.97ρ - 147.02	0.72	0.71	<0.05
UCS-n	UCS = 213.26n-0.448	0.84	0.83	<0.05
UCS-Wa	UCS = 125.39e-0.114Wa	0.79	0.78	<0.05
UCS-Vp	UCS = 10.474Vp1.3712	0.82	0.81	<0.05
UCS-Is	UCS = 19.079Is + 26.879	0.88	0.87	<0.05

4. Conclusion

A wide range of microfacies can be identified in the Ilam formation and includes different types of limestone including mudstone, wackestone, packstone and grainstone. The average porosity and percentage of water absorption increases from grainstone samples to mudstone, which is due to the presence of a higher percentage of carbonate mud and finer texture. Although the average density of all 4 types of samples are very close to each other, the density of grainstone samples was higher than other samples. The average P-wave velocity, point load index and uniaxial compressive strength in packstone samples are higher than other types of stones, which is due to the presence of more grains in the texture and as a result its higher strength. In this study, appropriate experimental relationships between uniaxial compressive strength and physical characteristics of Ilam Formation were obtained. Statistical analysis shows that the best UCS correlation is related to porosity and the lowest is related to density. Besides, there is a reliable correlation between the point load index and the uniaxial compressive strength, which allows a reasonable estimation of the strength of Ilam limestones. Regression analysis shows that the classification of samples can increase the correlation coefficient. Therefore, increasing the number of samples with different types does not always increase the correlation coefficient between the parameters, but the analysis based on the classification of the rock type can show the relationships between the parameters better and more realistically.

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