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Correlation study some dynamic properties with density, point load Index and Uniaxial compressive strength of some units of Mukdadya (lowerBakhtiari) Formation

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Abstract
Geotechnical study conducted upon 10 rock samples have been taken from outcroup of Mukdadiya Formation (Lower Bakhtiari) which are located in Kirkuk anticline. Seismic wave velocities (shear and compressional), the dynamic modulus of rigidity, young, bulk and poisson's ratio, density, point load index test and uniaxial compressive strength test were measured of the rock samples in the laboratory. The dynamic properties values were correlated with geotechnical properties inculding uniaxial compressive strength, point load index and dry density. The rock samples have low to medium seismic velocites and very weak to weak mechanical strength. The mathematical relations showed a good correlation coefficient between the dynamic and geotechnical properties of the rock samples, that confident relations could use to estimate the geotechnical properies in the field by measuring sciesmic wave velocities in any future engineering projects.

Keywords: Mukdadiya Formation, dynmic properties, uniaxial compressive strength test, point load index test, density, mathematical correlation.

Introduction
Estimation of the commonly rock mechanical properties like uniaxial compressive strength and triaxial test are very important parameters must have determinde in the design and stability evaluation of any underground and surface structure like dam, tunnel, piles, cavern, road and high way cut slopes. The determination of these properties in the laboratory is difficult and time consuming, it also requires great accuracy in the preparation and testing of samples. Therefore there is need for a simple technique for the determination of the mechanical properties of rocks by an indirect but reliable method.[1] and [2].

Ultrasonic techniques are non destructive and easy to apply in both site and laboratory conditions. In rock engineering, SV (sound velocity) that represented in this study as compressional (V_p) and shear (V_s) waves techniques have increasingly been used to determine the dynamic properties of rocks. Some of those important influencing factors are rock type, grain size, and density, weathering and joint properties [1].

Many researchers, such as[1-10]. have studied the relations between rock properties and SV and they have found that the SV is closely related to the rock properties.

The rock samples of this study were collected from Mukdadiya (Lower Bahktiari) Formation that located at north-east of Kirkuk city latitude (N 35° 28$^{'}$ -N 35° 58$^{'}$), longitude (E 44° 26$^{'}$ - E 44° 22$^{'}$).

Mukdadiya Formation comprise up (2000 m) of fining upwards cycles of gravelly sandstone , sandstone and red mudstone. The sandstone often strongly cross bedded and associated with channel lags and clay balls, the formation was deposits in fluvial environments, in a rapidly subsiding for deep basin and have Pliocene age [11].

The aim of this study is to determine the value of mechanical and physical properties that included uniaxial copressive strength (σ), point load index test ($I_{s(50)}$, dry density (ρ) and some dynamic properteis SV (V_p, V_s) compressional and shear seismic wave velocities , (μ,E,K,α,) the modulus of rigidity, young, bulk and poisson's ratio respectively of rock samples and then correlation mathematically between mechanical and dynamic properties.

Materials and Methodology
The rock samples were collected from 3 different locations grouped as (K1, K2, K3) to determine some static and dynamic geotechnical properties which geologically belongs to the Mukdadiya (Lower Bahktiari) formation.The name, the location and the class of the collected rocks are given and shown in table (1) and fig. (1).

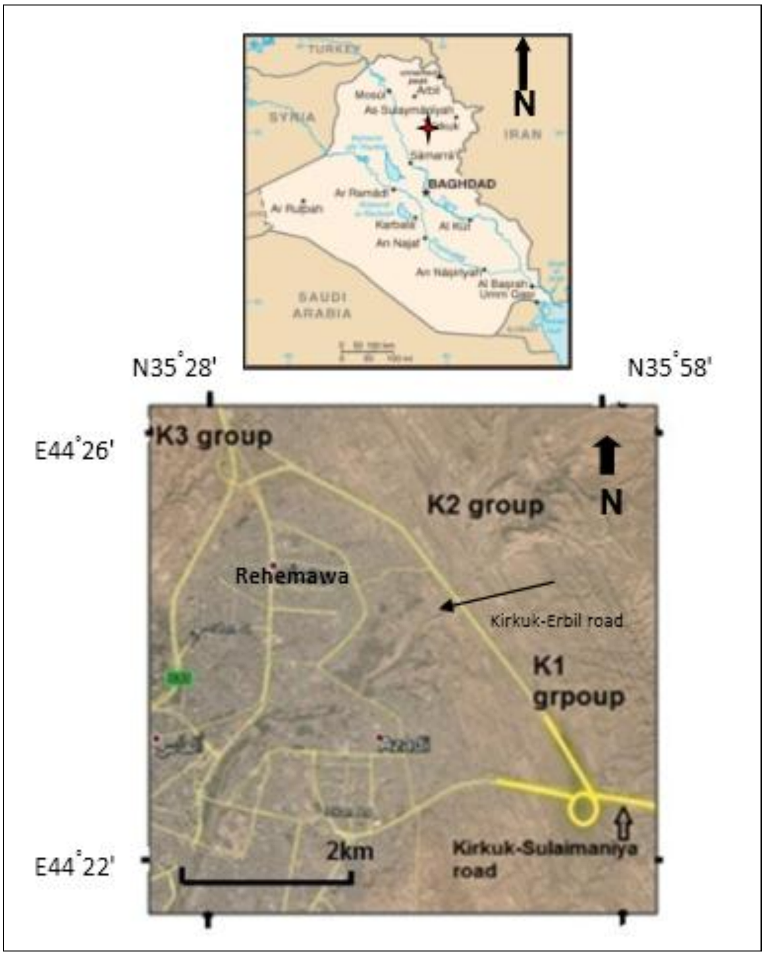

Fig. (1): Maps showing the study area and sampling locations (google earth;http://teachmideast.org) [12]

Some of physical, mechanical and dynamic properties value of 10 rock samples have been determined which consist of sandstone, siltstones and claystones. In this study the physio-mechanical properties represented by uniaxial compressive strength test, dry density and point load index test of rocks while the dynamic properties of selected rock samples represented as V_p and V_s seismic wave velocities, modulus of Rigidity, Young, bulk and poisson's ratio.

Table 1: Rock samples description

Station	Sample no.	Group name	Rock type	Rock sample description according to [13]
Station one	1	K1	Siltstone	Fresh, medium block size, jointly, brown gry-clayly siltstone
	2	K1	Sandstone	Coarse grain size, slightly weathered, large block size brown silty sandstone
	3	K1	Claystone	Very fine, small block size,compacted, jointly, fresh, brown claystone
	4	K1	Sandstone	Fresh, jointly, large block, gry silty coarse sandstone
Station two	5	K2	Sandstone	Fresh, medium block size, fine, brown silty sandstone
	6	K2	Siltstone	Fresh, jointly, large block size, brown clayly siltstone
	7	K2	Sandstone	Fresh, jointly, medium block size, grysilty coarse sandstone
Station three	8	K3	Sandstone	Fine, large block size, jointly, fresh, brown silty fine sandstone
	9	K3	Sandstone	Greyish, fresh, jointly, pebbly silty sandstone
	10	K3	Claystone	Very fine, slightly weathered, small block size brown claystone

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The rock samples were tested in the applied geology laboratory of Kirkuk University for determination of mathematical relationships between some physico-mechanical and dynamic properties of sellected samples.The samples were prepared in the laboratory condition, all tested methods of rock samples measurement and have been standardized by the International Society for Rock Mechanics according to [14], in order to determine the value of uinaxial compressive strength the test samples are prepared by cutting them to the specified length and are thereafter grinded and measured ,there are high requirements on the flatness of the end surfaces in order to obtain an even load distribution, the samples are loaded axially up to failure. Some of Uniaxial compressive strength values determined directly [15,16] and others determined indirectly by using point load index test [17] table (2). The Ultrasonic device (Matest) was employed to determine the compressional seismic waves velocity (V_p) and shear seismic velocity (V_s) for the samples, in addition to their density in the laboratory. Seismic waves velocity (V_p) and (V_s) and other seismic properties were determined in the laboratory as [18] standard.The results of laboratory study are given in table (2,3).

The main equations which have been used to calculate the dynamic parameters and their symblos are as the followings:-

$V_p = L/T_{wave}$ (1)

$V_s = L/T_{wave}$ (2)

$\mu = \alpha \ V_s$ (3)

$E = 2\mu(1+\alpha)$ (4)

$k = E/3(1-2\alpha)$ (5)

$\alpha = V_p{}^2 - 2\,V_s{}^2/2(V_p{}^2 - V_s{}^2)$ (6)

where ;

V_s: *velocity of shear wave* (m/esc)

V_s : *velocity of compressional wave* $(m/esc\,)$

T_{wave}: *time of transport* (sec)

L: *length of sample* (cm)

E: *young modulus* (Mpa)

k: *bulk modulus* (Mpa)

μ: *shear modulus* (Mpa)

α: *poisson ratio*

(V_p,V_s, μ,E,k,α), uniaxial compressive strength, point load and dry density of the rocks were analyzed using the method of least squares regression. The equation of the best-fit line, the 95% confidence limits, and the correlation coeffecient (r) were determined for each regression.

Results and discussion

As it showed in the table (2,3) the maximum and minimum values some of the geomechanical and dynamic properties of tested samples are as following: for uniaxial compressive strength (σ) ranges (2.93-40.95) Mpa, while the values of compressional seismic waves (V_p) velocity ranges (0.95-2.48) km/sec, The shear sceismic waves velocity (V_s) is between (0.66–1.66) km/sec, The dry density values is between (2.11-2.74) (gm/cm^3). Poisson's ratio (α) is between (0.033-0.22). Rigity module (μ) is between (919-7247) Mpa.Young modulus (E) is between (1899-15770) Mpa.Bulk modulus is between (678-7961) Mpa. According to [2] the samples strength were classified as weak and very weak strength rocks, the maximum and minimum values of uniaxial compressive and point load index strength showed a big variety this great differences may due to the petrographic, mineral composition and degree of weathering. [19] [20] [21] [22].

As table (2) shows the higher seismic compression and shear wave velocities are for claystones and siltstones which composed of fine and medium grains size and more compacted particles, while the medium and coarse grains size sandstones which might contribute in more porous rocks, have the lower velocities, respectively the higher poisson's ratio and each rigidity ,young and bulk modulus value are for claystones and siltstones ,while the sandstones have lower values of those modulus.

The results of regression equations and the correlation coffeciences (r) are given in table (4). The mathematical relation between SV and uniaxial compressive strength, point load and density and the dynamic modulus are shown in fig. (2 throught 11) . In all cases, the best-fitted relations were found to be straight lines.

The regression relations shows relatively high correlation between (V_p, V_s) and their uniaxial compressive strength of rock sample respectively fig. (2,3) ,and so likes in the relations between the Uniaxial strength with each of the rigidity and bulk modulus fig. (8,9).There are moderate relations between V_p and $I_{s(50)}$ and between V_s and $I_{s(50)}$ fig. (6,7), and so likes with each dry density and young modulus fig. (10,11), while the coefficient correlation between dry density and each V_p,V_s are moral less than the previous one fig. (4,5).

Table 2: Results of the SV tests and other rock properties of rock

Sample no.	Group name	Rock type	$I_{s(50)}$ (Mpa)	σ (Mpa)	Dry density ρ (gm/cm³)	V_p (km/sec)	V_s (km/sec)	Strength Classification According to [2]
1	K1	Siltstone	1.12	24.20^x	2.30	2.15	1.37	Weak
2	K1	Sandstone	0.56	12.60	2.35	1.26	0.80	Very weak
3	K1	Claystone	1.82	44.95^x	2.47	2.48	1.48	Weak
4	K1	Sandstone	0.13	2.93	2.11	0.95	0.66	Very weak
5	K2	Sandstone	1.65	31.13^x	2.56	1.40	0.99	Weak
6	K2	Siltstone	1.63	36.68	2.63	2.47	1.66	Weak
7	K2	Sandstone	0.52	11.70	2.74	1.90	1.26	Very weak
8	K3	Sandstone	0.44	9.90	2.49	1.33	0.93	Very weak
9	K3	Sandstone	0.71	15.98	2.14	1.86	1.25	Very weak
10	K3	Claystone	0.54	12.15	2.18	1.72	0.95	Very weak
			Max=1.82 Min=0.13	**Max=40.95 Min=2.93**	**Max=2.74 Min=2.11**	**Max=2.48 Min=0.95**	**Max=1.66 Min=0.66**	

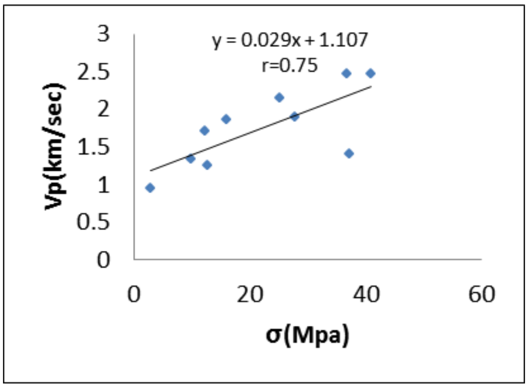
Note:x directed UCS samples, other samples of UCS determined by using poin load index test

Table 3: Dynamic modulus for the rock samples

Sample no	Poisson Ratio α	Shear module μ Mpa	Young module E Mpa	Bulk module K Mpa	$V_p \backslash V_s$
1	0.15	4317	9999	4874	1.56
2	0.16	1504	3496	1725	1.57
3	0.22	5410	13232	7961	1.67
4	0.033	919	1899	678	1.44
5	0.063	2509	5335	2036	1.46
6	0.088	7247	15770	6379	1.48
7	0.1	4350	9631	4013	1.5
8	0.095	2153	4715	1940	1.49
9	0.088	3343	7274	2942	1.49
10	0.15	2637	6065	2938	1.56

Table 4: Regression analysis results

Parameters to be related	Regression equation Y=AX±B	Correlation coefficient (r)
$V_p - σ$	$V_p = 0.029\ σ + 1.107$	0.75
$V_s - σ$	$V_s = 0.018\ σ + 0.72$	0.82
V_p - ρ	$V_p = 1.70ρ + 1.107$	0.55
V_s - ρ	$V_s = 1.07ρ + 1.53$	0.56
$V_p - I_{s(50)}$	$V_p = 0.37\ I_{s(50)} + 0.79$	0.68
$V_s - I_{s(50)}$	$V_s = 0.59 I_{s(50)} + 1.20$	0.65
σ--k	σ=0.004k+2.861	0.82
σ--μ	σ=0.005μ+2.074	0.74
σ--E	σ=0.001E+7.619	0.64
σ--ρ	σ=42.99ρ-83.23	0.69



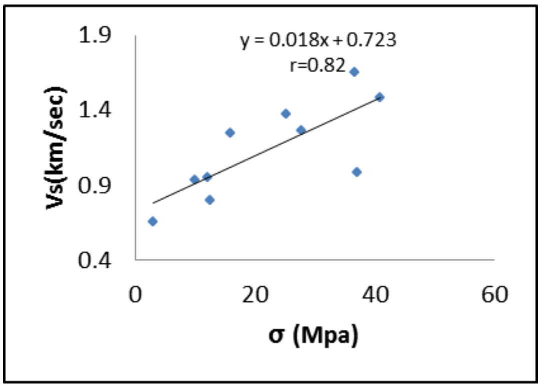


Fig. (2) and (3): Correlation between Uniaxial compressive strength and V_p, V_s

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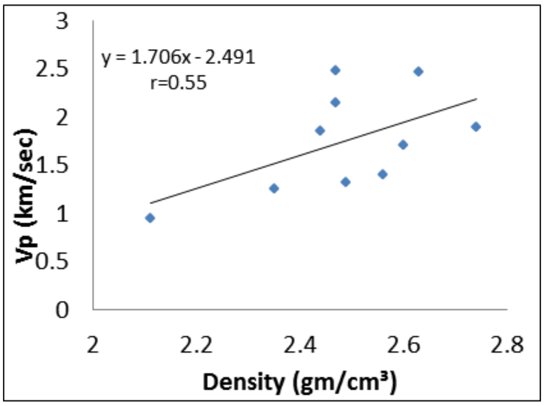


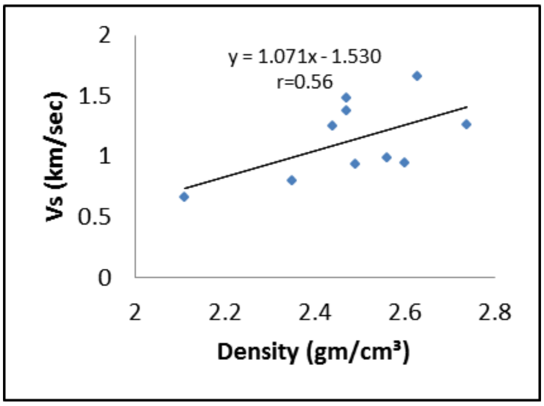
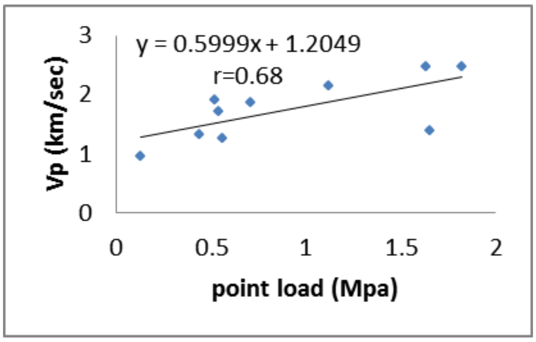


Fig.(4) and (5): Correlation between dry density and V_p, V_s.



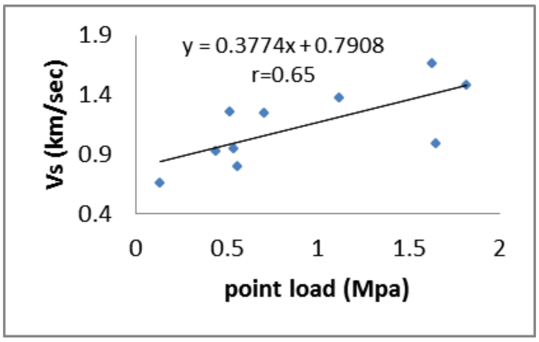
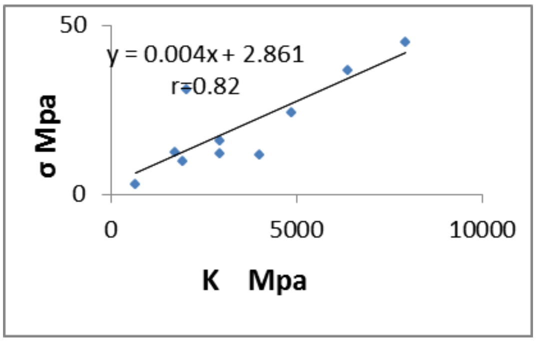


Fig.(6) and (7): Correlation point load index test with V_p and V_s



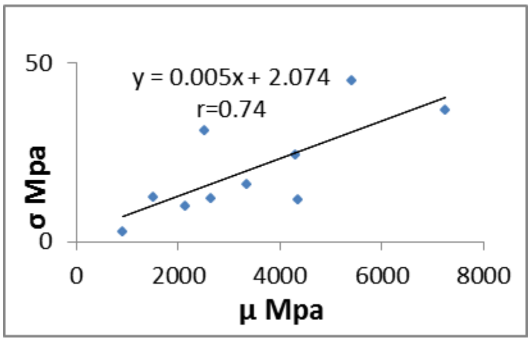
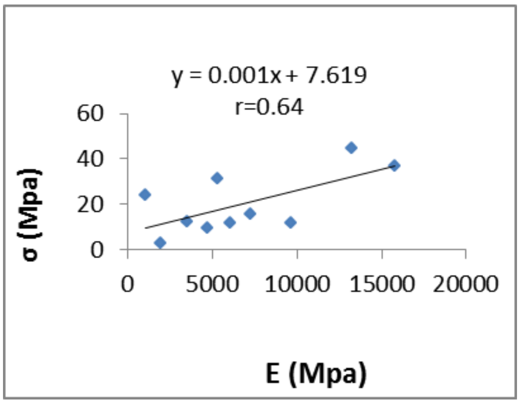


Fig.(8) and (9): Correlation Uniaxial strength with k and µ



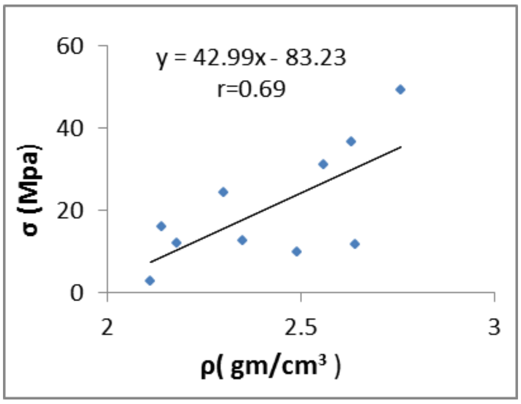


Fig.(10) and (11): Correlation Uniaxial strength with E and ρ

Conclusion

The rock samples have low to medium seismic velocites**.** The grain size and compaction controls the seismic compressional and shear velocities with dynamic modulus (µ,E,K) and poisson ratio of the rock samples .The rock samples have been classified as very weak to weak strength. There are good relations are between dynamic and uniaxial with point load strength relations which could use to estimation the rocks strength by measuring sciesmic velocites in field in future engineering projects.

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دراسة مقارنة لبعض الخواص الديناميكية مع الكثافة, معامل قوة التحمل النقطي والمقاومة الانضغاطية الاحادي المحور, لبعض وحدات تكوين المقدادية (البختياري الاسفل)

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الملخص

اجريت دراسة جيوتكنيكية لعشرة نماذج ماخوذة من طبقات الظاهرة العائدة الى تكوين المقدادية (البختياري الاسفل) الواقعة على قبة كركوك ذي احداثيات خطوط العرض: خطوط العرض ($N\ 35^0\ 58'$ -N $35^0\ 28'$), خطوط الطول ($E\ 44^0\ 22'$ - E $44^0\ 26'$). اجريت قياسات سرع موجات الزلزالية الانضغاطية والقصية, معاملات الديناميكية القصية,نسبة بوسون مع فحص التحمل النقطي مع مقاومة الانضغاط الاحادي المحور والكثافة لجميع النماذج الصخرية في المختبر. تم مقارنة بعض الصفات الديناميكية مع الصفات الجيوتكنيكية الاخرى المتضمنة بفحص التحمل النقطي ومقاومة الانضغاط الاحادي المحور والكثافة. اظهرت نتائج الدراسة بامتلاك النماذج الصخرية سرع زلزالية واطئة ومتوسطة ولها مقاومة ميكانيكية ضعيفة جدا وضعيفة. اظهرت العلاقات الرياضية التي اجريت بين قيم الصفات الديناميكية وقيم الصفات الميكانيكية الاخرى جيدة, تلك العلاقات الموثوقة ممكن ان يستخدم في تقدير الصفات الميكانيكية من اجراء قياسات السرع الزلزالية في الحقل عند تقييم المشاريع الهندسية المستقبلية.

الكلمات المفتاحية: الخواص الديناميكية للصخور، تكوين المقدادية، اختبار مقاومة الانضغاط الاحادي للصخور، اختبار مقاومة التحمل النقطي، العلاقات الاحصائية، الكثافة.