Correlation Study Between Point Load Test And Uniaxial Compressive Strength And Tensile Strength Of Some Sedimentary Rocks In Mosul City

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ABSTRACT

The point load test is used as a quick and inexpensive means of obtaining rock strength indexes when logging core samples in either a field or laboratory setting. In order to estimate the Uniaxial compressive strength, indirect tensile strength (Brazilian and 4-point bending)of the rocks, index to strength conversion factors are used to involve three types of the most popular sedimentary rocks in Mosul city, which are limestone, sandstone and gypsum in both dry and wet conditions. The results showed that a conversion factors,(14.55,15.9) can be used to estimate compressive strength for both limestone and gypsum rocks in dry and wet conditions respectively. The study also found that conversion factors,(1.4,2.6) are applied in dry condition for the three rocks in Brazilian and Bending tests.

Keywords: Point Load Index, Uniaxial Compressive Strength, Conversion factor.

دراسة العلاقة المتبادلة بين فحص التحميل النقطي وقوة تحمل الانضغاط الأحادي والشد لبعض الصخور الرسوبية في مدينة الموصل

الخلاصة

يعتبر فحص التحميل النقطي من الفحوصات الهندسية السريعة والاقتصادية لإيجاد دليل قوة تحمل الصخور الاسطوانية سوءا بالموقع أو بالمختبر. ولغرض تقدير قوة تحمل الانضغاط وقوة تحمل الشد الغير مباشر للصخور، تم إيجاد نسبة التحويل (k) بين دليل القوة في فحص التحميل النقطي وقوة تحمل بعض الصخور الرسوبية الشائعة في الموصل وهي الحجر الجيري، الحجر الرملي والجبس وذلك في حالتي الجفاف والتشبع بالماء. أظهرت نتائج الفحوصات بأنه يمكن استخدام نسب التحويل (14.55 , 15.9) لإيجاد قوة التحمل لكل من صخور الحجر الجيري والجبس في حالتي الجفاف والتشبع على التوالي. كما بينت الدراسة بأن نسب التحويل (1.4 , 2.6) يمكن استخدامها أيضا لإيجاد قوة تحمل الشد في الصخور الثلاثة قيد الدراسة وذلك في الفحص البرازيلي والانحناء على التوالي وفي الحالة الجافة فقط.

INTRODUCTION

The sedimentary rocks represent the most important type in civil engineering constructions, such as a foundation rock, building stone and in facing works. These rocks make up about (90%) of the Iraq surface (1).

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The point load test has become increasingly popular as a core logging index which gives a reliable estimation of the Uniaxial compressive strength of the rocks (2).
The aim of this study is to present the data analysis used to correlate the point load test indexes (Is_{50}) with the Uniaxial compressive strength, indirect tensile strength and to find the conversion factors for different sedimentary rocks in both dry and wet conditions. Many investigators, Das(3), Chau, KT. Wong, R.H.C (4) and others studied the relation between the point load test and the Uniaxial compressive strength for different sedimentary rocks from various locations. They found that, the conversion factors were ranged between (16-24) for dry state only. Hoek (5) pointed out at the mechanics of the point load test causes the rock to fail in tension. The Point load strength's accuracy in predicting the unconfined compressive strength depends on the ratio between U.C.S & Tensile strength.
The early studies, Bieniawski (2), Broch and Franklin (6) were conducted on hard strong rocks. They found that the relationship between U.C.S and the point load strength (Is) could be expressed as:

$$U.C.S = 24(Is)_{50}$$

Where U.C.S : Unconfined Compressive Strength.
The point load test allows the determination of the strength index (Is) using the following equation:

$$Is = P/(D_{50})^2$$

Where P: the failure load
D_{50}: core specimen diameter (50) mm.
The rock strength determined by point load test are an indication of intact rock strength and not necessarily the strength of the rock mass (7).

DESCRIPTION OF ROCKS

1- Limestone

The limestone rock used in this study was taken from Ain-Al Safra quarry (about 30 km to the east of Mosul city). It is medium grained with abundance of fossils. It has been considered from Middle- Upper Eocene Age (8). Block samples were taken from a depth of 15 meters of thickness over thirty meters.

2- Sandstone

Block samples of the rock was brought from Hai-Al-Arabi (10) km north of Mosul center. The studied location is lied within the upper most part of the Lower Fars Formation. The rock in general regarded as bedded and laminated sedimentary rocks, for their own specific environments of deposition(8).

Gypsum

The studied gypsum was obtained from Hamam-Al-Aleel quarry located at 10km to the west of Mosul city. samples were taken from a depth of (8) m below ground surface in a form of irregular blocks. It was white to grey colored.

Gypsum is available in the west and northern part of Iraq. It is a soft rock of Mohs hardness equal to (1.5-2.0).(9).

PHYSICAL PROPERTIES

The physical properties of the three studied rocks were determined according to the standard procedures given by ISRM (10). The average values of at least four results were given in Table (1).

1-Specimen Preparation:

The core samples were obtained from blocks to the required dimension using core drilling machine, the end of the samples were machined flat ground and parallel to each other, according to the limits recommended by ISRM (11) and ASTM (12). All tests were carried out under dry and wet conditions, but the temperature for gypsum samples did not exceed 70^{o}C in order not to effect the chemical composition of the rock.

Unconfined Compression Test (U.C.S)

The test is considered as a rough index which gives good range of rock strength that are likely to be used in different engineering problems like, roof support, Pillar design and excavation technique (5).

For most rock design problems a reasonable approximation of the Unconfined Compressive Strength is sufficient**.**

3-Point Load Test (P.L.T)

The point load test has been used in geotechnical analysis for over thirty years (13). The test is an alternative to the Unconfined Compressive Strength since it can give similar data at a lower cost.

The point load test involves compressing of a rock sample between conical steel platens till failure. The apparatus consists of a rigid frame, two point load platens, pressure gauge to indicate the failure load. Schematic diagram of the machine is shown in Figure (1) .

TENSILE STRENGTH

Brazilian Test

For indirect tensile strength determination of the studied rocks, Brazilian test was performed on a circular discs compressed a cross it‘s diameter. The tensile strength was calculated as:

$$\sigma_t = \frac{2P}{\pi D t}$$

Where:
σ_t: Tensile strength
P: Applied load at failure.
D: Specimen diameter.
t: Specimen thickness.

Bending Test

The strength was determined using four point bending test apparatus, since a constant bending region can be achieved within this system. The test was carried out under dry and wet condition on specimen of (L=240 mm., b=40 mm., d=25 mm.) according to the requirements given by ASTM (14). Formula suggested by Duckworth (15) was used to calculate the tensile strength.

$$\sigma_t = \frac{3M(\varepsilon_c+\varepsilon_t)}{bd^2\varepsilon_t}$$

Where:
σ_t: Tensile strength
M: Bending moment.
ε_c: Compressive bending strain.
ε_t: Tensile bending strain.
The apparatus are shown in Figure (2).

RESULTS AND DISCUSSION

1-Physical and Index Properties

As shown in Table (1), there is little variation in the specific gravities and dry densities of limestone and sandstone rocks. It would therefore appear that the individual compositions don't vary significantly. The porosity (22.1 %) and the saturation percent (18.5 %) of the sandstone rock were the greatest values among the three tested rocks, due to their internal voids and large sand grain constitute, while the gypsum rock has the lowest values for these properties as it contains very fine grains.

2-Uniaxial Compressive Strength

The average results of six cylindrical specimens in the Uniaxial Compressive test in both dry and wet conditions are given in Table (2). It can be noticed for the three types of rocks tested, that gypsum has the higher compressive strength than the other rocks, this high value is due to the high bond between their grains constitute, followed by limestone and sandstone. These results are with good agreement with the results obtained by Thabet, et. al. (1) and Nuri (9). Limestone specimens gave less strength with mean value of (287 kg/cm^2), while the strength of sandstone rock was the lower (116 kg/cm^2), and for this low strength it can be classified as weak rock (16), the weakness in it's binding material (clay and little silicate) is the reason for this behavior.

3-Tensile Strength

Two indirect methods of assessment the tensile strength of the rocks, were considered. Six beam specimens were tested in bending under both dry and wet conditions according to the method given by Ali (17). Table (2) gives the average results for the tensile strength. The three types of rock specimens were tested in Brazilian method so that , the results could be compared. The results in bending test in both dry and wet state showed higher values than the strength obtained from Brazilian test for the three types of rocks tested. Limestone and gypsum rocks showed little difference in strength between the two methods in the dry condition while sandstone showed more difference in strength in the two conditions (dry & wet).

4-Point Load Index

The point load index (Is) was obtained from the point load test for the three rocks. The average results for six specimens tested are listed in Table (3). The values of the conversion factor (k) was obtained from Uniaxial compressive strength in both dry and wet conditions. It can be seen that the conversion factors for limestone and gypsum rocks in dry state are (14.7 & 14.4) respectively and in wet state are (15.8 & 16.0) respectively which are almost equal, while the conversion factors of sandstone are (11.8 & 22.7) in dry and wet states which varies from the other rocks due to its high porosity and low strength. An average values of (14.55 & 15.9) can be used as conversion factors in dry and wet condition for both limestone and gypsum rocks respectively.

The relation between the unconfined compressive strength and point load index for dry and wet conditions are shown in Figure (3).

It can be noticed that the compressive strength is directly proportional with point load index. The rate of increasing in the strength is almost the same in dry and wet states. These behavior are concided with the results found by John Rusnak (7) in estimating the compressive strength, index to strength conversion factors for coal rocks measured in six states.

The average results of indirect tensile strength for six rock specimens tested in dry and wet conditions using Brazilian and bending methods are listed in Table (4).The conversion factors (k) are obtained from the two methods used and for the three types of rocks. It can be noticed that the average values of the conversion factors in the dry condition is (1.4 & 2.6) for Brazilian and Bending tests respectively, and the conversion factor for wet condition in Brazilian test was (1.5) while the values in wet-bending tests are (3.4) for limestone and gypsum rocks.

The relations between the results of the indirect tensile strength for Brazilian and Bending methods in dry and wet states are shown in Figure (4 and 5) respectively.

The same trend of the curves are noticed which are similar to the curves obtained in Figure (1) for the three type of rocks.

CONCLUSIONS

1-Point load test is an efficient method to determine intact rock strength properties from drill core samples.

2-The study found that a conversion factor (k), (14.55, 15.9) worked well in compressive strength for both limestone and gypsum rocks in dry and wet conditions respectively. While a conversion factors of (11.8, 22.7) may be used for sandstone rock in dry and wet conditions.

3-The study also showed that conversion factors of (1.4, 2.6) can be used for the three rocks limestone, sandstone and gypsum in the indirect tensile strength (dry condition) in Brazilian and Bending tests respectively. The wet condition of limestone and gypsum rocks gave conversion factor (k= 3.4) for the two indirect tests used.

4-The conversion factors in wet condition for all the rocks tested was greater than that in dry condition.

REFERENCES

[1]Thabet, K. Khattab, S A. and Nuri, Th M. "Geotechnical Characteristics of Mosul Marble", Dirasat Magazine, Vol.21B, No.6, pp. (25-40), 1994.

[2]Bieniawski, Z T. "The point load test in Geotechnical practice", Eng. Geol., pp.(1-11), Sep. 1975.

[3]Das, B M. "Evaluation of the point load strength for soft Rock Classification", Proceeding of the 4th. International Conference on Ground Control in Mining Morgantown, pp.(220-226), 1985.

[4]Chau, K T. Wong, RH C. "Uniaxial Compressive Strength and Point Load Strength of Rocks" Int. Journal of Rock Mech. Min. Sci, Vol.33, No.2, pp.(183-188), 1996.

[5]Hoek, E. "Rock Mechanics Laboratory Testing in the Context of Consulting Engineering Organization" Int. J. of Rock Mech. Min. Sci., Vol.14, pp.(93-101), 1977.

[6]Broch, E. Franklin, J A."The point load strength test", Int. J. of Rock Mech. Min. Sci., Vol.9, pp.(669-697), 1972.

[7]John, R. Christopher M. "Using the point load test to determine the Uniaxial Compressive Strength of Coal Measure Rock", National Institute for occupational Safety & Health Pittsburgn, PA, pp.(23-35), 1998.

[8]Al-Naqib, S Q. and Agwan, T A. "Sedimentelogical Study of the Clastic Units of the Lower Fars Formation", Iraqi Geological Journal, 26(3), pp.(108-121), 1993.

[9]Nuri, Th M. "Geotechnical properties of some Sedimentary Rocks in Mosul ", Al-Rafidain Engineering, Vol.10, No.1, pp.(45-52), 2002.

[10] ISRM. "Suggested Methods for Determining Water Content, Porosity, Density, Absorption and Related properties" Int. J. Rock Mech. Min. Sci. Vol.16, pp.(143-156), 1979.
[11] ISRM. "Suggested Methods for Determining the strength of Rock Materials in Triaxial Comp." Int. J. Rock Mech. Min. Sci. Vol.15, No.2, pp.(49-51), 1979.
[12] ASTM. "Standard Method for Triaxial Compressive Strength of Undrained Rock specimens" ASTM Designation D2664-80.
[13 ISRM. "International Society of Rock Mech. Commission on Testing Methods, Suggested Methods for Determining Point load strength" Int. J. Rock Mech. Min. Sci. Abstr.22, pp.(51-60), 1985.
[14] American Society of Testing and Materials – Annual Book for ASTM Standards, Part 19, 1983.
[15] Duckworth, W H. "Precise Tensile properties of Ceramics Body" Amer. Cer. Soc. Vol.34, No.1, pp.(1-9), 1951.
[16] Jaeger, J C. and Cook, N G W. "Fundamentals of Rock Mechanics" CHAPMAN and HALL, 3rd edition, London, 1979.
[17]Ali, S A. "Creep properties of Evaposite Rocks with particular Reference to Gypsum" Ph.D. thesis, University of Sheffield, 1979.

Table (1): Physical and Index Properties of Rocks

Rock Type	Dry Density (g_d) kN/m^3	Specific Gravity (G_s)	Absolute Porosity (n%)	Saturation (%)
Limestone	19.9	2.63	8.5	9.6
Sandstone	18.2	2.54	22.1	18.5
Gypsum	22.7	2.35	3.6	1.2

Table (2): Mechanical Properties Results

Rock Type	Compressive Strength, s_c (MPa)		Tensile Strength, s_t (MPa)			
			Brazilian		Bending	
	Dry	Wet	Dry	Wet	Dry	Wet
Limestone	28.7	18.2	2.7	1.75	5.0	3.9
Sandstone	11.6	2.5	1.35	0.23	2.6	1.2
Gypsum	33.2	19.7	3.2	1.9	5.8	4.2

Table (3): Conversion Factors (k) obtained from Uniaxial Compression Tests

Rock Type	Uniaxial Comp. Strength, s_c (MPa)		Point load index, Is, (MPa)		Conversion Factor $k = \frac{s_c}{Is}$	
	Dry	Wet	Dry	Wet	Dry	Wet
Limestone	28.7	18.2	1.95	1.15	14.7	15.8
Sandstone	11.6	2.5	0.98	0.11	11.8	22.7
Gypsum	33.2	19.7	2.31	1.23	14.4	16.0

Table (4): Conversion Factors (k) obtained from Indirect Tensile Strength

Rock Type	Tensile Strength, σ_t (MPa)				Point load index, Is, (MPa)		Conversion Factor $k=\frac{\sigma_t}{Is}$			
	Brazilian		Bending				Brazilian		Bending	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Limestone	2.7	1.75	5.0	3.9	1.95	1.15	1.4	1.5	2.6	3.4
Sandstone	1.35	0.23	2.6	1.2	0.98	0.16	1.4	1.44	2.65	7.5
Gypsum	3.2	1.9	5.8	4.2	2.31	1.23	1.4	1.5	2.5	3.4

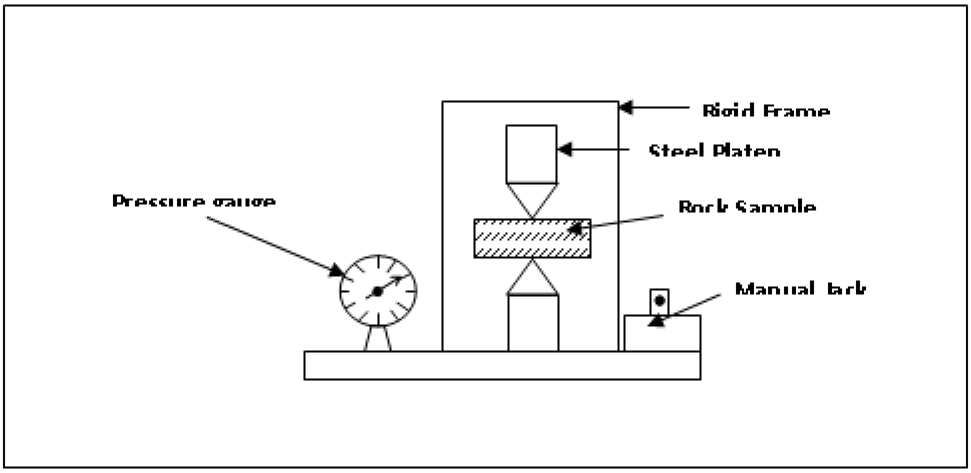

Figure (1): Schematic Diagram for Point Load Test

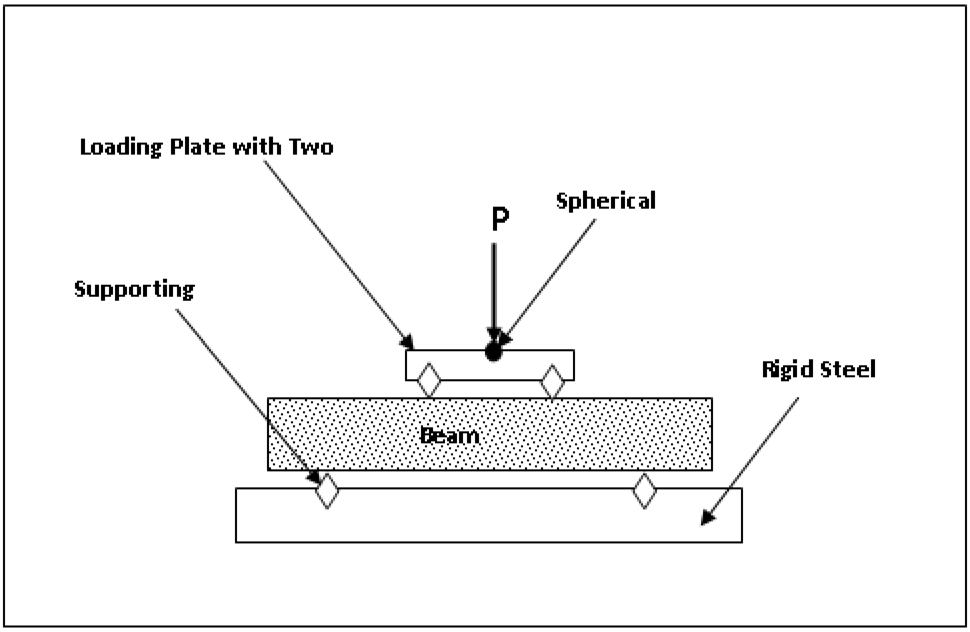

Figure (2): Schematic Diagram for Bending Test

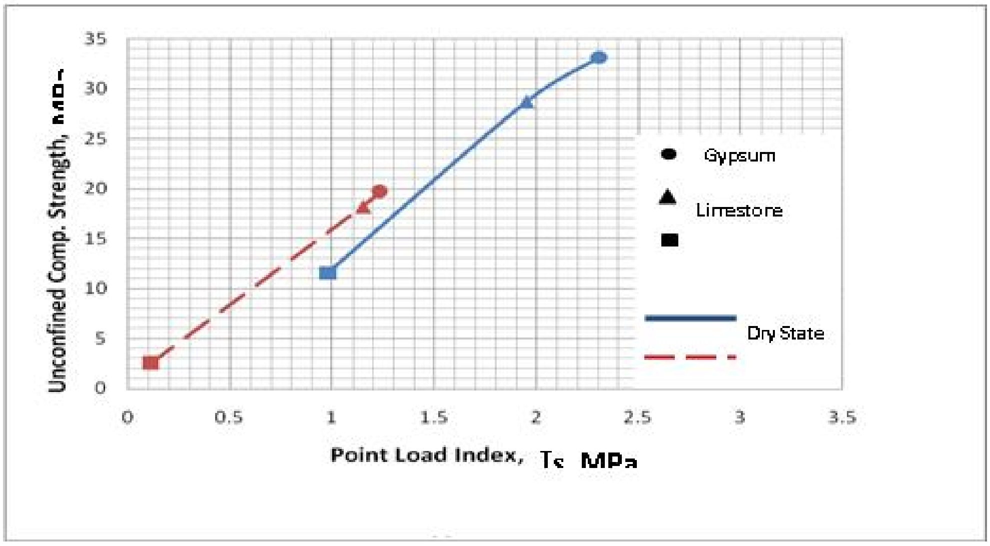

Figure (3): Relationship between Point Load Index, Is and Uniaxial Comp. Strength for the Limestone, Sandstone and Gypsum Rocks

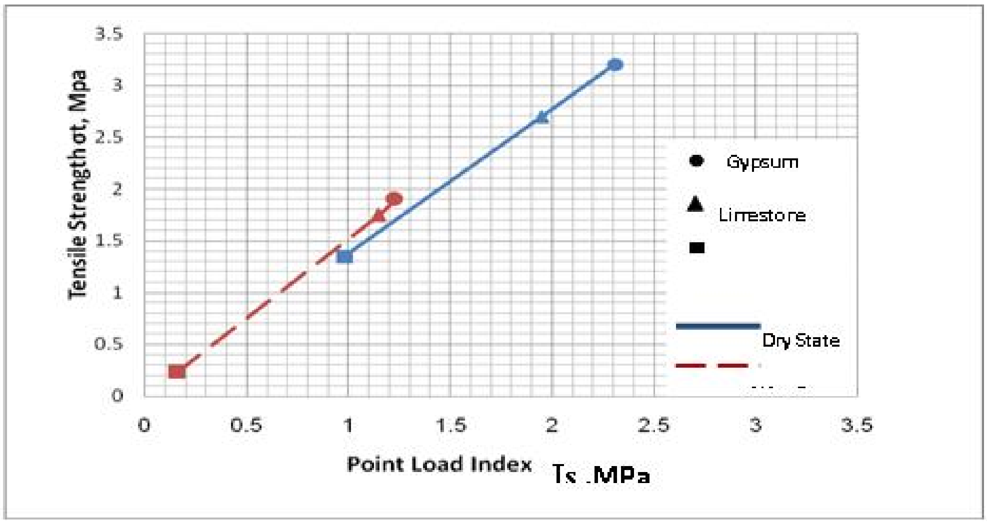

Figure (4): Relationship between Point Load Index, Is and Tensile Strength from Brazelian test for the Limestone, Sandstone and Gypsum Rocks

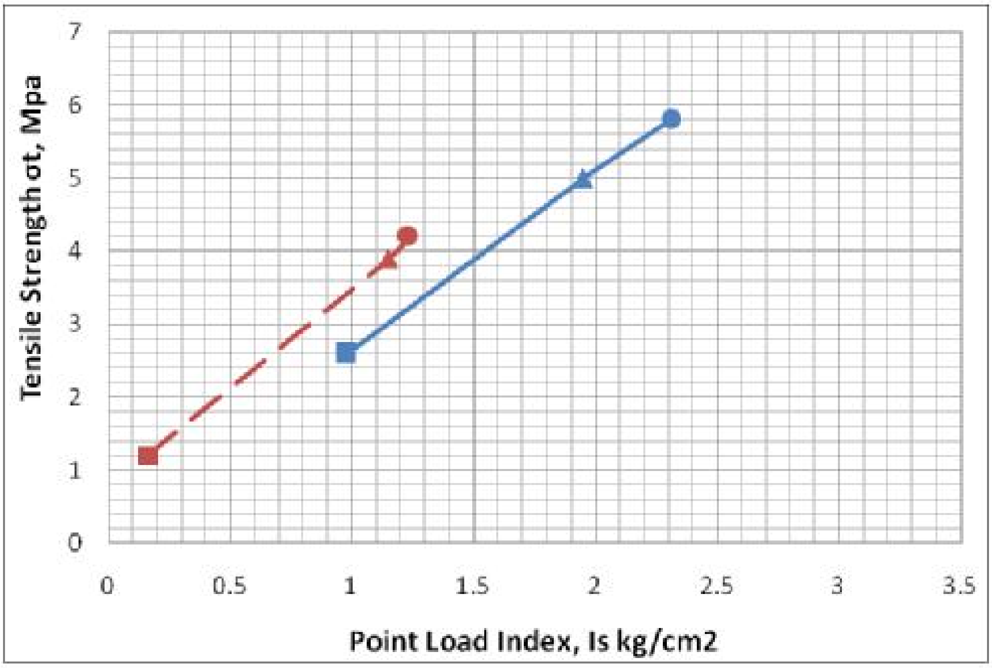

Figure (5): Relationship between Point Load Index, Is and Tensile Strength from Bending test for the Limestone, Sandstone and Gypsum Rocks