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Correlation Between Compressive Strength and Tensile Strength/ Index Strength of Some Rocks of North-West Frontier Province (Limestone and Granite)

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ABSTRACT: *The use of the building stones is increasing day by day and engineering activities are also in progress. Therefore the mechanical properties of building stones such as limestones, marbles, granites etc are required to be investigated to estimate the strength and give recommendations in designing safe structures. The present research deals with the investigation and correlation of compressive, tensile and index strength of granites and limestones from different localities of North-West Frontier Province. The test results are given in table 1-2, which reveal suitability of Shahbaz Garhi micro granite for heavy constructions and in foundations of buildings while Malakand granite in light constructions, crushed stones, floor material and ballast under railway tracks. The strength values of Cherat and Kohat limestones are low, and very much suitable for cement, chemical industry and ballast under roads.*

INTRODUCTION

Since prehistoric days rock is used for constructing different components of building like foundations, walls, floors, roofs, bridges, weirs and dames. Most of the ancient temples and forts were built with natural stones.

In most of these applications rocks are subjected to high degree of compression, tension and shear. Strength can be regarded as a tool of suitability and stability for the usage under different conditions. Geomechanical properties such as compressive strength, tensile strength and index strength are important in analyzing rock strength, stability of roofs, domes of underground openings, in mining for minerals and in preparing rock drilling and blasting programs.

In Pakistan, rocks are used and excavated rarely knowing their engineering behavior. This is not a good practice both from safety and economic points of views. Keeping into consideration the engineering properties of these rocks exposed at various places in N.W.F.P, the work was started in recent years by various workers including Haider, et al, (1990), Rafiq, et al, (1991), Khan, (1995) and Usman, et al, (1995).

The present work deals with the determination and correlation of compressive, tensile and index strength of limestone and granite of some areas of N.W.F.P.

GEOMECHANICAL PROPERTIES

The strength of a rock depends upon the model composition, grain size, texture, structure and degree of deformation of the rock. The strength of a rock can be determined in the laboratory satisfactorily than in the field. However rock properties can change from place to place and the effects of a structural discontinuities such as joints or cracks cannot be estimated by the laboratory test. The strength is given the name on the basis of nature of stress to which the rock

is subjected such as compressive strength, tensile strength, flexural strength, index strength and shear strength (Goodman, 1980).

Laboratory work

Fresh samples in the form of big boulders nearly one cubic foot were collected from different areas under study. Five samples of each rock were prepared having length double that of diameter for uniaxial compressive strength and half for tensile strength. Cores of different sizes ranging from 3.00 cm to 4.50 cm were used for the investigation of index strength of the rocks.

TABLE 1. OBSERVATION AND CALCULATION. TEST RESULTS OF INDEX STRENGTH OF GRANITE FROM MALAKAND AND SHAHBAZ-GARHI AND LIMESTONE FROM KOHAT AND CHERAT

Test No.	Rock type and Locality	G/Pressure "p" (Kg/cm^2)	Core dia. "D" (cm)	Load/Force "F= PxA" (Kg)	Index st. "I_s" (Kg/cm^2)
1.	Granite, Malakand, (Malakand Agency).	11.00	3.00	158.62	17.62
2.		08.50	3.50	115.36	9.41
3.		12.00	3.00	173.04	19.23
4.		14.00	3.00	201.88	22.43
5.		09.00	4.00	129.78	8.11
6.	Granite, Shahbaz-Garhi, (Distt.Mardan)	42.00	4.00	605.64	37.85
7.		40.00	4.50	576.80	28.48
8.		38.00	4.50	547.96	27.06
9.		45.00	4.00	648.09	40.56
10.		50.00	4.50	721.00	35.60
11.	Limestone, Kohat, Limestone quarry of Kohat Cement Factory.	13.00	3.50	187.46	15.30
12.		20.00	3.80	288.40	19.97
13.		25.00	3.50	360.50	29.43
14.		17.00	4.00	245.14	15.32
15.		12.00	4.50	173.04	8.55
16.	Limestone, Cherat, Limestone quarry of Cherat Cement Factory.	22.00	4.00	317.24	19.83
17.		25.00	4.20	360.50	20.44
18.		29.00	3.90	418.18	27.49
19.		32.00	4.50	461.44	22.78
20.		26.00	4.30	374.92	20.27

1. Index strength

This test is carried on any shape and size of the sample. In the present study, the tests were conducted on core specimens. The core specimen is compressed along the diameter as in Brazilian test (Gokhale, 1960). But rough/unprepared specimens used for the test save time and for this reason it is considered as attractive and rapid testing method (Goodman, 1980). Index strength is also used to estimate

uniaxial compressive strength indirectly. In index strength testing method, the specimen fails at a relatively low applied force due to tension and the strength at failure is expressed as a point load index strength and calculated by; (Goodman, 1980).

$$I_S = \frac{F}{D^2}$$

Where

F = The total force at failure = p x A in Kg

p = Gauge pressure in Kg/cm^2

A = Area of the piston = 14.42 cm^2

D = Diameter of the core sample or the distance between conical heads of the testing machine in cm.

The index strength of the rocks under investigation varies from 27.06 to 40.56 Kg/cm^2 in case of Shahbaz Garhi granite, 8.11 to 22.43 Kg/cm^2 in case of Malakand granite, 8.55 to 29.43 Kg/cm^2 in case of Kohat limestone and 19.83 to 27.49 Kg/cm^2 in case of Cherat limestone (see table 1).

TABLE 2. TEST RESULTS OF COMPRESSIVE AND TENSILE STRENGTH OF GRANITE FROM MALAKAND AND SHAHBAZ GARHI AND LIMESTONE FROM KOHAT AND CHERAT. (Dia.of the Specimen=5.47 cm)

Test No.	Rock type & locality	Load (KN)	Compressive st (Kg/cm^2)	Load (KN)	Tensile st (Kg/cm^2)
1.	Granite, Malakand, (Malakand Agency).	75.00	325.72	5.00	21.71
2.		63.00	273.60	4.00	17.37
3.		55.00	238.86	4.00	17.37
4.		70.00	304.00	10.00	43.43
5.		45.00	195.43	7.00	30.40
6.	Granite, Shahbaz-Garhi, (Distt. Mardan).	104.00	451.66	11.00	47.77
7.		88.00	382.18	13.00	56.45
8.		76.00	330.06	15.00	65.14
9.		185.00	803.45	25.00	108.59
10.		215.00	933.74	35.00	152.04
11.	Limestone, Kohat, Limestone quarry of kohat cement factory.	82.00	356.12	8.00	34.76
12.		69.00	299.66	10.00	43.43
13.		60.00	260.57	11.00	47.77
14.		90.00	390.86	13.00	56.47
15.		115.00	499.44	16.00	69.52
16	Limestone, Cherat, Limestone quarry of Cherat cement factory.	95.00	412.58	11.00	47.77
17		80.00	347.43	13.00	56.45
18		69.00	299.66	14.00	60.81
19		145.00	629.73	14.00	60.81
20		127.00	551.55	18.00	78.19

TABLE 3. SUMMARY OF LOCATION, CORRELATION AND AVERAGE COMPRESSIVE, TENSILE AND INDEX STRENGTH OF GRANITE AND LIMESTONE

Rock type	Locality	Compressive strength (Kg/cm^2)	Tensile strength (Kg/cm^2)	Index strength (Kg/cm^2)	Correlation between Compressive, Tensile and Index Strength
Granite	Malakand	267.52	26.05	15.36	$C_{US} = 10.26\ T_{BS}$ $C_{US} = 17.41\ I_S$
Granite	Shahbaz-Garhi	580.21	85.99	33.91	$C_{US} = 6.74\ T_{BS}$ $C_{US} = 17.11\ I_S$
Limestone	Kohat	361.33	50.38	17.71	$C_{US} = 7.17\ T_{BS}$ $C_{US} = 20.40\ I_S$
Limestone	Cherat	448.19	60.80	22.16	$C_{US} = 7.37\ T_{BS}$ $C_{US} = 20.22\ I_S$

Rafiq, et al. (1991) and Khan, (1995) also worked on some of the rocks under study which shows that the index strength values in case of Malakand granite are very much close but Index strength values for Kohat limestone are smaller than the previous values determined by Rafiq et. al. (1991).

2. Tensile strength

The tensile strength of a rock is determined by direct as well by indirect method. In the present work, the tensile strength of the rocks was determined by an indirect method called Brazilian method. Brazilian test is performed on cylindrical rock cores having length-to-diameter ratio of 0.5. The core sample of the standard size is loaded till failure along the diameter of core specimen. The tensile strength of a rock is calculated by; (Gokhale, 1960).

$$T_{BS} = \frac{2F}{\pi DL}$$

Where

F = Tensile load at failure

D = Diameter of the rock specimen

L = Length or thickness of the rock specimen

The tensile strength of the rocks under study varies from 47.77 to 152.04 Kg/cm^2 in case of Shahbaz Garhi granite, 17.37 to 43.43 Kg/cm^2 for Malakand granite, 34.76 to 69.52 Kg/cm^2 for Kohat limestone and 47.77 to 78.19 Kg/cm^2 in case of Cherat limestone.

3. Compressive strength

Cylindrical rock cores of different size are used for this test. This test is also duplicated on cubic shape sample with all faces smooth to ensure more accurate results. The end surfaces of the specimen must be polished and gradually increasing load is applied.

For standard results the length of the specimen is twice of its diameter and loading shall be applied at a rate of 0.1 to 1 MP_a/sec. (Gokhale, 1960).

The uniaxial compressive strength is calculated as;

$$C_{US} = \frac{F}{A}$$

where

F = load at failure

A = cross-sectional area of the rock core

The compressive strength of the rocks under investigation varies from 299.66 to 629.73 Kg/cm^2 for Cherat limestone, 260.57 to 499.44 Kg/cm^2 in case of Kohat limestone, 195.43 to 325.72 Kg/cm^2 in case of Malakand granite and 330.66 to 933.74 Kg/cm^2 in case of Shahbaz Garhi granite.

Comparing this data with the previous work of Haider S; et al, (1990), Rafiq, et al, (1991), Khan, (1995) and Usman, et al, (1995), it

was concluded that the compressive strength values for Malakand granite are close except that of Khan M; (1995). (see table 4). However Shahbaz Garhi micro granite, clos the data of Khan M., 1995. The compressive strength values of limestone from Cherat and Kohat are more or less the same as investigated by early workers.

TABLE 4. PREVIOUS WORK

Rock type & locality	Authors	Compressive st. (psi)	Tensile st. (psi)	Index st. (psi)
Granite,	1. Haider S., et al., 1990.	146.09 - 400.93	----------	----------
Malakand.	2. Rafiq M., et al., 1991.	233.76 - 401.41	----------	8.01 - 15.05
	3. Khan M., 1995.	320.59 - 451.64	----------	1.30 - 1.51
	4. Usman M., et al., 1995	217.86 - 305.06	7.38 - 8.65	----------
	5. Present, 1996.	195.43 - 325.72	17.33 - 43.43	8.11 - 22.43
Granite,	1. Haider S., et al., 1990.	508.15 - 730.45	----------	----------
Shahbaz-	2. Rafiq M., et al., 1991.	----------	----------	----------
Garhi	3. Khan M., 1995.	310.23 - 950.00	----------	1.97 - 2.41
	4. Usman M., et al., 1995	309.42 - 431.43	34.81 - 52.25	----------
	5. Present, 1996.	330.66 - 933.74	47.77-152.04	27.06 - 40.56
Limstone,	1. Haider S., et al., 1990.	----------	----------	----------
Kohat.	2. Rafiq M., et al.,1991.	----------	----------	27.07 - 39.10
	3. Khan M., 1995.	----------	----------	----------
	4. Usman M., et al.,1995.	239.66 - 335.58	26.09 - 39.17	----------
	5. Present, 1996.	260.57 - 499.44	34.76 - 69.52	8.55 - 29.43
Cherat,	1. Haider S., et al.,1990.	529.46 - 730.45	----------	----------
Limstone.	2. Rafiq M., et al.,1991.	670.32 - 905.13	----------	----------
	3. Khan M., 1995.	---------	----------	----------
	4. Usman M., et al., 1995	278.90 - 392.26	34.81 - 43.53	----------
	5. Present, 1996.	299.66 - 629.73	47.77 - 78.19	19.83 - 27.49

DISCUSSION

1. Correlating the compressive, tensile and index strength of rocks under study, it was concluded that the compressive strength of Shahbaz Garhi granite is 6.74 times that of its tensile strength and 17.11 times that of its index strength.

   While the compressive strength of the granite from Malakand is 10.26 times that of its tensile strength and 17.41 times that of its index strength (Table-3). The strength values for Shahbaz Garhi microgranite are close to the values of American standard for testing materials (ASTM). The rock is suitable for heavy construction and foundations of the buildings but for Malakand granite the values are lower than the standards values and the rock under investigation can only be used for boundary walls, as a crushed material, flooring material and ballast under railway tracks.

2. Similarly correlating the compressive, tensile and index strength of limestone from Kohat and Cherat, it was concluded that the compressive strength of Cherat limestone is 7.73 times that of its tensile strength and 20.22 times that of its index strength, but the compressive strength of kohat limestone is 7.17 times that of its tensile strength and 20.40 times that of its index strength (Table-3). The strength values of limestones from Kohat and Cherat are lower than the standard range of ASTM. The limestones are recommended for the industrial use like cement manufacturing, chemical industry, road constructions and for other light works and structures.

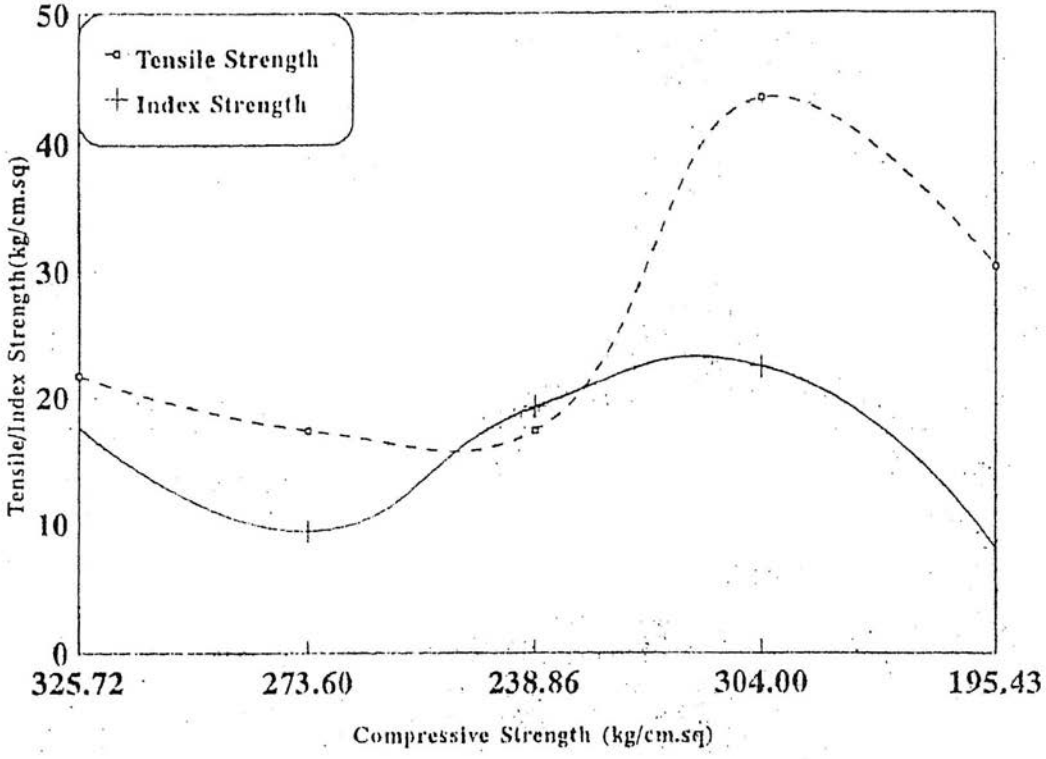

Fig. 1. Graph between Compressive and Tensile Index strength of Malakand Granite.

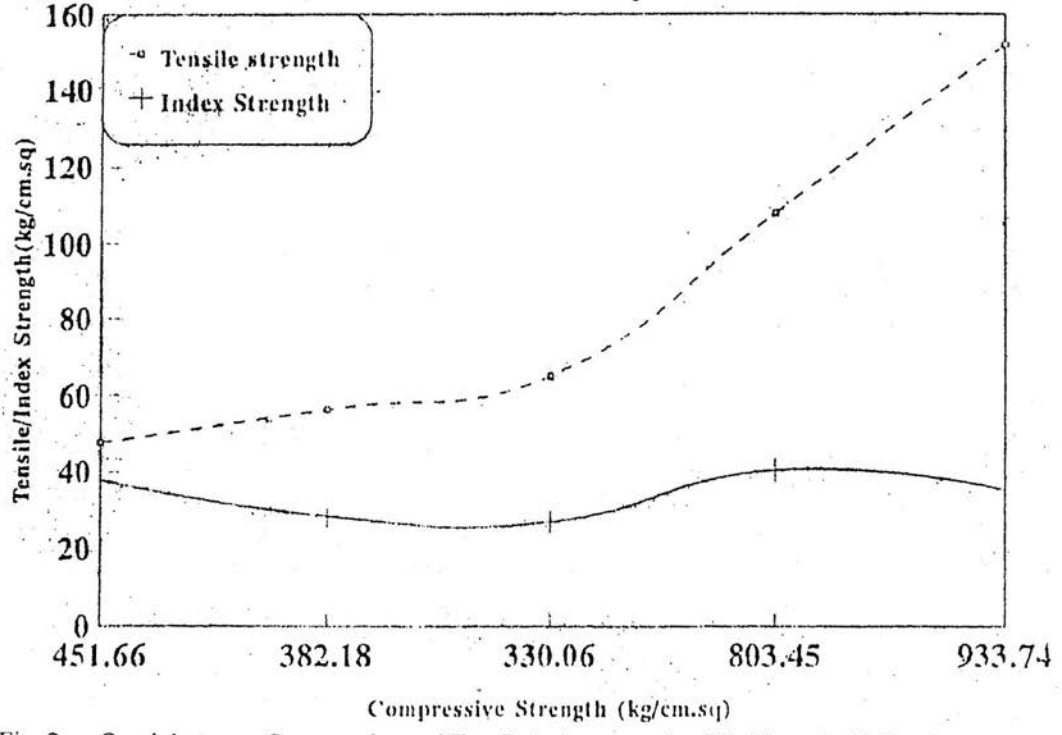

Fig. 2. Graph between Compressive and Tensile/Index strength of Shahbaz-Garhi Granite.

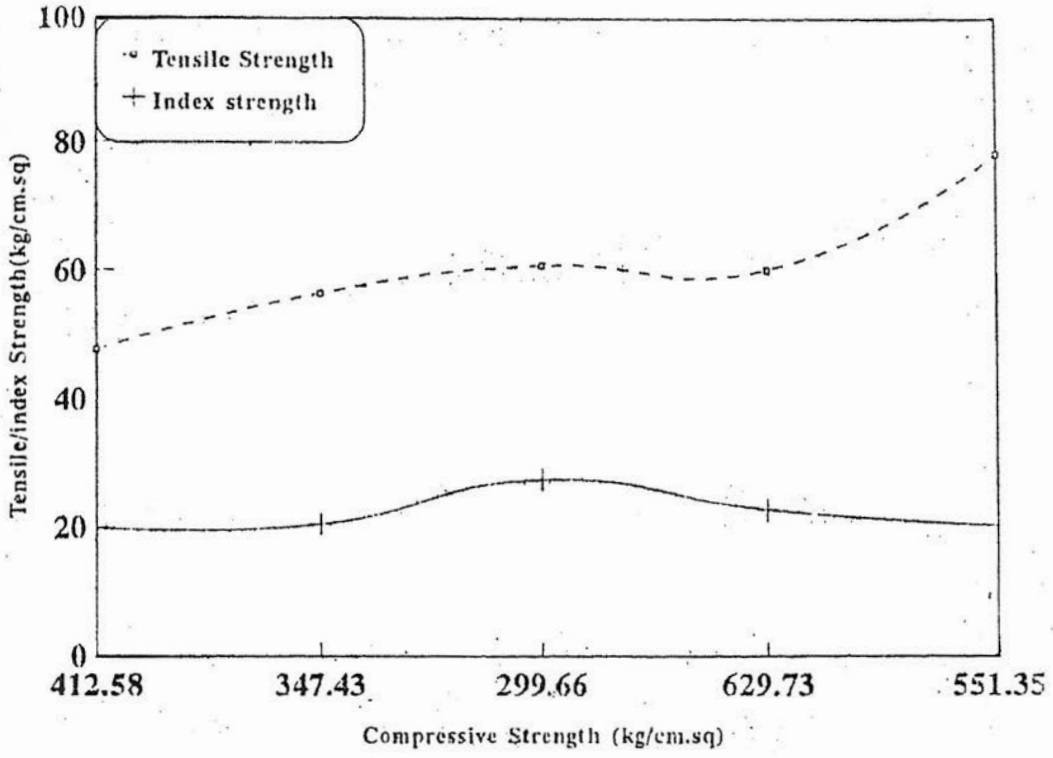

Fig. 3. Graph between Compressive and Tensile/Index strength of Cherat Limestone.

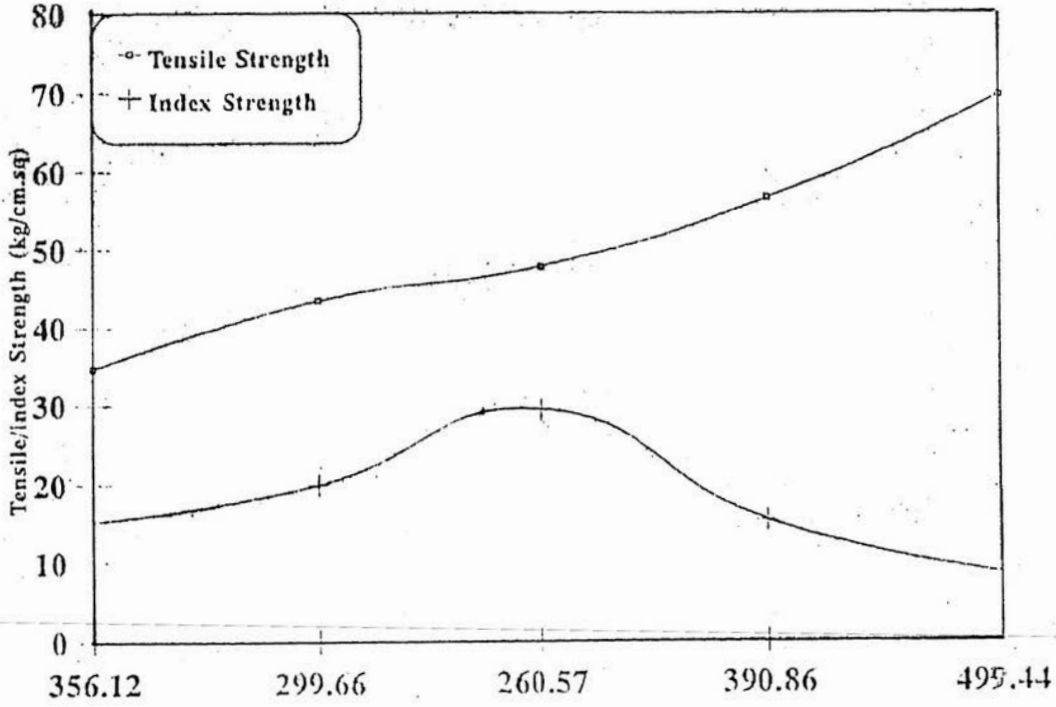

Fig. 4. Graph between Compressive and Tensile/Index strength of Kohat Limestone.

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