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# Laboratory Assessment of Granite-Gneissic Rocks

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**ABSTRACT:** In the present study, four variants of Granitic Gneisses, namely - Granite Gneiss (GG), Garnetiferous Granite Gneiss (GrGG), Micaceous Granite Gneiss (MGG), Granite Gneiss with quartzo-feldspathic bands (QFGG), from eastern Himalayas have been investigated in the laboratory for various geotechnical properties including uniaxial compressive strength (UCS), tangent modulus (E), point load strength indices (PLI), indirect tensile strength ( $\sigma_t$ ), all in saturated state. Various correlations were evaluated between UCS and E, PLI and  $\sigma_t$ , using regression analysis. It was found that there is high scatter in the data when all the lithologies are considered together, whereas the scatter is reduced when the lithologies are considered individually. This was attributed to wide variations in the mineralogical and textural characteristics of different rocks.

**KEYWORDS:** uniaxial compressive strength, laboratory study, gneiss, point load strength, indirect tensile

## I. INTRODUCTION

The accurate estimation of the strength characteristics of rocks is of the utmost importance in different engineering constructions such as dams, tunnels, bridges, roads and underground caverns. Out of all, uniaxial compressive strength (UCS) is the most commonly used parameter to evaluate classification of rock, slope stability and tunnel related investigations. However, UCS is a destructive test which is time consuming and expensive to perform. Therefore, indirect methods are used for fair and reliable estimation of UCS, which are cheaper, easier to carry out. Previous studies have indicated that the estimation of UCS is rock dependant, so they have provided different equations for different rocks. Singh et al. (2012) derived different equations for UCS and PLI for different rock lithologies. Table 1 presents the published correlations between UCS and PLI in the literature.

However, the strength data on the Himalayan region are limited. The sustainable development of the projects located or being planned in the region requires the knowledge of UCS and other strength parameters. Hence, in the present study four variants of Granitic Gneisses, namely - Granite Gneiss (GG), Garnetiferous Granite Gneiss (GrGG), Micaceous Granite Gneiss (MGG), Granite Gneiss with quartzo-feldspathic bands (QFGG), from different locations of eastern Himalayan region, have been assessed for various strength parameters, that include - uniaxial compressive strength (UCS), tangent modulus (E), point load strength indices (PLI), indirect tensile strength ( $\sigma_t$ ). Also, for these rocks, the correlations were evaluated between UCS and E, PLI and  $\sigma_t$ , using regression analysis.

## II. METHODOLOGY AND LITERATURE

In accordance with the above objective, four variants of GG have been investigated (a total of 37 samples) for different properties and parameters as per ISRM suggested methods [4], in saturated conditions. The rock cores are prepared from same drilled hole for different tests, to obtain a true representation of the test data and elucidate correlations among the different parameters. For uniaxial compressive strength (UCS), NX size cylindrical cores with length to diameter ratio of 2.5, were loaded until failure under static loading. The longitudinal and lateral strains were measured with the help of electrical resistance strain gauges. In the first instance, the samples were subjected to load up to half of anticipated strength, and unloaded (to the value seating load) to know permanent set. In the second cycle, samples were loaded until failure. Tangent modulus is measured at 50% of failure stress. The Indirect Tensile Strength is assessed employing Brazilian test, the NX size saturated specimens, with length to diameter ratio of 0.5, were tested under static loading. The justification of the test is based on the experimental fact that most of rocks in biaxial stress fields fail in tension at their uniaxial tensile strength when one principal stress is tensile and the other finite principal stress is compressive with a magnitude not exceeding three times that of the tensile principal stress.



Using NX size cylindrical samples,  $I_{s(50)}$ , is evaluated in saturated state, under axial loading. The test is considered valid only if the failure plane passes through both the loading points. As per standard, size correction is subsequently applied to make it correspond to 50 mm size sample.

Table 1 Published correlation between UCS and PLI for different lithologies

Lithologies	R value	Correlation	References
Granitic gneiss, slate, granite, basalt, gabbro, schist, marble	0.92	UCS=20.7(PLI) + 4.299	Deere and Miller (1966)
Quartzite, norite, sandstone	0.92	UCS=24(PLI) NX sized UCS=21(PLI) BX sized UCS=18(PLI) EX sized	Bieniawski(1975)
Granitic rocks	0.92	UCS=16(PLI)	Ghosh and Shakoor(1990)
Granite, tuff	0.73	UCS=12.5(PLI)	Chau and Wong (1996)
Sedimentary rocks	0.93	UCS=23(PLI)	Triaboas and Sabatakakis(2004)
Basalt, andesite, grandorite, granite, marble, gneiss, schist,	0.84	UCS=24.8(PLI)-39.6(for rocks porosity <1%)	Kahraman et al (2005)
Migmatite, dolomitic limestone	0.86	UCS=10.22(PLI)+24.3(for rocks porosity>1%)	
Quartzite	0.99	UCS=22.8(PLI)	Singh et al (2012)
Khondalite	0.91	UCS=15.8(PLI)	
Sandstone	0.89	UCS=21.9(PLI)	
Rock salt	0.71	UCS=16.1(PLI)	
Shale	0.82	UCS=14.4(PLI)	
Gabbro	0.97	UCS=23.3(PLI)	
Amphibolite	0.98	UCS=23.5(PLI)	
Dolomite	0.82	UCS=22.7(PLI)	

### III. RESULTS AND DISCUSSION

Table 2 shows the strength parameters namely uniaxial compressive strength (UCS), Tangential Modulus (E), Point load strength index (PLI), indirect tensile strength ( $\sigma_t$ ) for four variants of Granite-Gneissic rocks. In order to unravel the relations between UCS and E, PLI and  $\sigma_t$ , regression analysis were performed for individual lithologies as well as combination of all lithologies. Figures 1, 2 and 3, shows the correlations between parameters.

Table-2 Test data for the GG samples

Lithology	Sample No.	UCS	E (MPa)	PLI (GPa)	$\sigma_t$ (MPa)	$\sigma_t$ (MPa)	
Granite Gneiss	GG1	33		21	4.1	4.3	
	GG2		59		23	2.6	6.0
	GG3			34	38	4.7	4.4
	GG4			29	23	4.7	4.9
	GG5			28	25	2.7	4.2



		GG6	25		17		2.1		6.2	
		GG7	26		27		3.5		3.1	
		GG8	18		16		3.0		3.8	
		GG9	19		27		4.4		2.0	
		GG 10	26		34		4.8		5.0	
		GG 11	58		30		4.5		5.2	
		GG 12	40		36		4.4		5.0	
		GG 13	21		28		2.9		5.6	
	Granetiferous									
	Granite Gneiss									
		GrGG1	3631		0.8		3.8			
		GrGG2	32		9		1.4		4.2	
GrGG3			35		31		1.4		4.2	
	GrGG4		30	21	2.9		5.5			
		GrGG5	61		37		2.3		5.2	
		GrGG6	65		39		2.3		5.1	
		GrGG7	46		22		2.1		4.8	
		GrGG8	74		29		2.4		3.9	
	Micaceous									
	Granite Gneiss									
		MGG1	42		20		4.8		6.4	
		MGG2	20		20		3.7		5.0	
MGG3			44		27		5.0		5.2	
	MGG4		50	31	3.5		6.1			
		MGG5	53		26		5.8		5.2	
		MGG6	54		29		6.7		5.0	
		MGG7	78		34		5.0		8.2	
		MGG8	89		34		4.6		8.9	
	Granite Gneiss									
		QFGG1	21		20		1.8		1.8	
	Quartzo-feldspathic	QFGG2	61		39		2.5		4.8	
QFGG3			53		33		1.9		4.4	
	QFGG4		63	43	3.9		5.1			
		QFGG5	37		30		5.0		3.3	
		QFGG6	32		20		8.3		3.2	
		QFGG7	53		33		8.1		4.9	
		QFGG8	16		48		2.7		1.4	



Tangent Modulus (E) vs Uniaxial Compressive Strength (UCS):

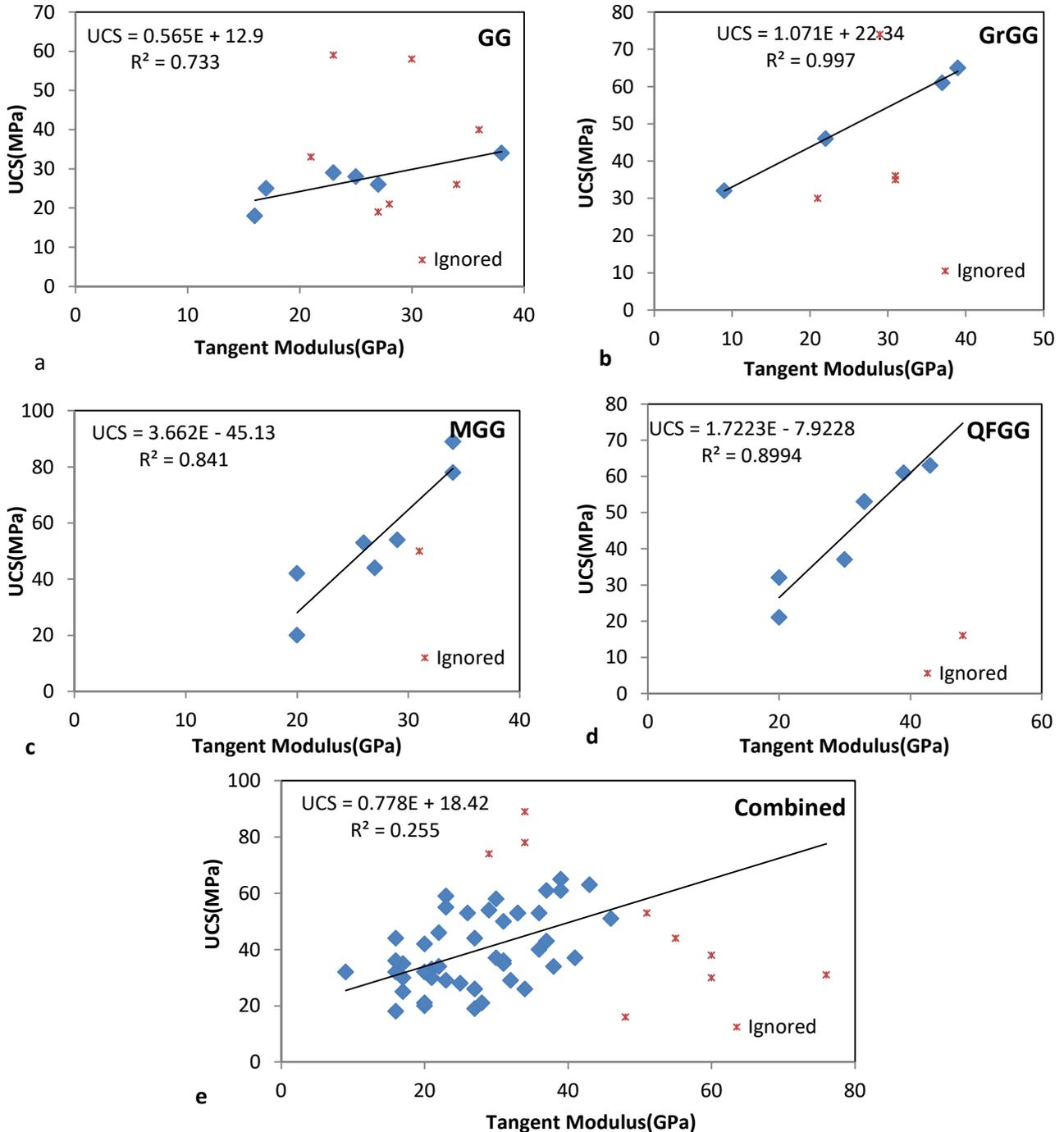


Fig.1 Relationship between Tangent Modulus and UCS for each variant of GG (a-d) and for combined GG (e)

Figure 1 depicts the relation between E and UCS for each variant of GG and for all lithologies combined together. It is observed that for all rock variants (ignoring few samples) a positive correlation is evident. A strong correlation, as reflected by the correlation coefficient, ( $R^2$ ), is observed for GrGG, QFGG variants than MGG and GG variants. Further, the correlation relationships between E and UCS is weaker when all the lithologies are combined together



( $R^2 = 0.26$ ) than when each of variant of GG is considered separately. The similar results are also evident when studied on other rock types such as quartzite, granite, Meta basics and dolomite (Tandon RS and Gupta V, 2014).

**Point Load Strength Index (PLI) vs Uniaxial Compressive Strength (UCS):**

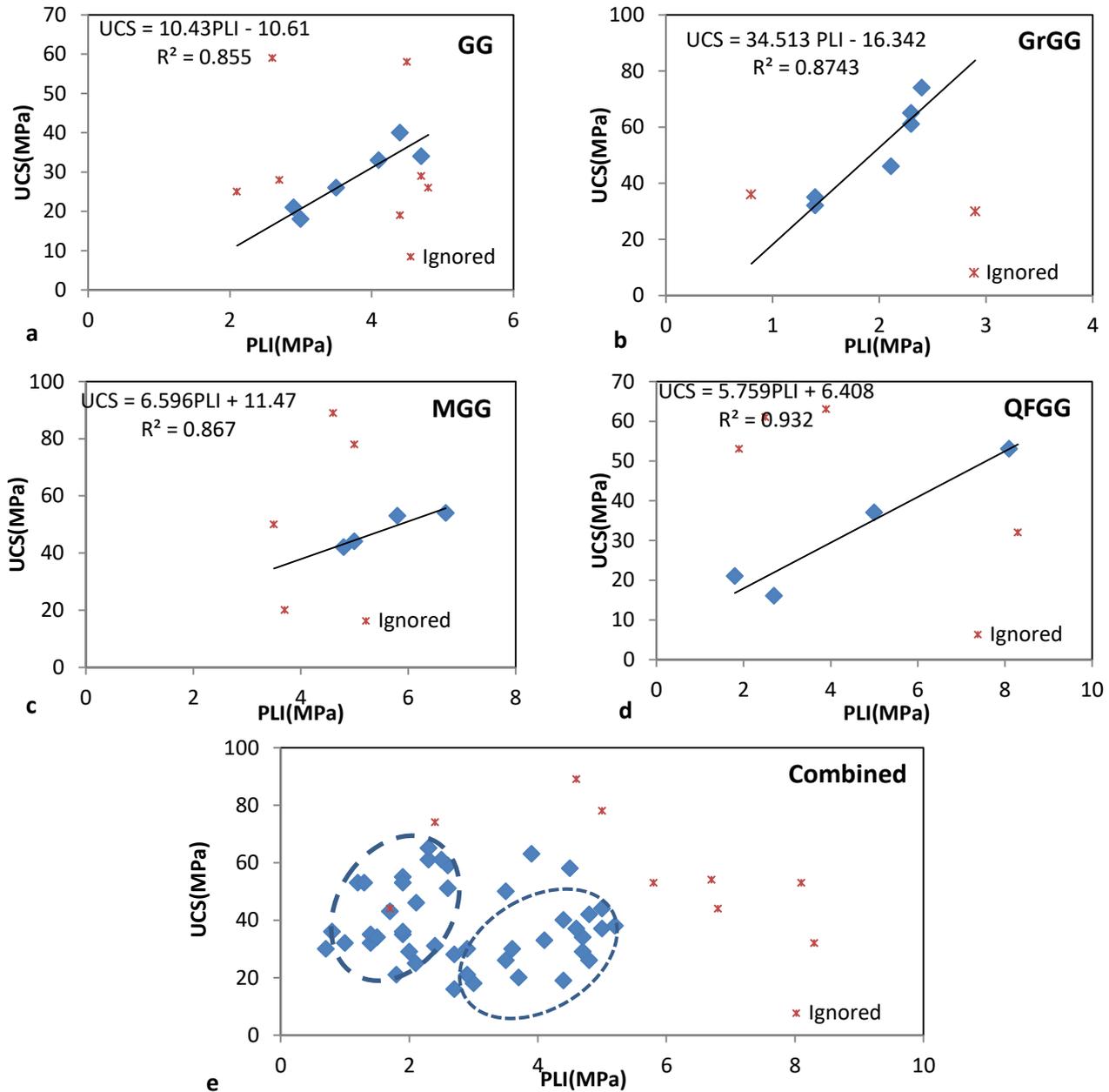


Fig.2 Relationship between PLI and UCS for each variant of GG (a-d) and for combined GG (e)

Figure 2 shows the relation between PLI and UCS for each variant of GG and for all lithologies combined together. In general (ignoring few samples), there is a positive relation is observed between these two parameters, even though this relationship is substantially varied among the studied rock variants of GG. It is observed a strong correlation for QFGG variant and a moderate correlation for other variants of GG. Further, the scatter in the data values is higher for GG and MGG variants. It is inferred that the variation in crack propagation or intensity across different samples of GG may have effected the strength values of GG. The presence of micaceous minerals such as muscovite and biotite, in Himalyan gneisses influenced largely the rock strength of MGG variants. There does not appear to be any relation



between PLI and UCS parameters when all the variants of GG are combined together. The lack of relationship between PLI and UCS may be related to anisotropy in Gneissic rocks.

**Indirect Tensile Strength ( $\sigma_t$ ) vs Uniaxial Compressive Strength (UCS):**

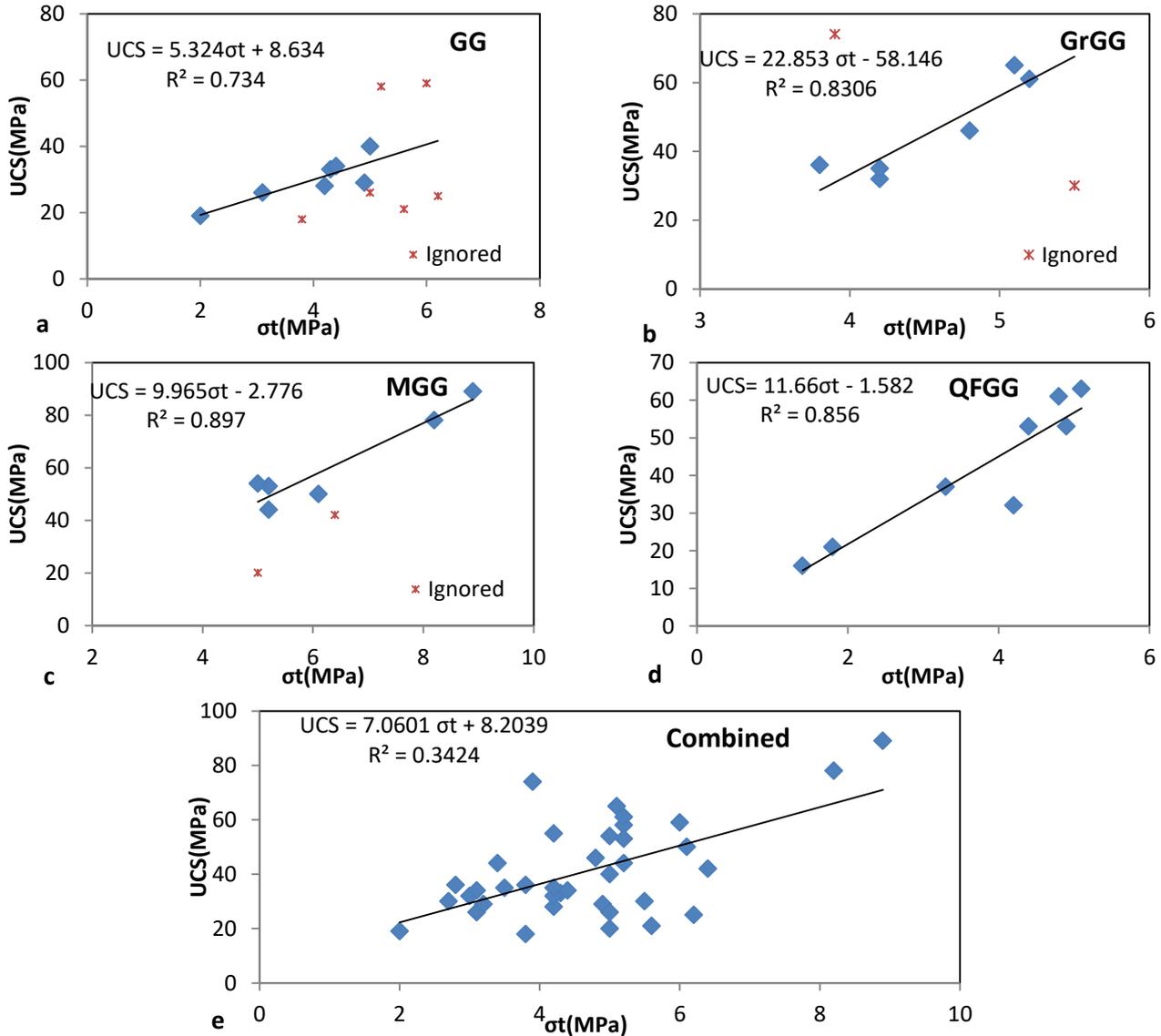


Fig.3 Relationship between indirect tensile strength and UCS for each variant of GG (a-d) and for combined GG (e)

Figure 3 depicts the relation between indirect tensile strength ( $\sigma_t$ ) and UCS for each variant of GG and for all lithologies combined together. It is observed that the scatter in the data values is higher for GG, GrGG and MGG variants than QFGG variant. Ignoring few samples, a positive and moderate correlation is evident in all the studied rocks. Further, the correlation relationships between  $\sigma_t$  and UCS is weaker when all the lithologies are combined together ( $R^2 = 0.34$ ) than when each of variant of GG is considered separately.

In general, the strength of the relations between UCS and other parameters vary from weak to strong, which may be related to the fact that various rock properties are sensitive to mineralogical changes, textural heterogeneity along with microcrack propagation. Also, in case of granite gneisses, the amount and intensity of the preferred alignment of micaceous minerals mainly controls the strength of UCS, E, PLI and  $\sigma_t$  values.



#### IV. CONCLUSIONS

In the light of above discussions, the following conclusions were drawn from the present study on Granite-Gneissic rocks.

- PLI cannot be used as a parameter for estimation of UCS of Himalayan granite-gneisses, as these rocks have undergone various tectonic activities and thus exhibit wide anisotropy.
- The UCS-E relation is stronger than the UCS-PLI and UCS- $\sigma_t$  relation for Himalayan GGs.
- Different correlations should be used for different rock variants rather than grouping all together.
- The amount and intensity of the preferred alignment of micaceous minerals mainly controls the strength of UCS, E, PLI and  $\sigma_t$  values.

#### V. ACKNOWLEDGEMENT

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