Geol. Bull. Univ. Peshawar, Vol.30, pp. 69-81, 1997.

Correlation of Some Engineering Geological Properties of the Murree Formation at Lower Topa (Murree District), Pakistan

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ABSTRACT: *Uniaxial Compressive Strength, Young's Modulus, Point Load Strength Index, Schmidt Rebound Hammer Number and Matrix (calcitic as well as clayey) are correlated for 90 samples (30 from each lithology of alternating sadstones, siltstones and claystones) to determine the effect of lithological boundaries and that of the cementing material. Correlation Coefficients of different combinations of Strength, Young's Modulus and Schimidt Hammer Rebound Number were determined. Similarly various combinations of mineral assemblages and matrix with clasts and lithological position of samples were tried and compared with strength. It is observed that strength is not only variable in each lithology but also changes with position of sample with reference to the upper or lower lithological boundaries. Laboratory tests on cores seem to be imperative for supplementing the field index tests on such detritus materials.*

INTRODUCTION

Alternating layers of clays/claystones, silstones /sandstones are present in the Murree Formation near the hill resort of Murree (Fig.1) Their varied mechanical response has been found due to local geological and lithological conditions (Fig. 2). The effect of matrix (calcitic and clayey) material and lithological boundaries (transition from one sedimentary phase to other) is also pronounced. The most accepted criteria of failure of such rock (the ultimate strength) has been used and compared with Point Load Index, Young's Modulus, Schmidt Hammer Rebound Number, cementing material and position of sample in the lithology with reference to lithological boundary i.e. near the contact with overlying/underlying rock or in the middle of bed. The variation of geotechnical properties in a small stratigraphic sequence (20-30 m) is yet important and significant with reference to civil engineering projects. It is therefore, imperative to understand the engineering geological behaviour of rocks not only in different lithologies of such formations but also within the individual lithologies as the engineering properties may change at lithological boundaries. The variation of strength becomes prominent if a large number of tests are carried out at different locations in a single bed with reference to contact with top or bottom beds. This requires accurate sampling and obtaining cores of required sizes for laboratory testing. To simplify this, sometimes only quick and easy tests are carried out in the field which alone, cannot be used as criteria, unless supplemented by laboratory tests on cores, for projects where most accurate results are required.

Correlation of Uniaxial Compressive Strength, Young's Modulus, and Point Load Strength Index has been made by Deer and Miller (1966), Broch and Franklin (1972), Bieniawski (1974), ISRM (1985), Sachapazis (1900) and ASTM (1992a,b). Similar correlations using Uniaxial Compressive strength, Point Load strength Index, Young's Modulus, Schmidt Hamer Rebound Number and grades of weathering (suggested by Geological Society Engineering Group Working Party, 1977) have been made by Aggistalis et al. (1996) using statistical packages. Papageorgieu et al. (1992) proposed non linear relationship between Uniaxial Compressive Strength and Point Load Strength Index on igneous and metamorphic rocks, while Sachpazis (1990) obtained good correlation between Schmidt Hammer Rebound Number, Uniaxial compressive strength and Young's Modulus in carbonate rocks.

The present study is restricted to determination of strength (Fig. 3) and correlation of engineering geological properties in alternate stratigrahic sequences of detrital origin where grain size, amount and type of cementing material and most of all distance from lithological boundaries seem to be effective and detrimental parameters. Due to difficulties in determining the degree of weathering quantitatively this phenomenon, although of great importance, could not be used. Instead, attempt was made, as far as possible, to obtain samples from fresh surfaces.

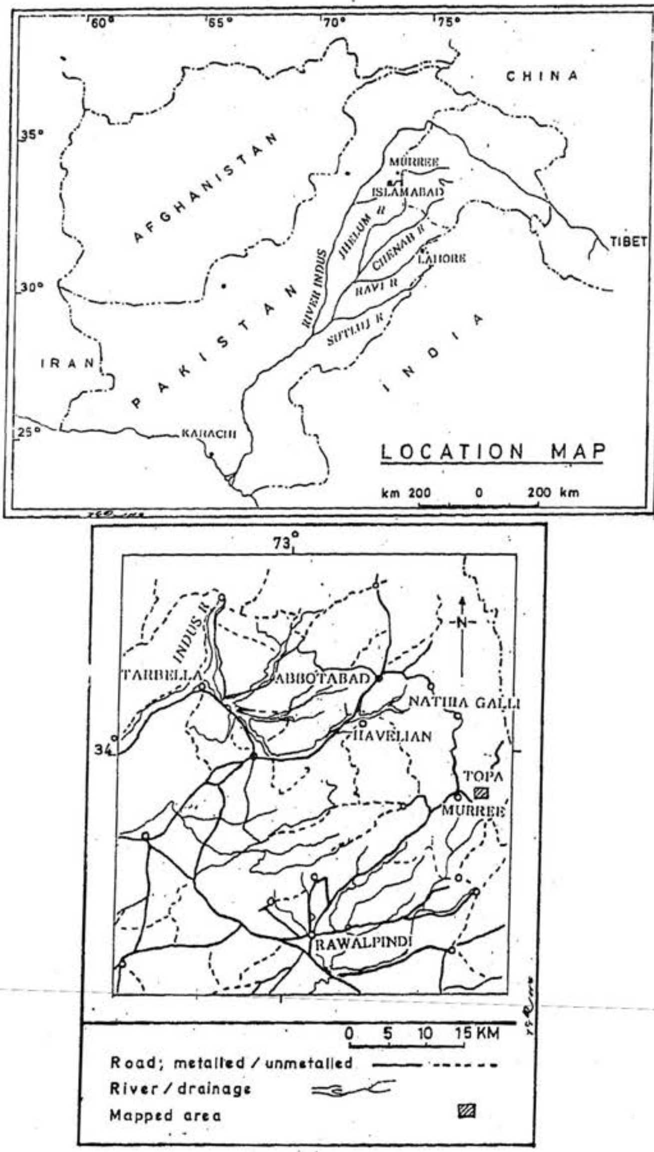

Fig. 1. Location map.

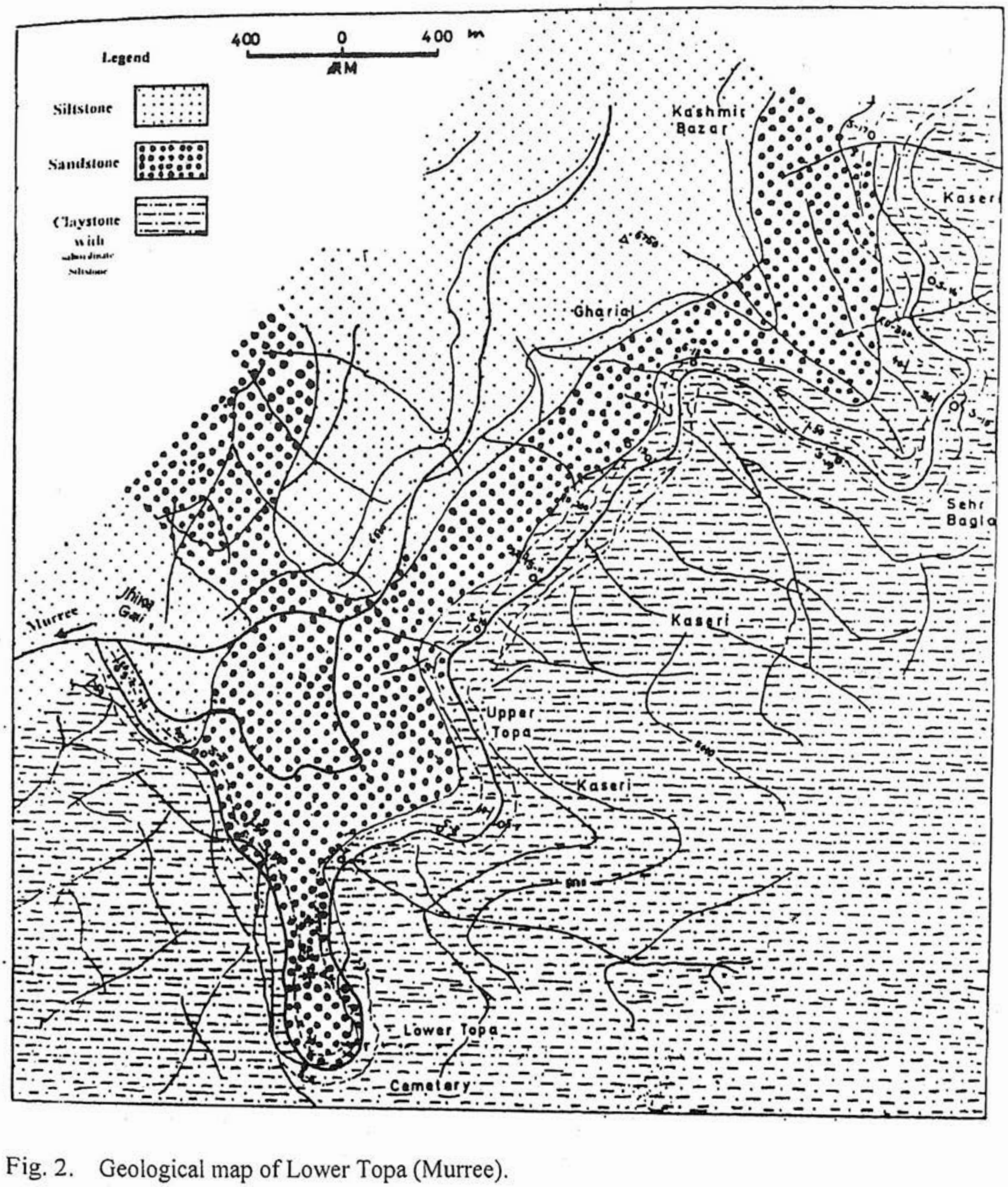

Fig. 2. Geological map of Lower Topa (Murree).

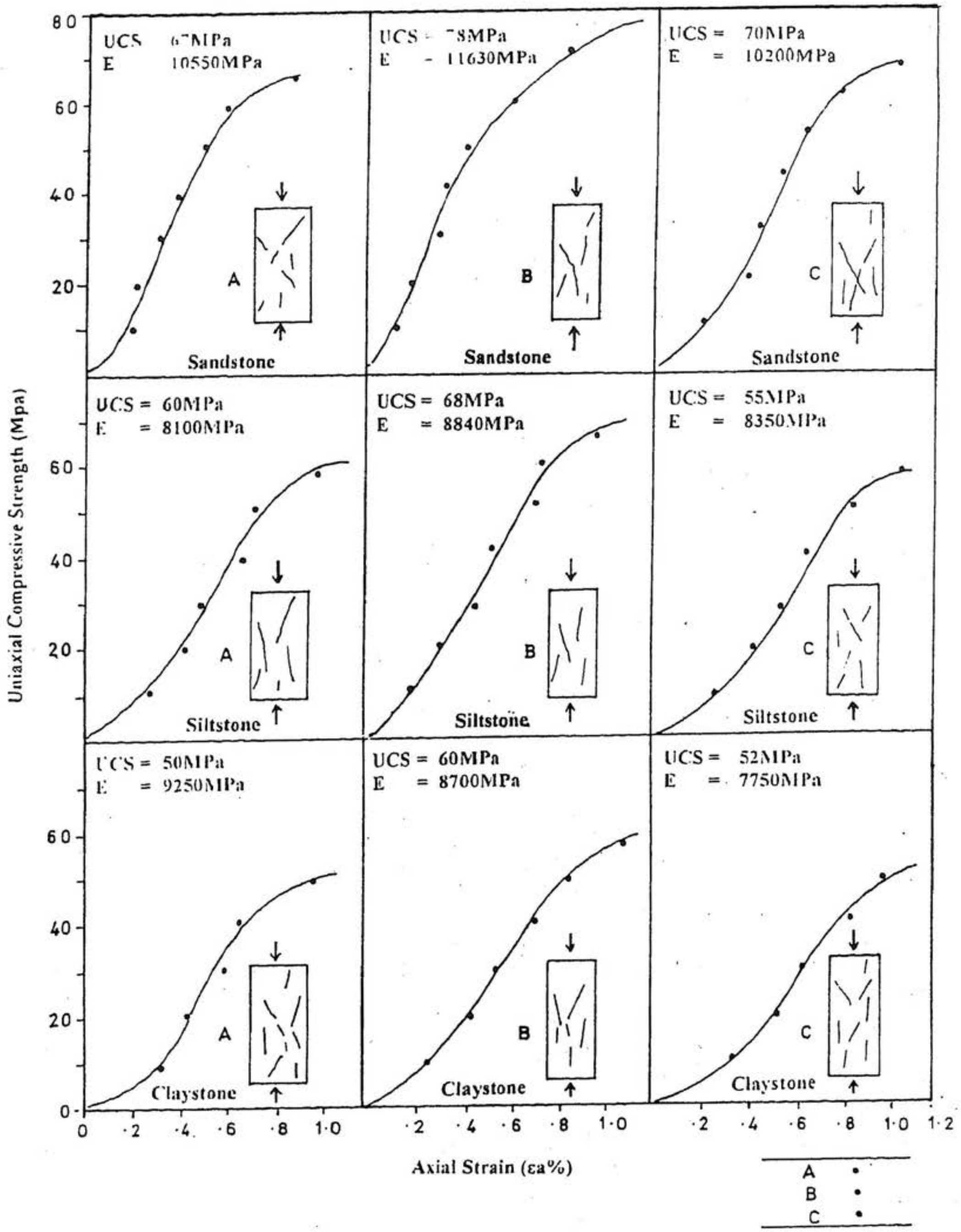

Fig. 3. Stress strain curves of some samples of sandstone, siltstone and claystone under uniaxial compression.

Different indices were determined (Table 1-3) and correlated with Uniaxial Compressive Strength as listed below:

Ucs Vs E
Ucs Vs Is(50) Ucs = Uniaxial compressive strength
Ucs Vs RN
where Is(50) = Point Load Strength Index
RN = Schmidt Hammer Rebound Number

The correlation coefficients of Uniaxial Compressive strength with these indices are given in (Table 4) and are plotted in Figs. 4a-4i.

A number of mineralogical parameters along with matrix which could possibly effect the strength of sandstones and silstones were grouped and plotted against strength and their correlation coefficients were determined (Table 5-6).

TABLE 1. TESTS ON SANDSTONES

UCS (MPa) Sample position			Is (50) MPa Sample position			E (MPa) Sample position			RN Sample position		
A	B	C	A	B	C	A	B	C	A	B	C
60.0	77.5	60.0	2.7	3.85	2.40	8187	9760	7544	40	38	38
66.0	81.0	62.0	3.5	3.9	2.8	7342	8987	6765	45	39	42
65.0	82.5	60.0	3.6	3.88	2.1	6765	8730	6980	36	44	38
62.0	77.0	56.0	2.9	3.2	1.7	7367	9689	7625	40	35	35
67.0	78.0	70.0	3.5	3.2	3.1	10550	11630	10200	45.	45	40
70.5	85.0	67.0	3.7	4.0	2.6	10996	12880	9870	45	45	42
70.0	86.0	70.0	3.5	4.3	2.7	8567	10773	8080	45	42	45
60.0	78.0	58.0	2.7	3.8	2.0	4660	5987	5990	35	38	32
65.0	82.0	67.0	3.3	4.1	2.7	7787	9590	7120	35	36	35
60.0	78.0	60.0	2.8	3.9	2.5	6280	7850	4530	40	42	35

TABLE 2. TESTS ON SILTSTONES

UCS (MPa) Sample position			Is (50) MPa Sample position			E (MPa) Sample position			RN Sample position		
A	B	C	A	B	C	A	B	C	A	B	C
55.3	67.2	51.0	1.9	2.8	1.7	7760	8890	5770	40	40	38
48.1	55.0	40.0	1.8	2.3	1.5	670	7210	6500	38	29	27
60.0	68.7	55.0	2.7	3.2	2.8	8100	8840	8350	40	42	40
52.1	75.1	45.0	1.7	3.4	1.7	9545	11200	8540	38	30	34
47.5	60.5	40.2	1.6	2.7	1.4	7550	8670	5440	25	29	35
39.2	56.5	49.0	1.5	2.2	1.9	4450	6852	3850	30	27	35
54.5	66.1	59.0	2.0	3.1	2.7	8770	9540	6980	38	42	30
41.4	54.5	48.2	1.8	2.4	1.6	5880	6320	4750	26	29	35
52.6	60.5	48.2	2.2	2.6	2.0	6652	7760	6880	25	28	29
55.0	62.3	57.1	2.1	2.9	2.6	8875	9420	7100	40	32	32

TABLE 3. TESTS ON CLAYSTONES

UCS (MPa) Sample position			Is (50) MPa Sample position			E (MPa) Sample position			RN Sample position		
A	B	C	A	B	C	A	B	C	A	B	C
45.6	62.2	48.1	1.7	3.2	1.7	5380	6380	5575	30	38	29
42.7	61.7	46.0	1.6	2.8	1.5	6730	8750	7720	35	40	32
40.3	55.2	52.6	1.6	2.1	2.1	3990	6120	4550	40	40	36
48.1	66.6	42.3	1.9	3.0	2.0	5880	8750	9650	38	46	30
50.0	60.0	52.0	2.3	2.75	2.3	9250	8700	7750	30	35	32
48.0	59.7	50.3	2.0	2.9	1.95	8210	7880	9260	36	32	36
46.6	60.2	50.3	1.9	3.2	2.1	6820	6540	4460	40	42	30
50.7	56.9	40.3	2.2	2.7	1.8	6540	8870	5870	35	40	30
58.1	62.1	50.0	2.7	2.9	2.1	7880	7750	6870	42	32	36
50.0	56.1	52.3	2.4	2.3	2.2	7650	10400	8850	38	46	30

Ucs = Uniaxial Compressive Strength.
Is (50) = Point Load Strength Index.
E = Young's Modulus.
RN = Schmidt Hammer Rebound Number.

TABLE 4. CORRELATION COEFFICIENTS OF UNIAXIAL COMPRESSIVE STRENGTH (UCS) WITH YOUNG'S MODULUS (E), POINT LOAD STRENGTH INDEX IS (50) AND REBOUND NUMBER

Rock	Corr. Coeff. UCS. Vs. E	Relation of UCS with E	Corr. Coeff. UCS. Vs. Is (50)	Relation of UCS with Is (50)	Corr. Coeff . UCS. Vs. RN	Relation of UCS with RN
Sandstone	0.66	UCS=.0084E	0.86	UCS=21.95 Is(50)	0.38	UCS=1.74RN
Siltstone	0.43	UCS=.0073E	0.92	UCS=24.28 Is(50)	0.32	UCS=1.62RN
Claystone	0.35	UCS=.0072E	0.91	UCS=23.1 Is(50)	0.46	UCS=1.45RN

TABLE 5. CORRELATION OF UNIAXIAL COMPRESSIVE STRENGTH OF SANDSTONE WITH PARAMETERS AND THEIR VARIABILITY

Parameter Vs. UCS	Corr. Coeff.	Variable of Parameter vs. Strength	Corr. Coeff.
Matrix + Clasts Vs. UCS	0.901	d(m+cl)/ds Vs. UCS	0.545
Matrix + Quartz content	0.872	d(m+Q)/ds Vs. UCS	0.668
Matrix Vs. UCS	0.655	d(m)/ds Vs. UCS	0.570
Quartz content Vs. UCS	0.460	d(Q)/ds Vs. UCS	0.359

TABLE 6. CORRELATION OF UNIAXIAL COMPRESSIVE STRENGTH OF SILTSTONE WITH PARAMETERS AND THEIR VARIABILITY

Parameter Vs. Strength	Corr. Coeff.	Variable of Parameter vs. Strength	Corr. Coeff.
Matrix + Clasts Vs. UCS	0.922	d(m+cl)/ds Vs. UCS	0.497
Matrix + Quartz content Vs. UCS	0.865	d(m+Q)/ds Vs. UCS	0.680
Matrix Vs. UCS	0.712	d(m)/ds Vs. UCS	0.611
Quartz content Vs. UCS	0.479	d(Q)/ds Vs. UCS	0.415

m= Matrix, Q= Quartz Content, Cl= Clasts, UCS = Uniaxial Compressive Strength, dm/ds = variability of matrix with strength (example)

GEOLOGY

The area is located along the Murree-Muzaffarabad Road (Fig. 1) which is a vital link between Pakistan and the Independent Kashmir and is dominated by the tectonically disturbed Murree Formation. This Formation (Fig. 2) is composed of a series of alternating beds of sandstone, siltstone and claystone and clay/shale with subordinate marls and limestones (Fatmi 1973). The stratigraphic position of the Murree Formation is given under:

Recent Deposits

-------------------Unconformity-------------------

Murree Formation (Miocene)

-------------------Unconformity-------------------

Lower Tertiary (Marine succession)

The rock fragments in the Murree Formation at Lower Topa are mainly Quartz, Carbonates and Cherts. These deposits are of continental origin comprising fine grained detritus material held together by clayey or calcitic matrix of varying proportions. The sandstones are fine to medium grained, poorly sorted, and have angualr to subrounded grains with some distorted micas. Quartz varies from 30 to 50% whicle other clasts range from 5 to 10% (i.e. total clasts are 35-60%). Matrix (clayey and calcitic) varies from 30 to 45%. Silstones have a Quartz content of about 35% and other clasts range from 10 to 20% (total clasts being 40 to 60%).Matrix in silstones is mainly clayey ranging from 35 to 50%. This formation occupies the core of the Hazara-Kashmir Syntaxis and is distinguished from the younger rock zone by significant tectonic disturbance.

SAMPLE PREPARATION

Samples were obtained from clays/claystones, siltstones and sandstones of the Murree Formation at Lower Topa (Fig. 1) where detailed studies were also being carried out for slope stability and landslide problems under a different project. This opportunity was availed for detailed sampling and testing of rocks for comparison purposes. Samples were obtained at three locations from sandstone, silststone and claystone from top, middle and bottom of each bed and were designated symbols. A, B and C respectively. Block samples were obtained and cores of NX size were drilled by using laboratory coring machine (an improvisation of the concrete coring apparatus). An attempt was made to align all the cores perpendicular to bedding. Thin section studies and geochemical methods were used for determination of detritus calcite and calcitic and clayey matrix. Only representative samples i.e. three from each lithology were tested for Young's Modulus (Fig. 3), while a total of ten samples from each location i.e. thirty from each lithology were tested for Uniaxial Compressive Strength, Point Load Strength Index and the Schmidt Hammer Rebound Number etc.

(Tables 1-3). Fig. 3, therefore, gives results of stress strain curves on representative samples only. Extensive testing for Point Load of stress strain curves on representative samples only. Extensive testing for Point Load Strength Index and Schmidt Rebound Hammer Number was also carried out in the field.

TESTING AND INTERPRETATION OF RESULTS

Thin sections of representative samples (10 from each lithology) were prepared for microscopic examination for clasts, quartz and matrix content. The mineral assemblages are varied and the matrix is clayey with diagenetic clacite, while argillaceous sandstones which have only clayey matrix are not included in the present study.

Different combinations of Uniaxial Compressive Strength versus Young's Modulus, Point Load Strength Index, Schmidt Hammer Rebound Number, were tried for correlation purposes (Table 4). The correlation coefficients were determined using statistical package for regression and variables were isolated for better correlation (Figs. 4a-4i).

It is observed that excellent correlation occurs between uniaxial Compressive Strength and the Point Load Strength Index for all lithologies i.e. sandstone, siltstone and claystone. A reasonably good correlation exists between Uniaxial Compressive strength and the Young's Modulus for sandstone only, while for siltstone and claystone this relationship is rather poor. The best correlation exists between Uniaxial compressive strength, Point Load Strength Index and Young's Modulus for sandstones. A poor correlation of Uniaxial compressive strength and Schmidt Rebound Number was obtained for all lithologies. Since most of the readings were taken in the field, the effect of sruficial conditions on weathered surfaces seem to be responsible for this poor relation.

A very good correlation between Uniaxial Compressive Strength and Point Load Strength Index exists for all the rocks in the area and can be used with reliability in the field, while the Schmidt Hammer Rebound Number has a large variable due to surficial effects and should be used with reservations only.

It is observed that generally the strength increases towards the middle of the formation i.e. at location B (Fig. 5). In other words the effect of the overlying or underlying lithology or grain size variation due to transition has no considerable effect on strength. Parameters such as mineralogy or cementing material, therefore, seem to be operative and more effective than others.

It is for this reason that various mineral assemblages along with matrix (in sandstone and siltstone only) were tried for their effects on strength. The order (descending) in which mineralogical parameters are being effective in controlling the strength of sandstone and siltstone (Tables 5 & 6) is given as:

1. Matrix + Clasts
2. Matrix + Quartz Content
3. Matrix
4. Quartz Content

It is observed that no single mineralogical parameter can be held responsible for changes in strength; instead a combination of different parameters seems to be acting together. For instance, matrix when plotted with other contents as Quartz or Clasts, significantly increases the Coefficient of Correlation: indicating that basically the amount of matrix is important for an increase in strength. The variables of above mentioned factors with strength of individual lithologies were also plotted against strength and their Correlation Coefficients determined. It is observed that the amount of matrix (greater in the middle of the bed) is related with strength and its variability. It is also observed that when matrix is low, strength is also low but variable, while high matrix shows high strength but is less variable.

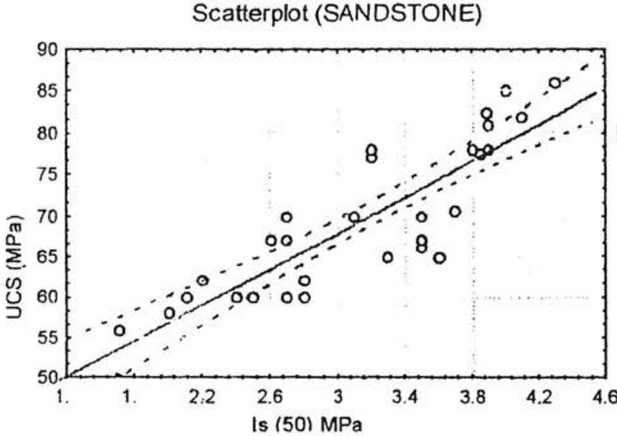

Fig. 4a. Correlatin between Uniaxial Compressive Strength and Point Load Strength Index Is(50).

Regression
95%

UCS=21.95 Is(50)
R=0.86

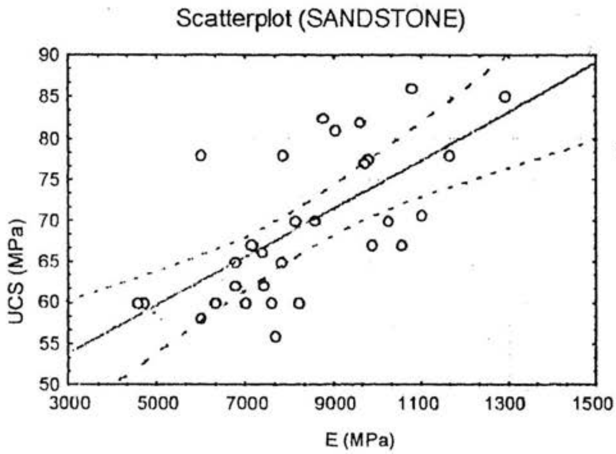

Fig. 4b. Correlation between Uniaxial Compressive Strength and Young's Modulus (E).

Regression
95%

UCS=0.0084E
R=0.66

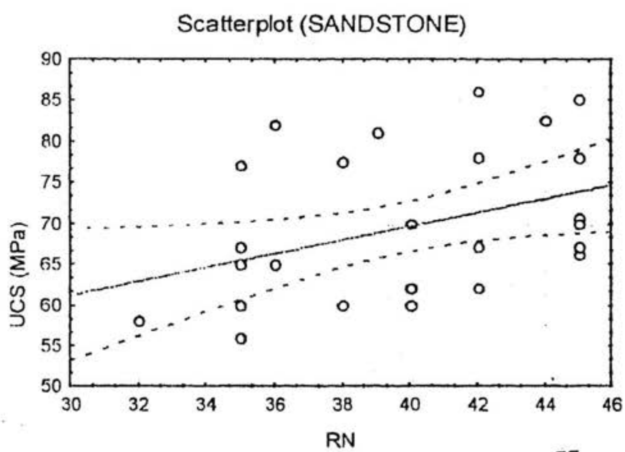

Fig. 4c. Correlation between Uniaxial Compressive Strength and Schmidt Hammer Rebound Number (RN).

Regression
95%

UCS=1.74RN
R=0.38

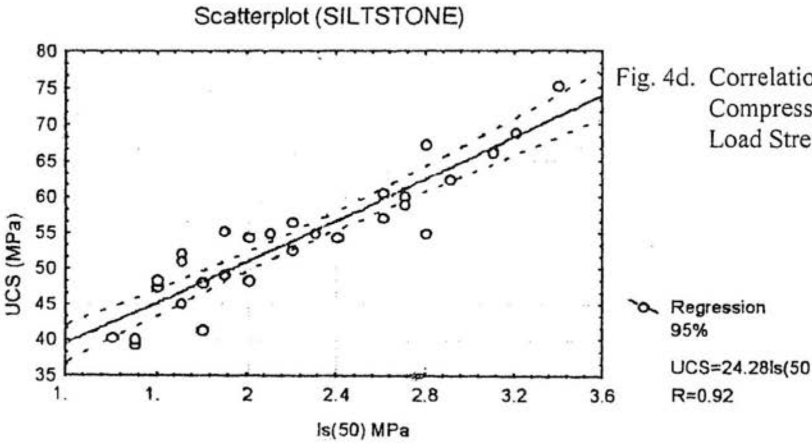

Fig. 4d. Correlation between Uniaxial Compressive Strength and Point Load Strength Index IS(50).

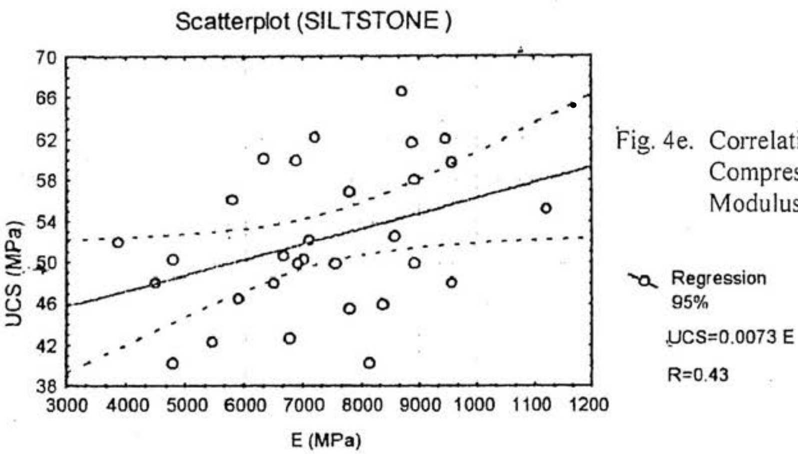

Fig. 4e. Correlation between Uniaxial Compressive Strength and Young Modulus (E).

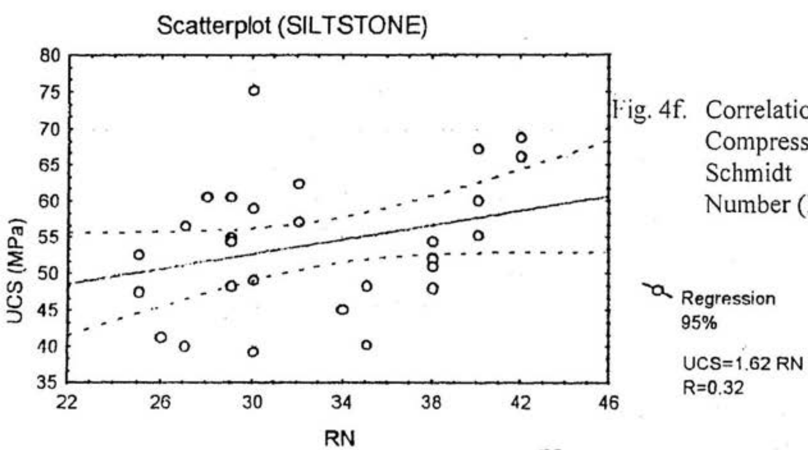

Fig. 4f. Correlation between Uniaxial Compressive Strength and Schmidt Hammer Rebound Number (RN).

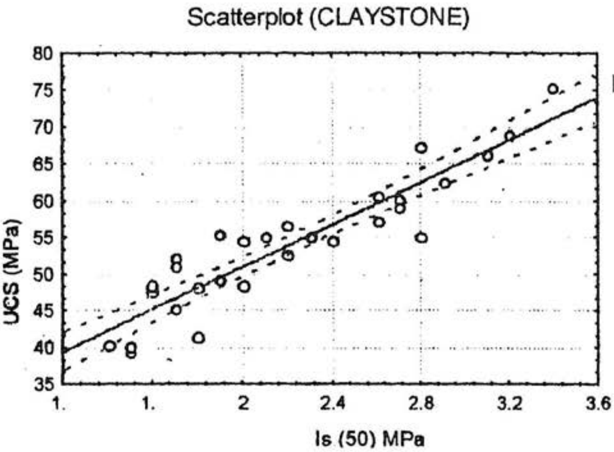

Fig. 4g. Correlation between Uniaxial Compressive Strength and Point Load Strength Index Is(50).

Regression
95%

UCS=23.1,
R=0.91

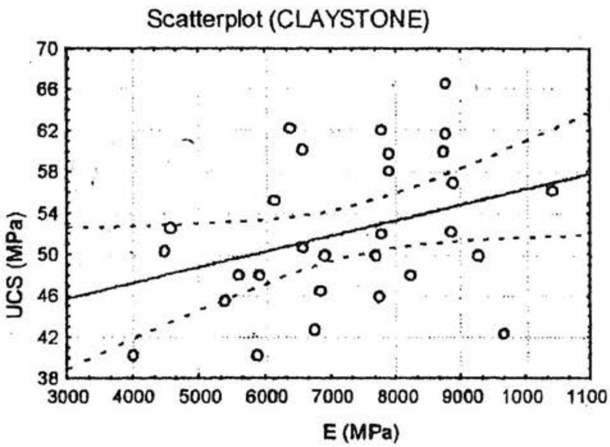

Fig. 4h. Correlation between Uniaxial Compressive Strength and Young's Modulus (E).

Regression
95%

UCS=.0072E
R=0.35

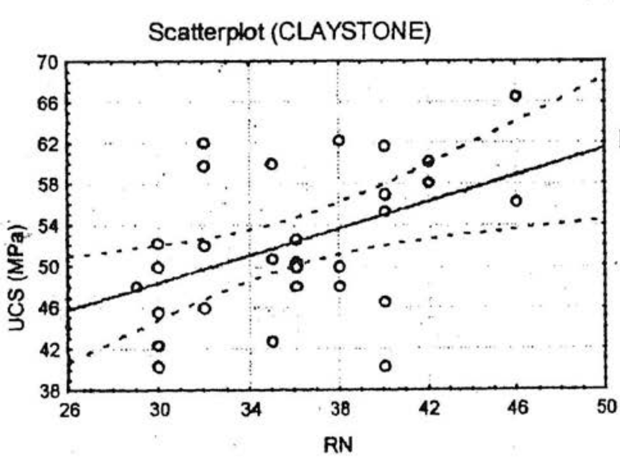

Fig. 4i. Correlation between Uniaxial Compressive Strength and Schmidt Hammer Rewbound Number (RN).

Regression
95%

UCS=1.45 RN
R=0.46

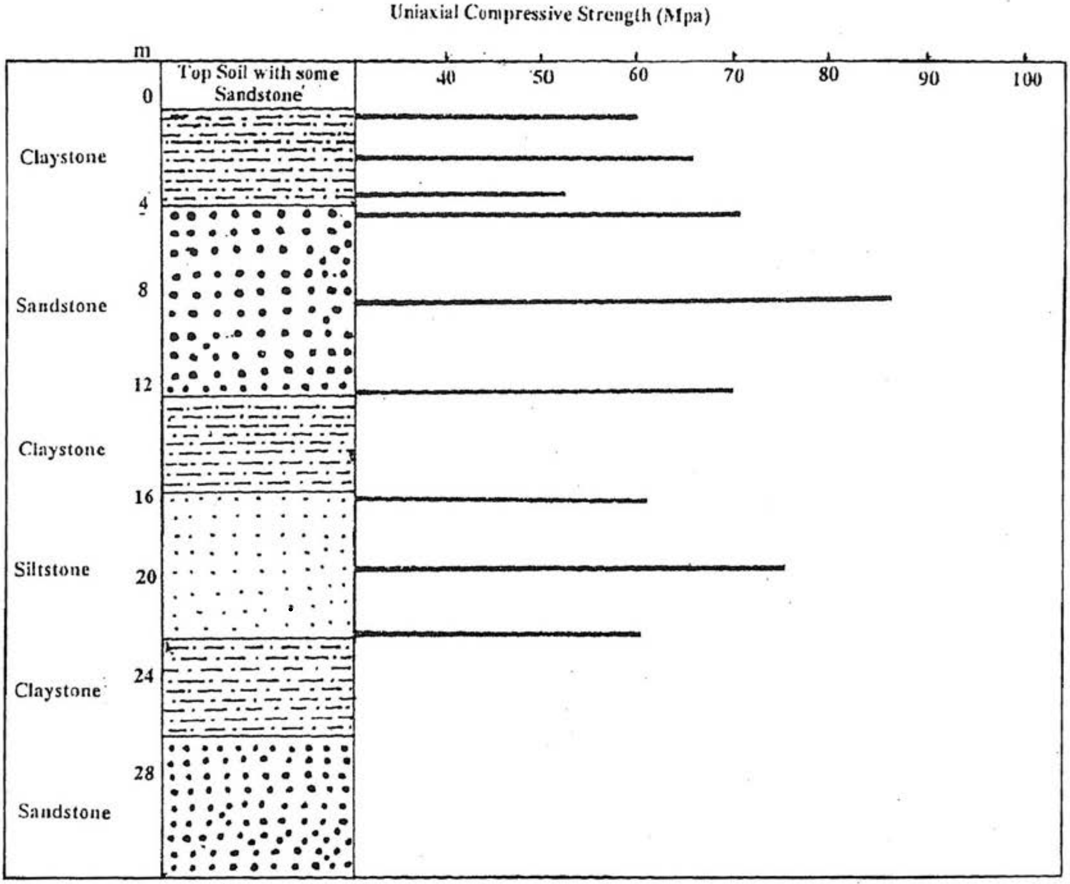

Fig. 5. Cross Section of Lithology indicating sample locations and strength which increases in the middle of the beds.

CONCLUSIONS

1. The strength is variable in each lithology and changes with amount of matrix.

2. The strength changes with location or position of sample in an individual lithology (its position with reference to contact with overlying or underlying beds). Generally it increases towards the middle of individual beds.

3. Good correlation Coefficients can be obtained using Uniaxial Compressive Strength versus Clasts + Matrix or Quartz + Matrix content

4. Excellent correlation of Uniaxial compressive strength with Point Load strength Index and Young's Modulus occurs for sandstones and siltstones, while Schmidt Hammer Rebound Hammer Number could not be used successfully.

5. The indices and correlations mentioned above should therefore be used with caution and supplemented with accurate test results on conventional cores in laboratory.

Acknowledgement: The authors are highly grateful to Dr. Riaz Ahmad Sheikh, and Prof. Dr. Nawaz Chaudhary, Director Institute of Geology Punjab University for most valuable help in carrying out petrographic analysis of thin sections, and to Prof. Dr. Aftab Ahmad Butt for useful suggestions. The authors are also greatly indebted to Mr. Muhammad Abaid Ullah, Lecturer, I.E.R, University of Punjab, Lahore Pakistan and Mr. Tanweer for carrying out the statistical analysis and preparing tables for correlation and regression analysis.

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