Geol. Bull. Univ. Peshawar, Vol. 28, pp. 15–25, 1995

Triaxial study of granites and limestones from north and south of Peshawar Basin, N.W.F.P., Pakistan

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ABSTRACT: *Determination of uniaxial and triaxial strength of different building stones is important both from practical as well as academic point of views. Triaxial testing is the most appropriate method which provides an identical field condition. In order to achieve this objective, granite and limestone from four different localities (Malakand granite, Shahbaz Garhi granite, Kohat limestone and Cherat limestone) were selected to carry out triaxial tests.*

Four samples of each rock, having length-to-diameter ratio of about two were tested under confining pressure of 0–30 MP_a range. The observations made and results obtained are plotted and after drawing Mohr,s envelope for each rock shear strength is calculated corresponding to different triaxial confining pressure.

The findings of the study are summarized in the form of conclusions and recommendations at the end of the manuscript.

INTRODUCTION

Structures in or on the rocks usually fail because of the insufficient strength of the material of which the rock is composed. Apart from proper designing, to control or resist the failure of the rock structure, the possible remedy is to exactly calculate the strength of the material and subject it to the load below its strength.

The geomechanical properties of rocks play a very important role governing the behavior of rocks in response to applied load. Some of the most important properties are hardness, durability, permeability and strength. In most of the applications, rocks are subjected to high degree of compression, tension and shear and in many cases failure or damage is caused by insufficient shearing resistance of the material.

Therefore the stability and suitability of all structures, deep cuts, openings in rocks, mine supports in the form of pillars, lining and filling and even river banks, can be based on the shearing strength of the material of which the rock is composed.

A number of methods have been established and are in practice for the determination of shear strength of rocks in the field as well as in the laboratory. Triaxial testing method is selected for the determination of shear strength of rocks, because of the closer and identical situation to that of the field conditions, (Goodman, 1980).

Keeping in view the importance of the problem the authors felt a serious need of such studies and determined the shear strength of limestone and granite of some areas of N.W.F.P. (Kohat limestone, Cherat limestone and Malakand granite, Shahbaz Garhi granite) using triaxial compression values.

METHODS OF TESTING SHEAR STRENGTH OF ROCKS

Shear strength is an important parameter of rocks for design purposes. Failure in rocks under load is often along the shear planes. Different methods have been practised to estimate values of rock shear strength.

Shear strength tests on rocks may be classified into a) Direct method, b) Indirect method and c) In-situ test. (Jumikis A. R., 1983). Among these the Indirect shear testing method was selected to carry out this work because this is a simplest and cheapest method. It consumes less time during sample testing and gives accurate results. Less sample prepration is required as compared to other methods.

SHEAR STRENGTH

Samples were collected from various areas of North-West Frontier Province. These include granite from Malakand (distt Swat) and Shabaz Ghari (distt Mardan) and limestone from Kohat and Cherat (distt Peshawar) ranging in size from 1 to 3 cubic feet and were reduced into various sizes for further required operations. The core samples taken were prepared with length-to-diameter ratio of 2 for triaxial testing. About 4 core samples were prepared of each rock. Cores were obtained by core drilling machine and were cut in the required length. End surfaces of the cores were polished to make them at right angle to the major axis of the core (Gokhale, 1960).

In this test the sample is confined under lateral pressure in a cell and vertically loaded. The lateral pressure is kept constant during the test. Under this lateral pressure, the sample is subjected to continuously increasing axial compression and measurements at failure are recorded during the test. (Table 1). The ultimate failure load is F, the major principal stress (σ_1) at failure is F/A where A is the cross-sectional area of the specimen. With the help of the values of the principal stresses σ_1 and σ_3 Mohr's circle is drawn. However, to draw accurate tangent, it is necessary to plot the Mohr's circle for at least 3 specimens tested at different lateral pressure and the envelop is then a common tangent to all these circles as shown in the Mohr's diagrams in Figures 1 - 4. The mode of failure is also shown in the photographs (plate 1 - 4). To be more accurate 4 samples of each rock have been tested in this study , one at zero confining pressure and the other three at different lateral pressures ranging from 7.50 to 30.0 MN/m^2.

Granite from Malakand were tested and the test result were compared with granite from Shahbaz Garhi. Similarly limestone from Kohat were tested and the test results were compared with limestone from Cherat as shown in Table 1.

Major principal stress (σ_1)

Consider the data for a specimen of Malakand granite. Diameter of the core (rock specimen) = D = 5.47 cm (Centimeter), X-sectional area of the core (rock specimen) = A = $\pi/4\ (D)^2$

$$A=\frac{22}{(7\text{x}4)}(5.47)^2=23.50cm^2=2.35\text{x}10^{-}3m^2$$

compressive force at failure = F = 410 KN
= 410 X 1000 = 410,000 N

Therefore major principal stress = σ_1 = F/A N/m^2

$$\sigma_1=\frac{410,000}{\left(2.35\text{x}10^{-}3\right)}=174468085.10N/m^2$$

or $\quad \sigma_1 = 174.46\text{MN}/\text{m}^2$

TABLE 1. CALCULATION OF MAJOR PRINCIPAL STRESSES AND SHEAR STRESSES

Sample No.	Locality	Rock Type	Forces failure (KN)	Area of the Sample (m^2)	σ_1 (MN/m^2)	σ_3 (MN/m^2)	S_s (MN/m^2)
1.	Malakand	Granite	141.0	$2.35*10^{-3}$	60.00	zero	25.00
2.	———	———	238.52	———	101.50	13.00	36.00
3.	———	———	286.70	———	122.00	18.00	45.00
4.	———	———	366.60	———	156.00	28.00	53.00
5.	Shahbaz Garhi	Granite	376.00	$2.35*10^{-3}$	160.00	zero	63.00
6.	———	———	470.00	———	200.00	10.00	74.00
7.	———	———	542.85	———	231.00	17.00	90.00
8.	———	———	611.00	———	260.00	23.00	93.00
9.	Cherat	Limstone	272.60	$2.35*10^{-3}$	116.00	zero	46.00
10.	———	———	336.60	———	156.00	10.00	59.00
11.	———	———	413.60	———	176.00	15.00	68.00
12.	———	———	521.70	———	222.00	27.00	79.00
13.	Kohat	Limestone	211.50	$2.35*10^{-3}$	90.00	zero	32.00
14.	———	———	329.00	———	140.00	11.00	50.00
15.	———	———	376.00	———	160.00	15.00	61.00
16.	———	———	448.85	———	191.00	24.00	65.00

Minor principal stress (σ_3)

Minor principal stress/confining pressure is directly observed from the gauge of the triaxial testing equipment and it is kept constant during the test. In case of testing the above sample, the minor principal stress $\sigma_3 = 17$ MN/m^2

After calculating σ_1 and observing σ_3, Mohr's circles are drawn by selecting a suitable scale i.e. 1.00 cm = 10 MN/m^2 with center C and radius R calculated as;

$$C = \frac{\sigma 1 + \sigma 3}{2}$$

$$R = \frac{\sigma 1 - \sigma 3}{2}$$

A common tangent is drawn to all these circles for samples tested at different values of lateral pressure cutting the Y-axis at a certain point. This shows the cohesiveness or the value of the constant C as shown in the Mohr's diagrams 1–4.

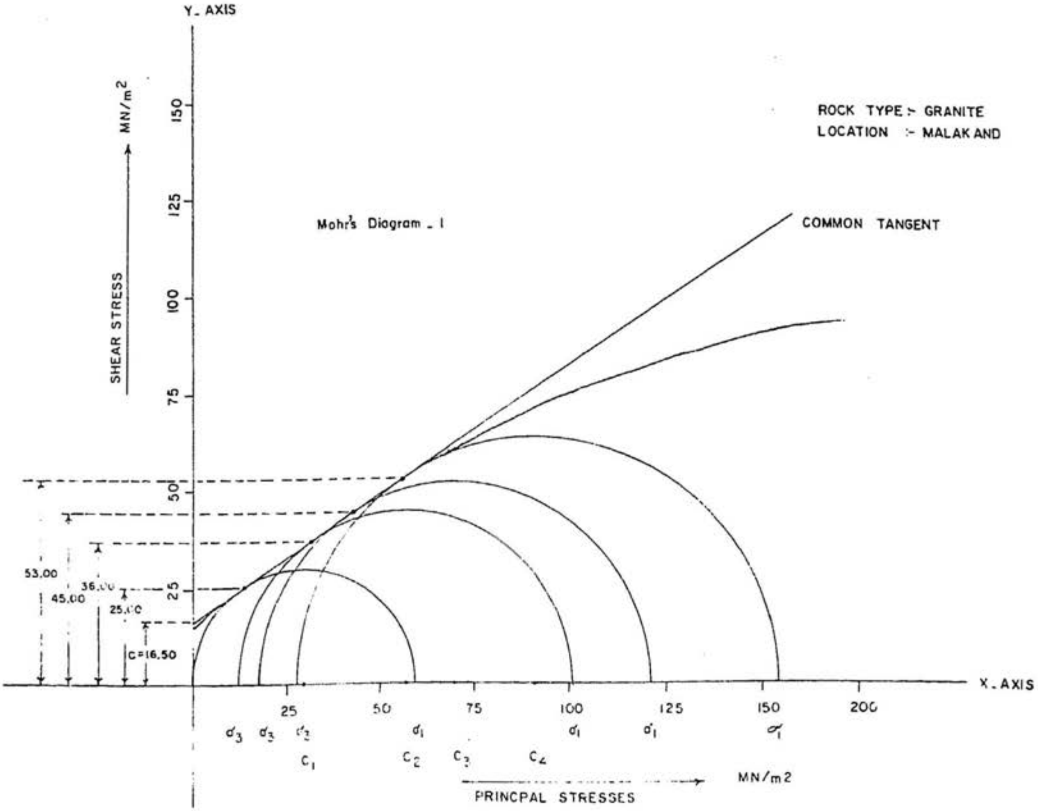


Fig. 1. Mohr's representation of shear strength for Malakand granite from triaxial compression values.

The co-ordinates of the points on the circumference of the Mohr's circles along the Y-axis give the values of the shear strength of the rocks corresponding to different confining pressure σ_3 (Farmer, 1983).

CONCLUSIONS

1. Comparing the strength values of Malakand granite and granite from Shahbaz garhi, the later show higher shear strength values than the former. The greater difference in strength is due to difference in grain size and geological defects. Texturally the micrporphyritic granite from Shahbaz Garhi is very fine grained and almost free from shear planes. On the other hand Malakand granite is coarse grained and have more shear planes. It indicates that grain size and their textural arrangements in rocks are important factors on which strength of the rock depends.

2. Similarly comparing the strength values of limestone from Cherat and Kohat, the Cherat limestone is stronger than Kohat limestone. The reason is that the limestone from Kohat are thin bedded, geologically involved under more compression forces than the Cherat limestone. It indicates that in-

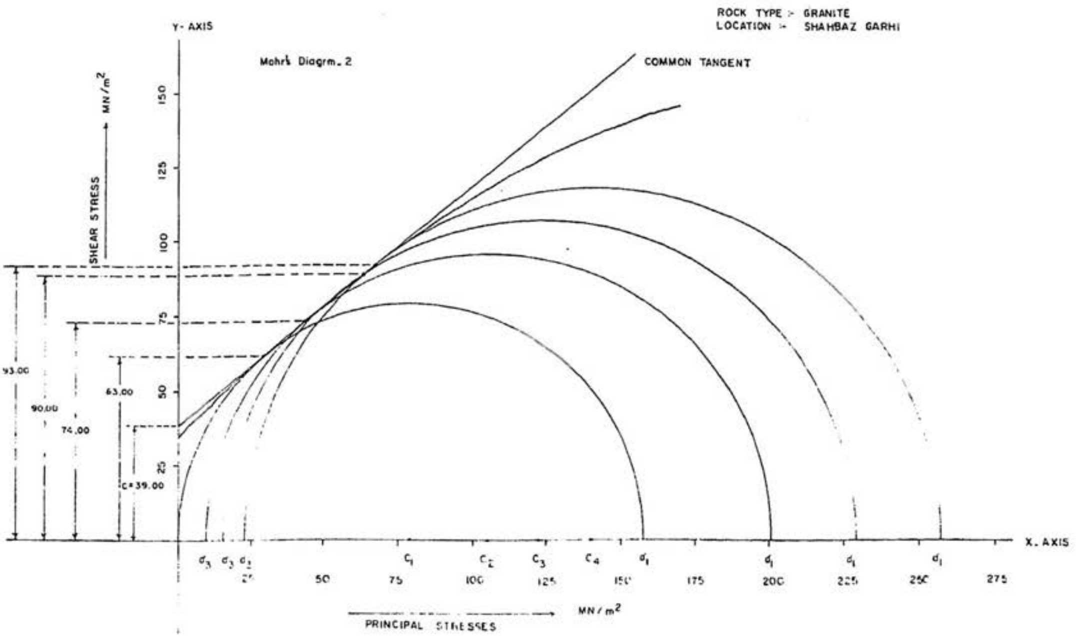


Fig. 2. Mohr's representation of shear strength for Shahbaz Garhi granite from triaxial compression values.

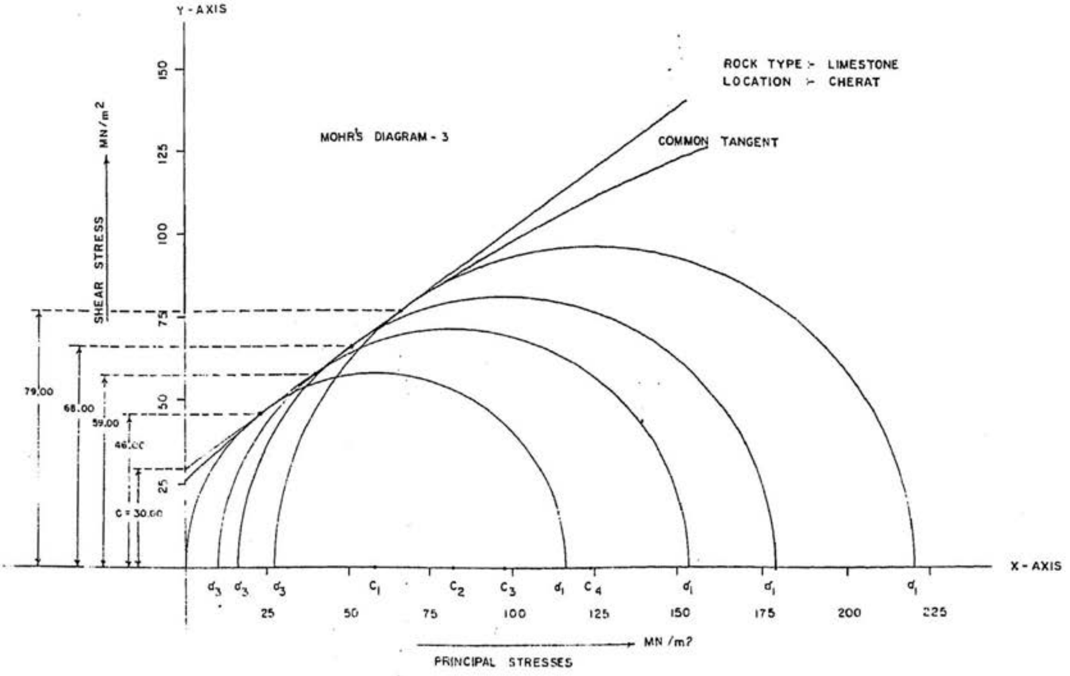


Fig. 3. Mohr's representation of shear strength for Kohat limestone from triaxial compression values.

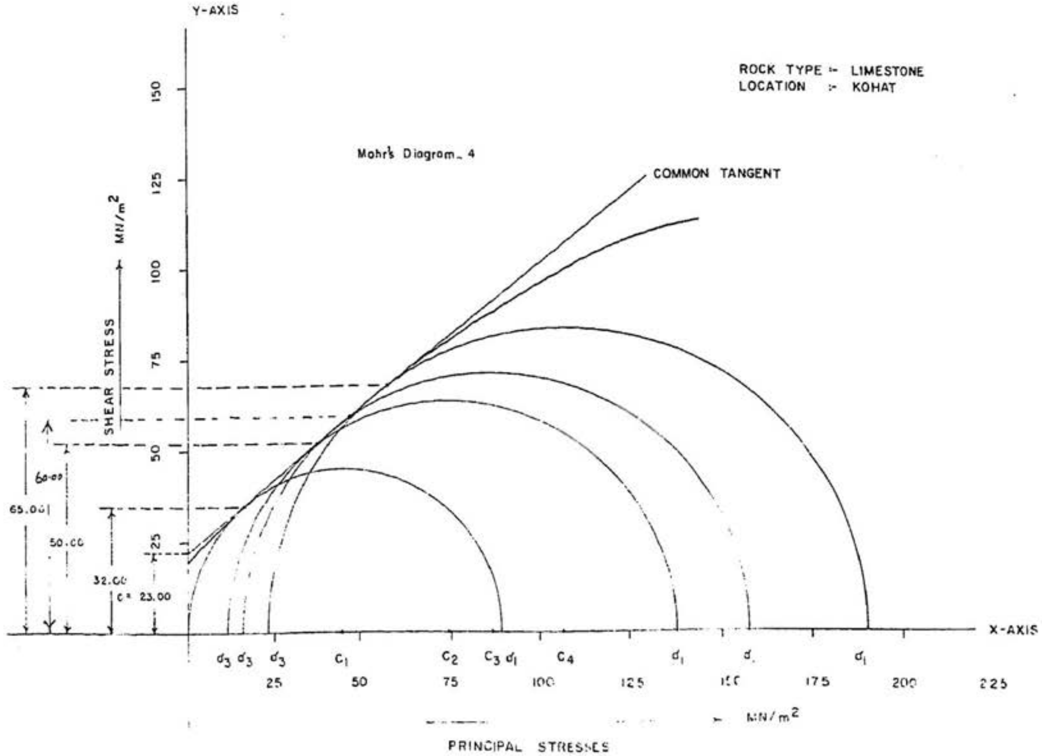


Fig. 4. Mohr's representation of shear strength for Cherat limestone from triaxial compression values.

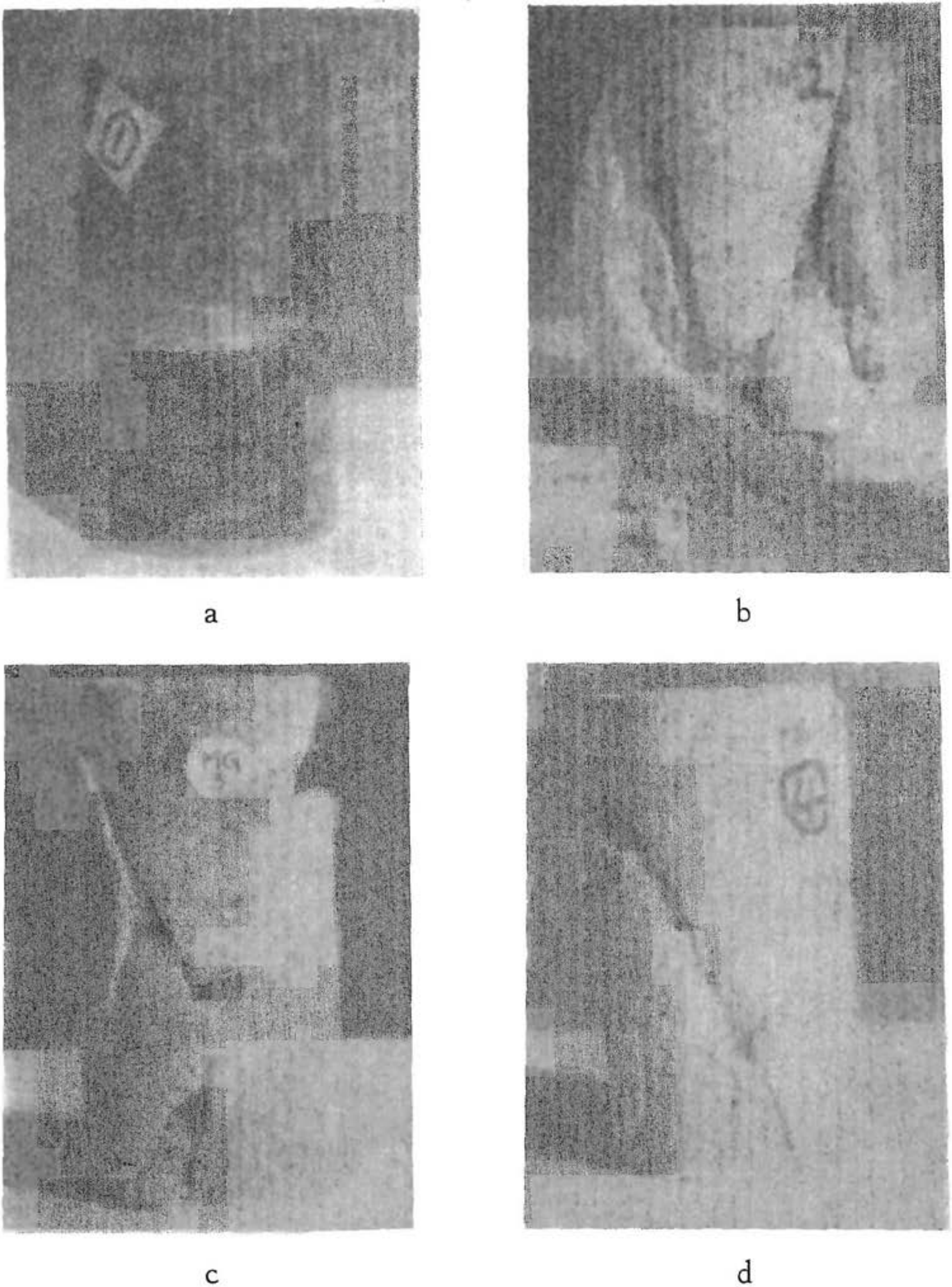
crease in geological defects also lowers the strength.

3. The results also indicate that rocks of the same type in different areas have different strength values. This is because of difference in grain sizes, cement, thickness of bedding, composition, structural environments and other geological defects. Thus it can be concluded that the change in texture, structure and the after effects of depositional/solidification environment and tectonisim appear to effect the strength properties of the same rocks in different areas.

4. Specimen preparation have significant effect on test results and therefore must be given due consideration. For example, end surfaces must be smooth, and perpendicular to the major axis of the specimen, because irregular sample may cause uneven distribution of stresses and oil drain from oil cell, thus reducing the confining pressure.

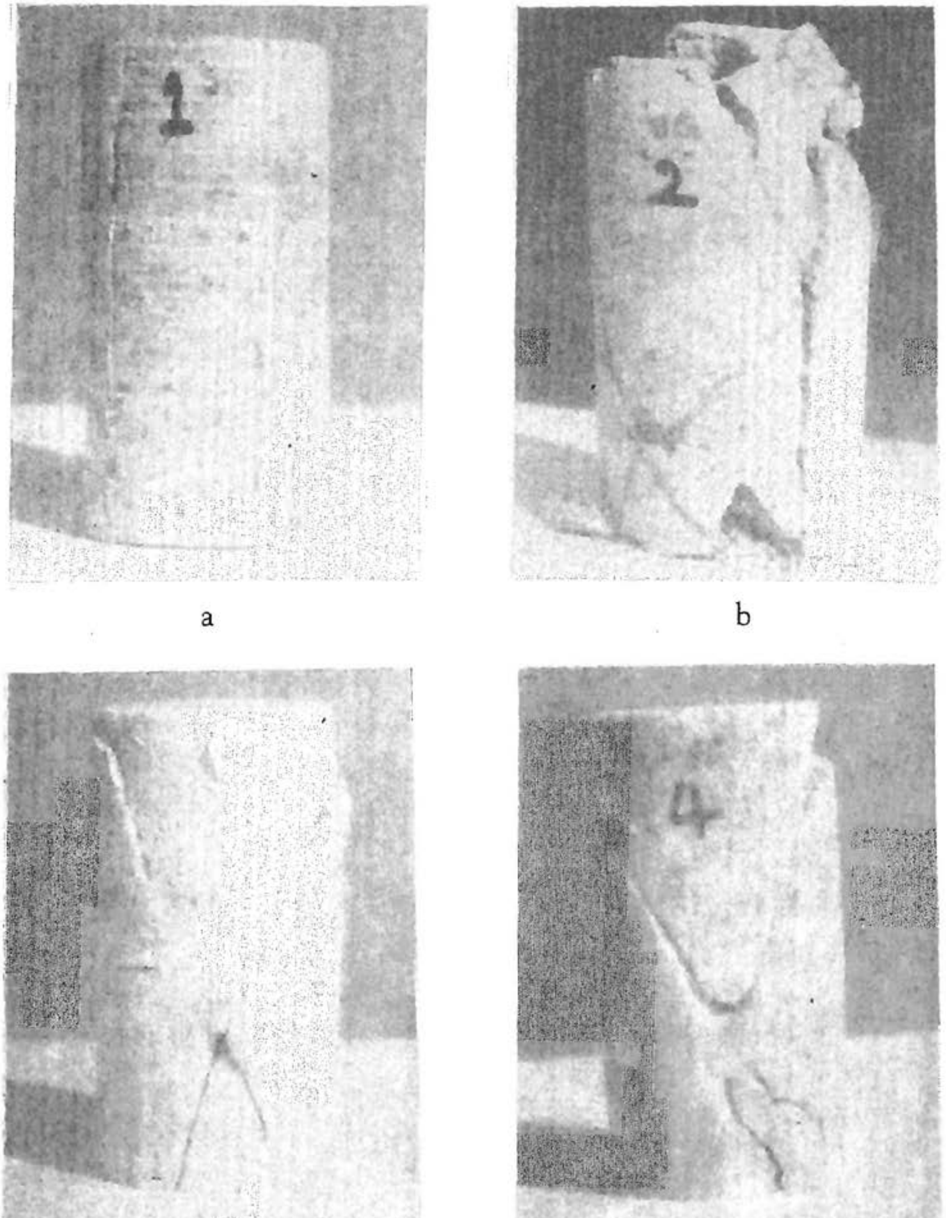
RECOMMENDATIONS

1. To compare the results, the shear strength of the rocks may also be determined by a direct method.
2. It is suggested that other important properties which influence the strength of the rocks such as slack durability, water absorption, hardness and porosity may be studied.
3. Chemical and mineralogical composition of the rocks will be of great help. In addition to modal composition of the rock, its textural and structural study is of utmost impor-



a b c d

Fig. 5 a-d. Showing the mode of failure of the Malakand granite (distt. Swat) Specimens were tested in triaxial compression at confining pressure from 0 to 30 MP_a range. Confining pressure of the fractured specimens reproduced in the photographs a to d are 0, 13, 18 and 28 MP_a, respectively.



a

b

c

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Fig. 6 a-d. Showing the mode of failure of the Shahbaz Garhi granite (distt. Swat) Specimens were tested in triaxial compression at confining pressure from 0 to 30 MP_a range. Confining pressure of the fractured specimens reproduced in the photographs a to d are 0, 10, 17 and 23 MP_a, respectively.

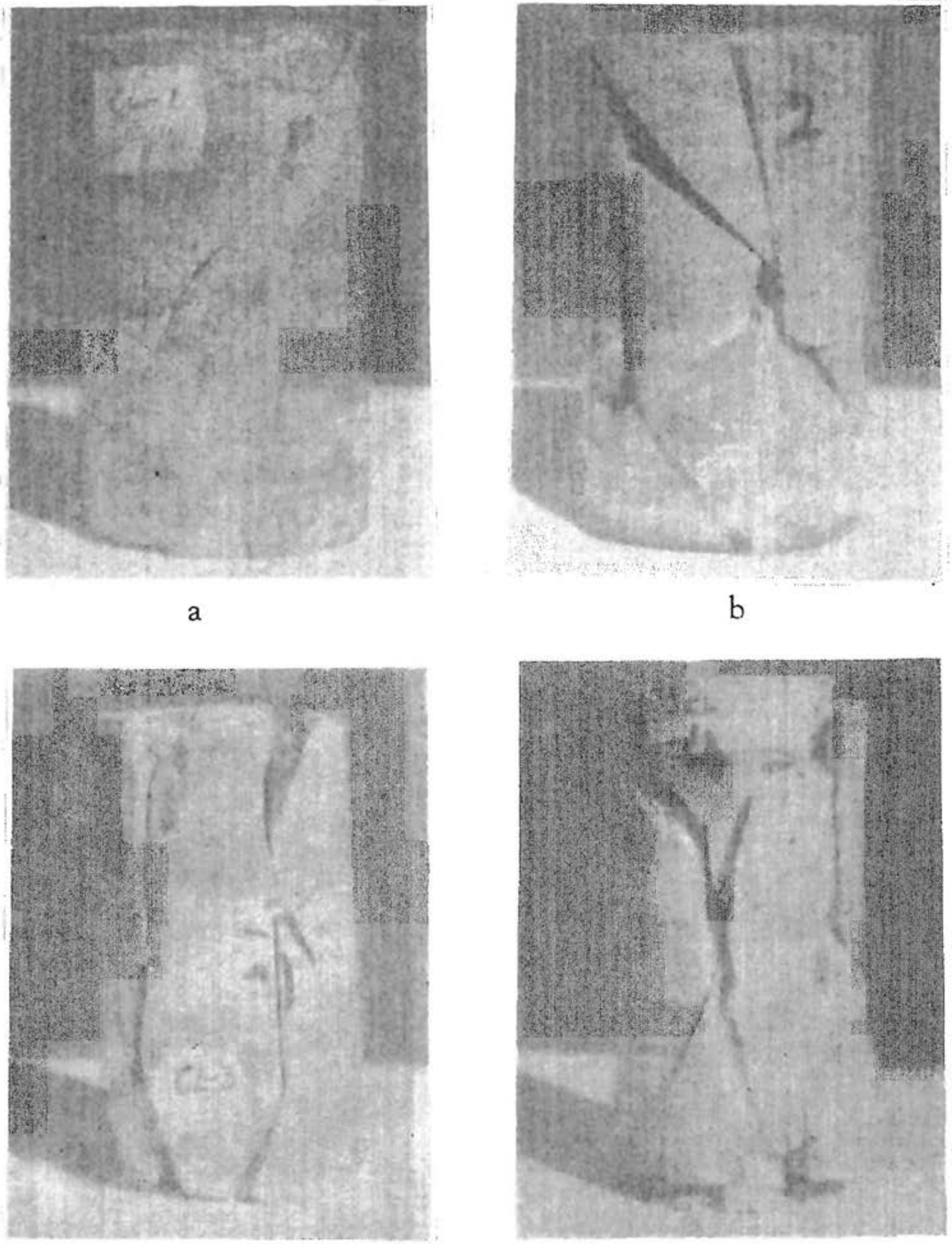
a

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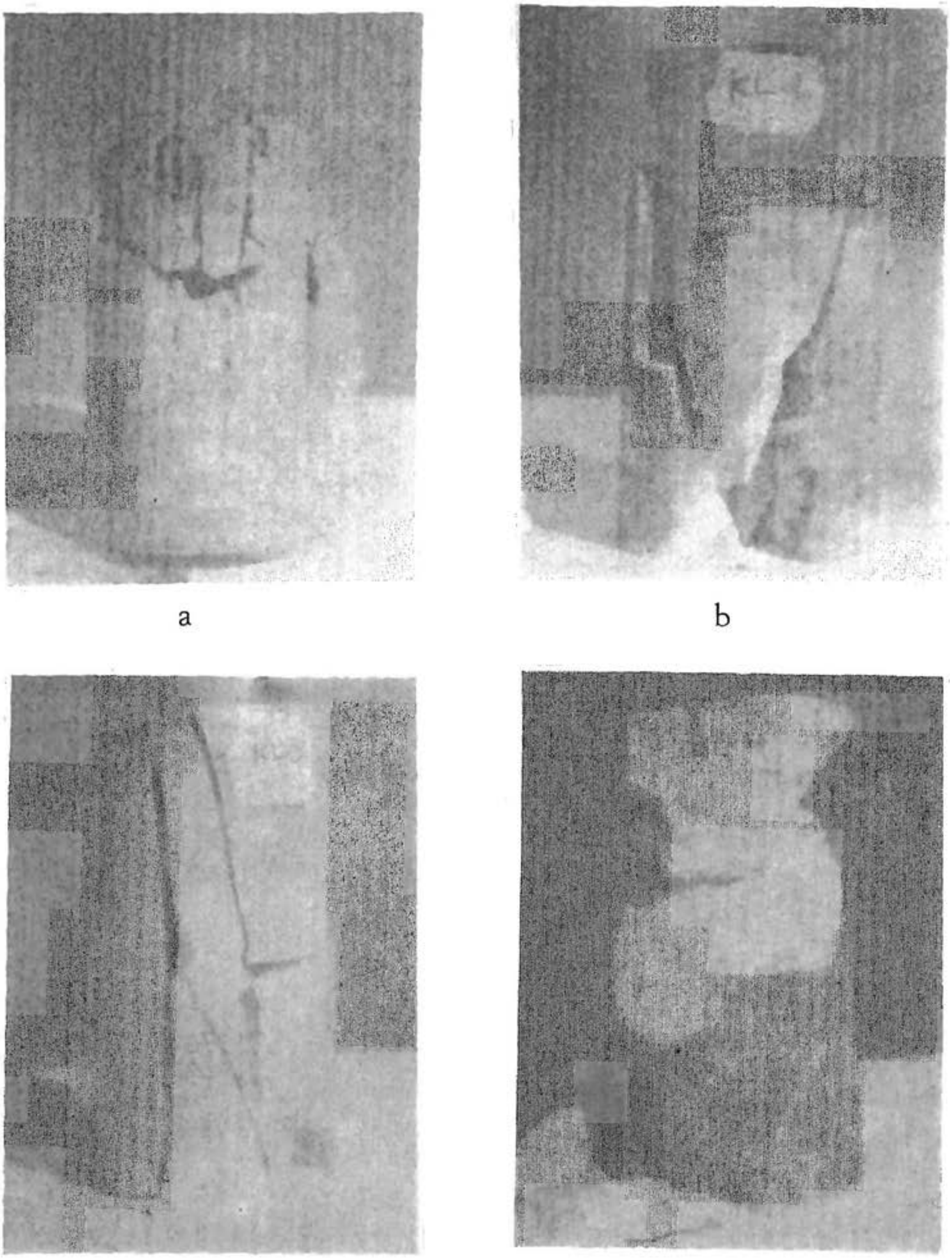
Fig. 7 a-d. Showing the mode of failure of the Cherat limestone (distt. Peshawar) Specimens were tested in triaxial compression at confining pressure from 0 to 30 MP_a range. Confining pressure of the fractured specimens reproduced in the photographs a to d are 0, 10, 15 and 27 MP_a, respectively.



a

b

c

d

Fig. 8 a-d. Showing the mode of failure of the Kohat limestone (distt. Kohat) Specimens were tested in triaxial compression at confining pressure from 0 to 30 MP$_a$ range. Confining pressure of the fractured specimens reproduced in the photographs a to d are 0, 11, 15 and 24 MP$_a$, respectively.

tance for knowing the structural defects present.

REFERENCES

Goodman, E. R., 1980. Introduction to Rock Mechanics. John Wiely & Sons, London.

Gokhale, K. V. J. K., 1960. Experiments in Engineering Geology. Tata McGraw-Hill, New Dehli.

Jumikis, R. A., 1983. Rock Mechanics. Trans Tech. Publication, Germany.

Farmer, I., 1983. Engineering Behavior of rocks. Chapman and Hall Ltd, London.