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Relationship between Point Load Strength and Uniaxial Compressive Strength of Abutment rocks of proposed Chamera Stage -II Hydroelectric Project, District Chamba, Himachal Pradesh, India.

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Abstract

Point Load and Uniaxial compressive Strength tests conducted on quartzite and phyllite rocks from Chamera Stage II dam in India, indicate conversion of 18 and 17 respectively, for BX (42 mm) size cores which is less than the generally reported value of 21 for BX cores. Based on their strength values, they are classified under high and medium strength categories. The test data exhibit the effect of rock anisotropy.

Introduction

The estimation of rock strength is an important parameter for classifying rocks in engineering practice. Point-Load (P-L) and uniaxial compressive strength (UCS) tests are the two most popular method for such estimations. Point load strength test is a versatile and quick method as it can be performed on cores (the diametral and axial tests), irregular lumps (the irregular lump tests), and on cut blocks (the block test). Moreover, because of the portable nature of the equipment, the test can be easily performed in the field. Another advantage is that the point load test data exhibit strong correlations with compressive strength and tensile strength data through suitable conversion factors (Broch and Franklin, 1972). It has also proved its usefulness in developing scale models for mine strata (Hanif, 1974; Brook, 1977). However, this test is quite sensitive to rock anisotropy. The uniaxial compressive strength test is comparatively more accurate and less sensitive to rock anisotropy, but it requires well prepared cores, expensive equipments and time consuming test procedure.

In order to estimate the strength of rock material as well as to establish a conversion factor for point load strength vs. uniaxial compressive strength, point load strength and uniaxial compressive strength tests were conducted on the abutment rocks of the proposed Chamera Stage-II Hydroelectic Project, Himachal Pradesh, India.

Geological setting

The rocks at the dam site are broadly classified into quartzite and phyllite intercalation (Fig. 1). The foliation strikes unidirectionally in NW-SE direction and dips upstream in NE direction. Stratigraphically, the succession belongs to Chamba Formation of Cambro-Silurian age (Dutta and Singh, 1972; Anon., 1984-85, 1985-86,

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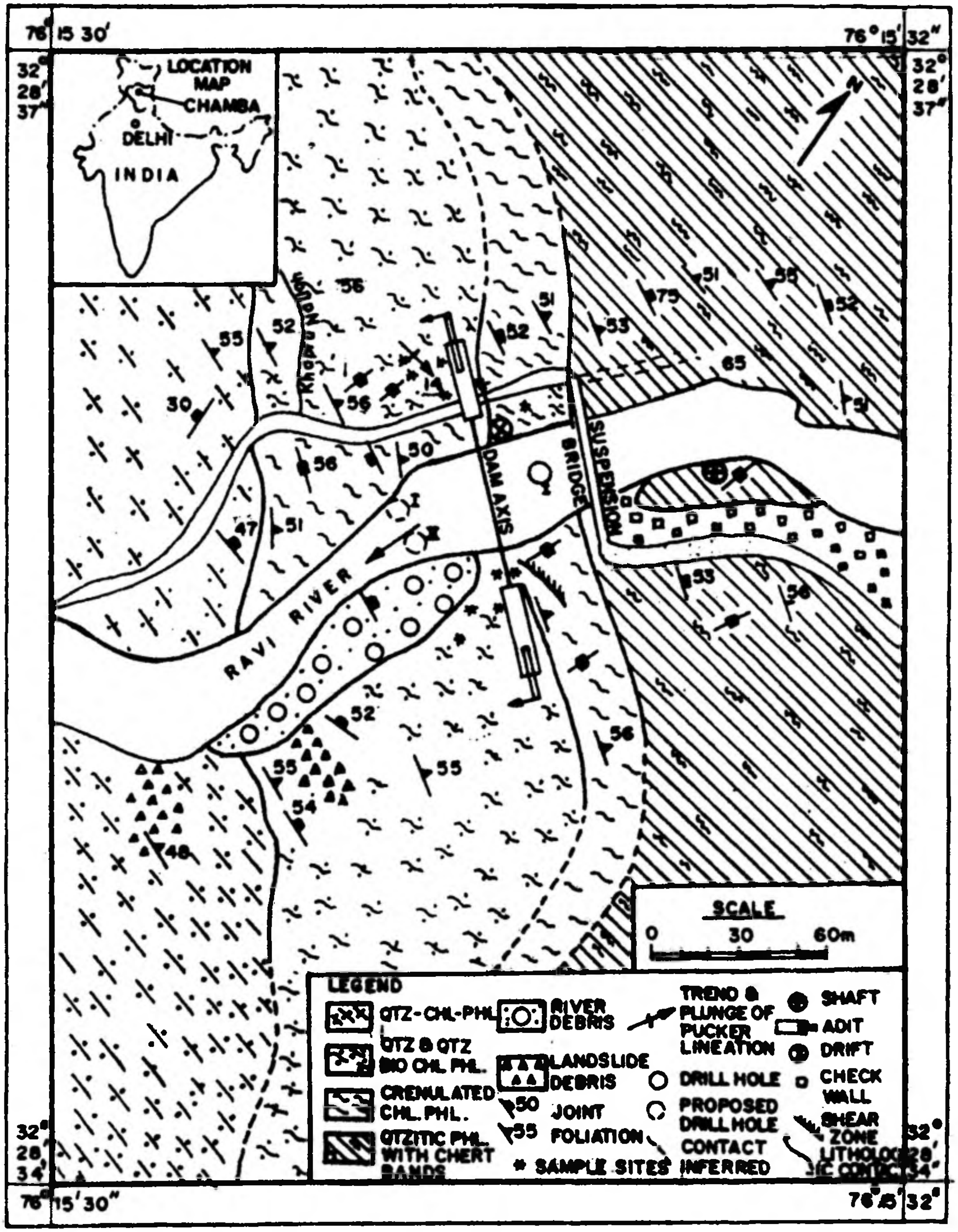

Fig. 1: Geological map of the dam site

1986-87).

Materials and methods

In order to estimate the strength of the rock material, oriented samples were collected both parallel and perpendicular to the bedding with sample dimensions varying from 17cm x 15cm x 13cm to 20cm x 18cm x 16cm. Samples were also collected for irregular lump test by point load method. Both quartzite and phyllite are fine grained, with interbanding nature. Three prominent joint sets and bedding planes give blocky appearance to the rockmass. The structural discontinuities show smooth to rough faces. Aperture is variable, mostly open but at a few places filled with secondary quartz veins and clay material. In thin sections, quartzite shows recrystallization of quartz grains giving rise to granoblastic texture with minor preferred orientation by biotite and chlorite. Phyllite shows prominent development of foliation which is marked by preferred orientation of biolite and chlorite rich bands that alternate with quartz rich bands. In some thin sections, alteration of biolite to chlorite, particularly along the rims, is prominently noticed,

In order to test the rock material for point load and uniaxial compressive strength, cores of BX (42mm) size were prepared by core drilling machine "Rockdrill", manufactured by Hydraulic and Engineering Instruments Company (HEICO), New Delhi. Cores were prepared perpendicular to fotiation to obtain the maximum strength values. The point load and uniaxial compressive strength tests were perfomed follwing the methodology proposed by the International Society for rock Mechanics Anon., 1985) and the American Society for Testing and Material (Anon., 1971). A portable point load tester, manufactured by Malhotra Bros., Delhi and a 50 tonne compression testing machine model "HS-26. 50" manufactured by HELCO, New Delhi were used in the present study.

Prior to the testing for point load and uniaxial compressive strength tests, textural and structural features of each specimen were described and a detailed Petrographic study was done to understand textural and micro-structural relationship of representative samples. Only fresh unweathered specimens were chosen and were air dried for three days before testing. The load was applied in such a manner that failure occurred within 10 to 15 minutes.

Point load strength test

The point load strength test was conducted on specimens of quartzite and phyllite obtained along the dam axis. The tests were conducted on irregular lumps, diametral and axial specimens to estimate Point Load Index $I_{s(50)}$) and Rock Anisotropy Index I_a. Since the tests were conducted on BX cores and on irregular lumps, standarisation to $I_{s(50)}$ became essential which was obtained by size correction factor F=(De/50)045 (Greminger, 1982) to minimise the effect of rock anisotropy. Point Load strength. I_s, was calculated by using the formula P/D^2 where (P) is rupture or failure load and (D) is the distance between the platens. Suitable corrections were done to obtain standard point load strength $L_{s(50)}$ on irregular lumps as well as diametral and axial cores (Brook, 1980; Anon., 1985). Rock anisotropy index $I_{a(50)}$ was calculated by dividing the corrected strengths $I_{s(50)}$ of perpendicular and parallel to the foliation directions tests. Tables 1 and 2 show the test results.

Uniaxial compressive strength test

To obtain the uniaxial compressive strength, 20 cores of BX size of quartizite and phyllite were tested perpendicular to the plane of foliation. The strength was calculated by using the formula $\sigma_c=F_{max}/\pi r^2$ where σ_c is

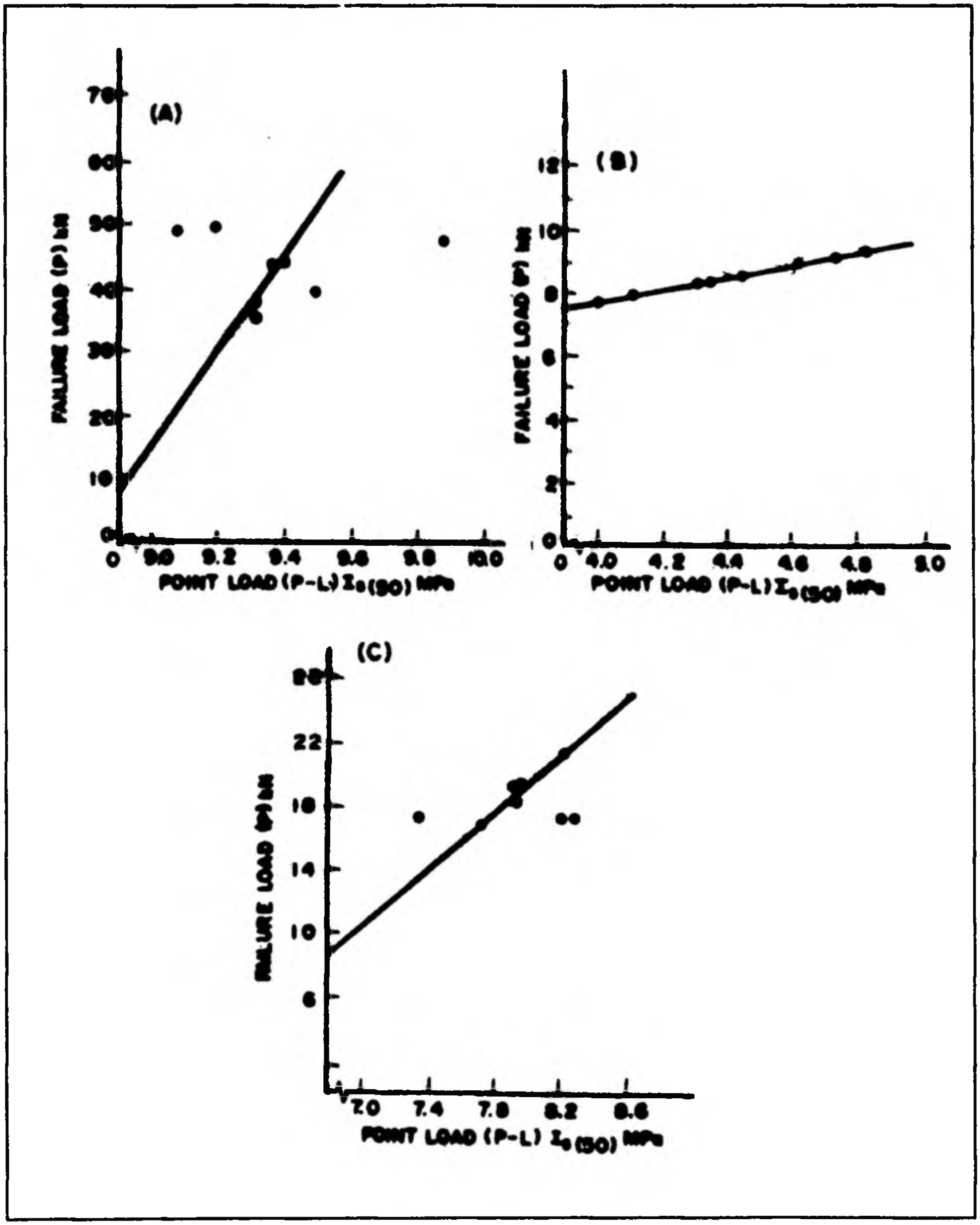

Fig. 2: Relationship between the failure load (P) and point load (P-L) strength $I_{s(50)}$ of irregular, diametrical and axial Quartzite specimens.

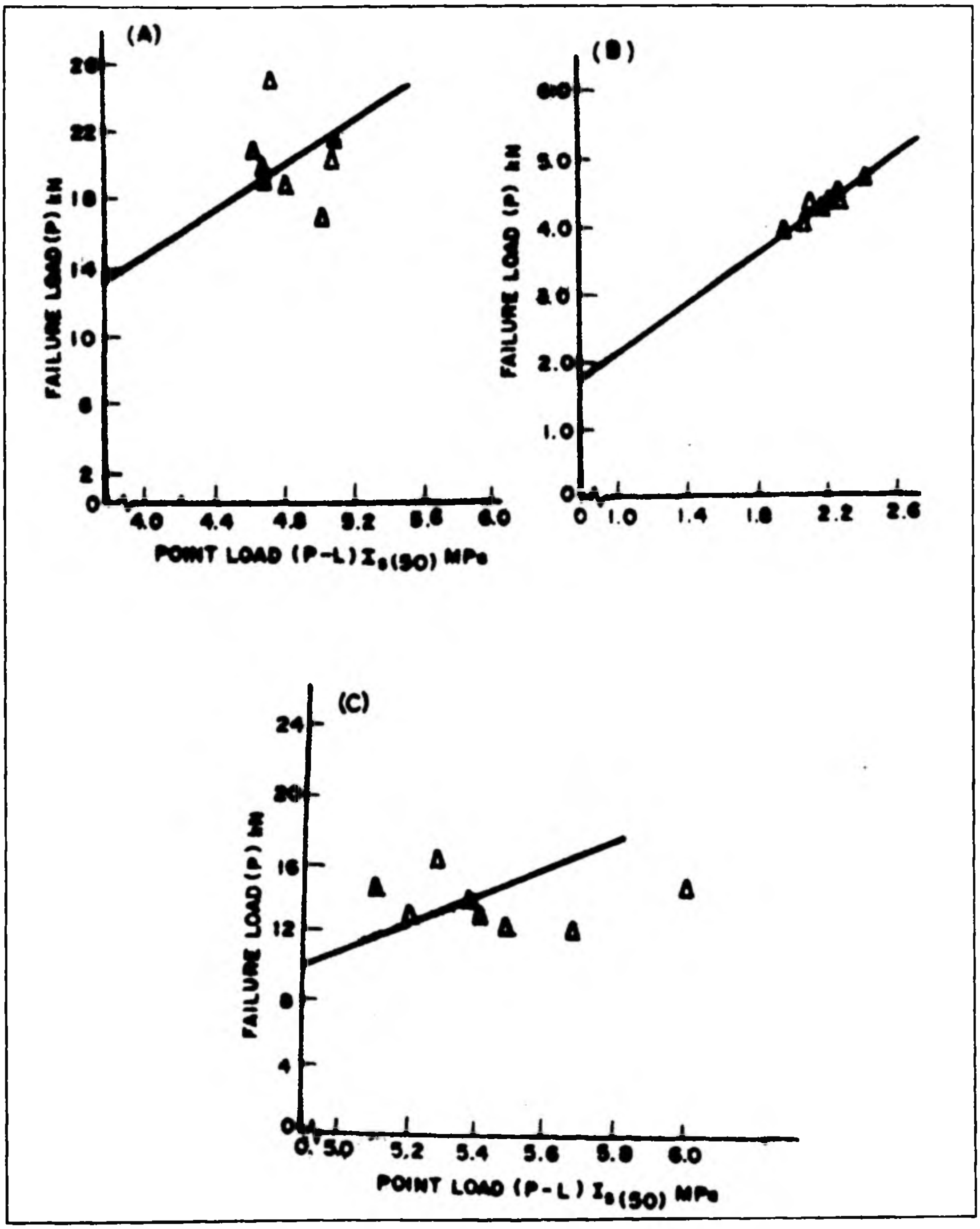

Fig. 3: Relationship between the failure load (P) and point load (P-L) strength $I_{s(50)}$ of irregular, diametrical and axial Quartz-Biotite-Chlorite Phyllite sepeciments.

Table-1: Results of the Point-Load strength test for the quartzite of the dam axis area

S. no.	Type	w	D	D_e	De^2	P	I_s	F	$I_{s(50)}$
1.	1 perp	110	48	82.01	67.26	49.000	7.28	1.249	9.092
2.	1 perp	100	46	76.55	5860	44.100	7.73	1.211	9.355
3.	1 perp	75	60	75.71	57.32	47.040	8.21	1.205	9.888
4.	1 perp	70	46	64.05	4102	37.240	9.09	1.118	10.163
5.	1 perp	72	52	69.09	4769	39.200	8.22	1.156	9.502
6.	1 perp	60	56	65.42	4280	35.280	8.24	1.129	9.303
7.	1 perp	65	42	58.97	3478	24.500	7.004	1.077	7.582
8.	1 perp	90	40	67.72	4586	37.240	8.12	1.146	9.306
9.	1 perp	92	48	75.00	5625	44.100	7.84	1.200	9.408
10.	1 perp	85	63	85.59	6822	49.980	7.33	1.253	9.184
1.	D parl.	-	42	-	-	7.840	4.44	0.925	4.111
2.	D parl.	-	42	-	-	8.820	5.00	0.925	4.625
3.	D parl.	-	42	-	-	8.330	4.70	0.925	4.348
4.	D parl.	-	42	-		9.310	527	0.925	4.822
5.	D parl.	-	42	-	-	7.350	4.17	0.925	3.857
6.	D parl.	-.	42	-	-	7.680	4.35	0.925	4.024
7.	D parl.	-	42	-	-	8.230	4.67	0.925	4.320
8.	D parl.	-	42	-	-	9.250	5.24	0.925	4.847
9.	D parl.	-	42	-	-	8.530	4.86	0.925	4.495
10.	D parl.	-	42	-	-	9.050	5.13	0.925	4.745
1.	a parp.	42	50	51.72	2675	21.650	8.09	1.015	8.211
2.	a parp.	42	46	49.61	2461	19.600	7.96	0.996	7.932
3.	a parp.	42	44	48.52	2354	17.950	8.33	0.987	8.218
4.	a parp.	42	38	45.10	2033	17.640	8.68	0.955	8.286
5.	a parp.	42	40	46.26	2140	17.150	8.01	0.965	7.735
6.	a parp.	42	47	50.15	2515	22.570	8.95	1.001	8.962
7.	a parp.	42	43	47.96	2301	17.250	7.50	0.981	7.356
8.	a parp.	42	48	50.68	2568	17.800	6.93	1.006	6.973
9.	a parp.	42	42	47.40	2247	18.350	8.17	0.976	7.973
10.	a parp.	42	45	49.07	2408	19.230	7.97	0.992	7.919

Mean $I_{s(50)}$ perp. = 8.7 MPa
Mean $I_{s(50)}$ perp. = 6.5 MPa
D - diametral
Mean $I_{s(50)}$ parl = 4.4 MPa
Mean $I_{a(50)}$ = 1.9 MPa
a = axial
Perp. = perpendicular to plane of weakness Parl, = parallel to plane of weakness

Table-2: Results of the Point-Load strength test for the quartzite of the dam axis area.

S. no.	Type	w	D	D_e	De^2	P	I_e	F	$I_{s(50)}$
1.	1 perp	80	35	59.71	3565	17.280	4.85	1.083	5.031
2.	1 perp	84	37	62.91	3957	18.150	4.59	1.109	4.324
3.	1 perp	88	39	66.10	4370	20.420	4.67	1.134	5.160
4.	1 perp	75	42	6333	4011	18.560	4.63	1.112	4.730
5.	1 perp	90	46	72.60	5271	24210	4.60	1.183	6.367
6.	] perp	72	45	64.23	4125	18.750	4.55	1.119	4.833
7.	1 perp	76	38	60.64	3677	19.890	5.41	1.091	4.634
8.	1 perp	85	51	74.29	5519	25.550	4.63	1.195	4.781
9.	1 perp	77	49	69.31	4304	21.650	4.51	1.158	5.515
10.	1 perp	63	42	60.30	3636	20.910	5.75	1.088	4.636
1.	Dparl.	-	42	-	-	4.650	2.64	0.925	2.438
2.	Dparl.	-	42	-	-	4.810	2.73	0.925	2.521
3.	Dparl.	-	42	-	-	4.420	5.50	0.925	2.317
4.	Dparl.	-	42	-	-	3.910	2.21	0.925	2.050
5.	Dparl.	-	42	-	-	4.240	2.40	0.925	2.222
6.	Dparl.	-	42	-	-	4.330	2.26	0.925	2.271
7.	Dparl.	-	42	-	-	4.480	2.54	0.925	2.350
8.	Dparl.	-	42	-	-	4.110	2.33	0.925	2.155
9.	Dparl.	-	42	-	-	3.820	2.16	0.925	2.002
10.	Dparl.	-	42		-	4.150	2.35	0.925	2.175
1.	a parp.	42	61	57.13	3264	16.280	4.99	1.062	5.297
2.	a parp.	42	45	49.07	2408	13.150	5.46	0.992	5.417
3.	a parp.	42	40	46.26	2140	12.280	5.74	0.967	5.549
4.	a parp.	42	38	45.09	2033	12.110	4.96	0.955	5.689
5.	a parp.	42	42	47.40	2247	11.450	5.10	0.976	4.974
6.	a parp.	42	46	49.61	2461	12.850	5.22	0.996	5.200
7.	a parp.	42	50	51.72	2675	14.140	5.29	1.015	5.365
8.	a parp.	42	48	50.68	2568	15.500	6.04	1.006	6.072
9.	a parp.	42	43	47.96	2301	14.880	6.46	0.981	6.344
10.	a parp.	42	47	50.15	2515	14.610	5.81	1.001	5.094

Mean $I_{s(50)}$ perp. = 5.2 MPa
Mean $I_{s(50)}$ perp. = 2.2 MPa
D - diametral

Mean $I_{s(50)}$ parl = 3.7 MPa
Mean $I_{a(50)}$ = 2.3 MPa
a = axial

Perp. = perpendicular to plane of weakness Parl. = parallel to plane of weakness

Table-3: Results of the uniaxial compressive strength of dam axis area

S. No.	Sample Length (mm)	Failure Load (N)	UCS (MPa)	Mean UCS (MPa)	Sample Length (mm)	Failure Load (N)	UCS (MPa)	Mean UCS (MPa)
1.	105	216.500	156.35		88	125.500	96.63	
2.	93	227.080	164.00		90	127.400	92.00	
3.	94	228.960	165.35		92	117.600	84.92	
4.	9S	205.670	148.53		95	121.570	87.89	
5.	96	225.250	162.66		96	118.920	85.88	
6.	95	203.560	147.00		97	122, 350	88.36	
7.	92	219.880	158.80		100	130.580	94.30	
8.	95	211.020	152.40		102	119.200	86.08	
9.	90	235.070	169.76		101	122.590	88.02	
10.	102	206.080	148.80	159.6	95	116.350	84.02	87.80
11.	95	215.010	155.27		96	123.510	89.20	
12.	98	209.050	150.97		92	120.980	87.37	
13.	101	225.010	162.50		90	119.700	84.44	
14.	92	217.020	156.72		101	126.860	91.61	
15.	97	235.230	169.87		100	118.760	84.76	
16.	98	230.510	166.46		92	119.280	86.14	
17.	96	225900	163.13		95	122.560	88.50	
18.	101	229.690	165.87		101	121.590	87, 81	
19.	91	225.600	162.92		96	119.970	86.64	
20.	92	226.970	163.91		98	118.780	85.78	

uniaxial compressive strength, F_{max} is the maximum force at which the sample was broken, r is the radius of the sample and π is a constant (3.14). The test result are shown in Table-3.

Discussion and conclusions

In order to determine empirical relationship between Point Load (P-L) strength and Uniaxial Compressive Strength (UCS) tests, Linear graphs were plotted between point load strength, $I_{s(50)}$, and failure load P (kN) for quartzite and quartz-biotite-chlorite phyllite rocks (Fig. 2 & 3). They show linear positive correlation in diametral test results but show somewhat scattering effect in irregular lump and axial test results. Graphs were also plotted between point-load (PL), $I_{s(50)}$, and Platen distance (D) which show no significant relationship (Fig. 4). The normal graphs were used in the case of uniaxial compressive strength and point load (P-L), $I_{s(50)}$, strength because the data show variation (Fig. 5). This plot shows minor linear positive correlation with a conversion factor of 18 for quartzite and 17 for quartz-biotite chlorite phyllite specimens.

Most of the quartzite sample broke either along foliation planes or at 30° to the vertically applied load with development of irregular and inclined cracks. Hence, shear failure was prominent. However, some

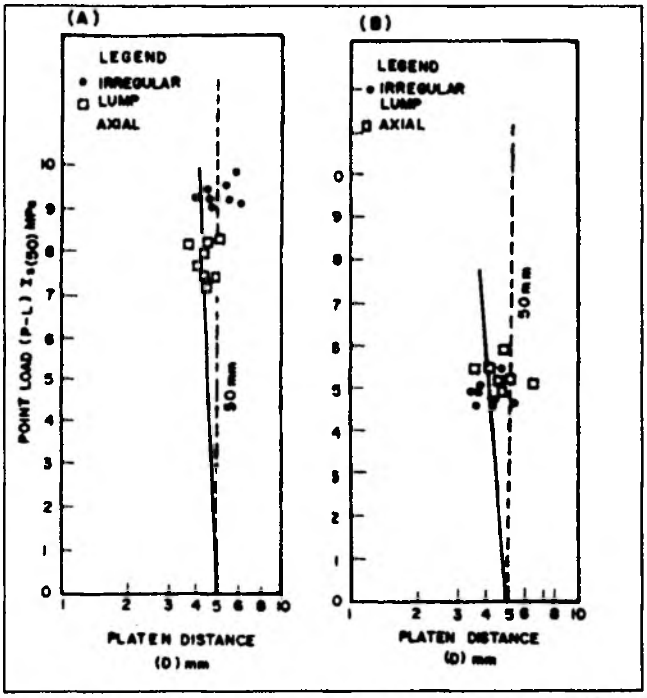

Fig. 4 : Relationship between the point load (P-L) strength and platen distance (D) of Quartzite axial Quartz-Biotite-Chlorite Phyllite specimens.

quartzite samples showed development of multiple cracks and cataclasis mode of failure (Hawkes and Mellor, 1970). In most of quartz-biotite-chlorite phyllite samples, the failure was along the foliation plane showing effect of rock anisotropy (foliation). In quartzite no prominent direct correlation was obtained between platen distance (D) and point load (PL), strength, $I_{s(50)}$. However, a minor inverse linear correlation was noticed in quartz-biolite-chlorite phyllite. Efforts were made to keep the platen distance (D) between 50±35mm in irregular lumps as well as in axial tests. All the calculated point load (P-L) strength values Is, were normalised to standard $I_{s(50)}$ by multiplying with size correction factor "F" by the expression $F = (D_e/50)^{0.45}$ as irregular lumps and

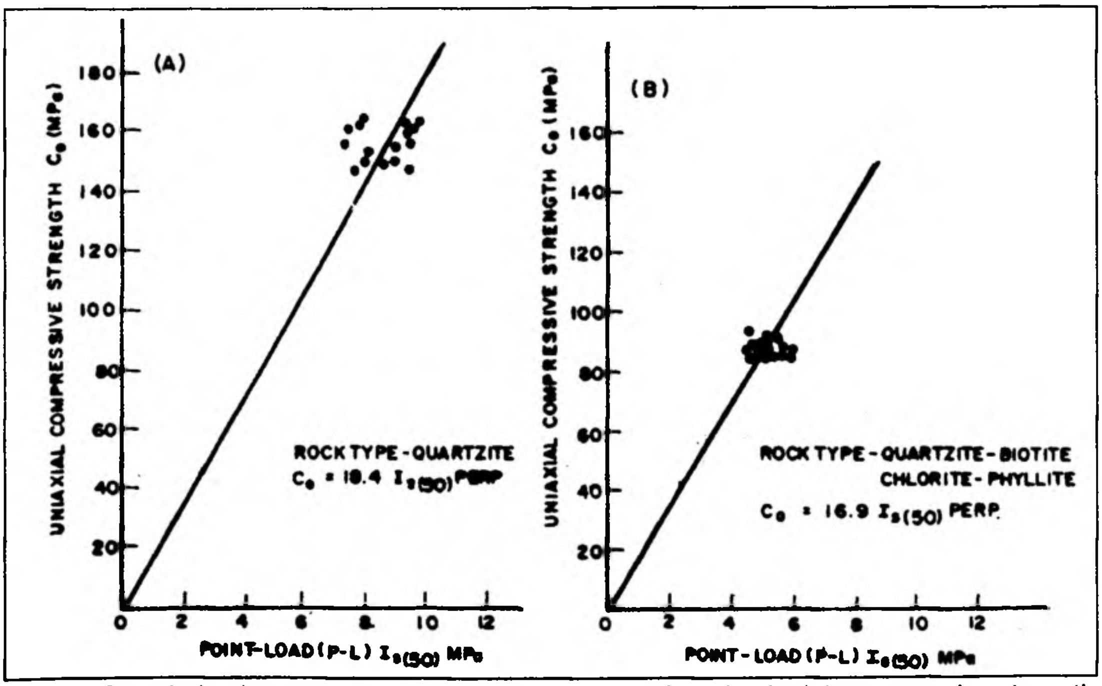

Fig. 5: Carrelation between the point load (P-L) strength and uniaxial compressive strength on perpendicular specimens.

BX cores were used (Greminger, 1982).

It is long being known that there is a high degree of positive linear correlation between point load strength and uniaxial compressive strength. Uniaxial compressive strength can be inferred from calculated point load strength as suggested by Broch and Franklin (1972). Bieniawski (1975) has established the relationship between these two tests and found the conversion factor to be 21 for BX size cores. International Society for Rock Mechanics (Anon., 1985) had found a conversion factor of 22 for 50 mm reference diameter cores. In the present study, conversion factors of 18 and 17 were obtained for quartzite and quartz-biotite-chlorite phylite rocks respectively (test results or irregular lumps and axial tests perpendicular to foliation have been correlated against the uniaxial compressive strength results obtained on cores prepared perpendicular to foliation to maintain the uniformity). The Indian Standard (Anon., 1978) gives conversion factor of 22 for the strength ratio for which no concrete basis has been given, In the present study quartzite gives mean values of $I_{s(50)}$ (perp.) 8.7 MPa, (Pari) 4.4 MPa, $I_{s(50)}$ 6.5 MPa, and $I_{a(50)}$ of 1.9. The mean value for quartz-biotite-chtorite phyllite is 5.2 MPa. [$I_{s(50)}$ perp.], 2.2 MPa, [$I_{S(50)}$ pari] 3.7 MPa, ($I_{s(50)}$) and 2.3 ($I_{s(50)}$) for the point load tests. The values obtained by the uniaxial compressive strength on BX cores (perp. to foliation) of quartzite and quartz-biotite-chlorite phyllite rocks are 159.6 MPa and 87.8 MPa respectively. According to Bieniawski (1975), the quartzite comes under the high strength category and the quartz-biotite-chilorite phyllite comes under the medium strength category. The effects of rock anisotropy I_a is clearly evident in the results and could be corrected with the conversion factor, that is, a high I_a of 2.3 in quartz-biotite-chlorite phyllite reduces the conversion factor to 17 as compared to I_a of 1.9 in quartzite which gives conversion value of 18 which is close to international standard of 22 for BX size cores. The test results clearly show that as rock anisotropy I_a increases the conversion factor decreases and hence $I_{s(50)}$ decreases.

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