



**IRCON INTERNATIONAL LIMITED**

(A Government of India Undertaking)

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**REPORT ON  
GEOLOGICAL AND GEOTECHNICAL  
INVESTIGATION OF SIVOK-RANGPO NEW BG  
RAILWAY LINE PROJECT**

**REPORT NO: ADPL/IRCON/2018/06**

**Revision No : R0**

**BOREHOLE NO NB-22A, NB-23A, NB-24A & NB-25A IN  
MELLI YARD HIGH CUTTING AREA**



**ARIHANT DRILLINGS PVT. LTD.**

**142/1, ADARS NAGAR, GURGAON -122001**

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## 1. INTRODUCTION

IRCON International Limited has been awarded the design and construction of Sivok (W.B.) – Rangpo (Sikkim) new BG Railway line project. The project will improve connections between Sikkim's north-eastern cities – which lie on the Chinese border – and the rest of India. The line is of national importance, as it will make it easier for the Indian Army to deploy soldiers along the border in the region. Once operational, it will be the first time Sikkim has been connected to the main Indian rail network, and as such is expected to boost local tourism and the region's economy

The proposed Railway line passes through steep terrain of Kanchenjunga mountain ranges foothills, dense reserve forest and Teesta Valley of Darjeeling district at West Bengal and East Sikkim district of Sikkim state. Out of the total 52.7km of the rail line, 51.7km will be in West Bengal and 1km in Sikkim. To avoid loss of forests, 14 tunnels have been planned, the longest being approx. 5 km. The total tunnel length is about approx. 38 km, about 72 % of the total route.

## 2. GEOLOGY

### 2.1. Regional geology

Sikkim-Darjeeling Himalayas are Techno-stratigraphically defined by four domains with characteristic stratigraphic and structural attributes. From south to north they are:

- i. Foothill belt
- ii. Inner Belt
- iii. Axial Belt and
- iv. Trans-Axial Belt.

The state is mostly covered by Precambrian metamorphic rocks of low to medium grade (Daling Group), high grade gneisses (Darjeeling Gneiss and Kanchendzonga Gneiss), Chungthang Formation (quartzite, calc-silicate rocks, marbles, graphite schist's and occasionally amphibolites) with intrusive granites (Lingtse granite gneiss) and Phanerozoic rocks including Gondwana and Tethyan sedimentaries. The Paleozoic and Mesozoic (Tethyan) sequence in the northern and north-western part of Sikkim are fossiliferous.

The Gondwana super Group consists of sandstone, shale and carbonaceous shale with occasional thin bands of coal and pebbly shale horizon.

**Daling group of rocks can be classified into three formations:**

- a. Gorubathan Formation: characterized by quartz-chloride-sericite schists, phyllite and quartzite's.
- b. Reyang Formation: characterized by quartzite's (occasionally calcareous), phyllite interbanded with carbonaceous slate.
- c. Buxa Formation: characterized by the presence of dolomitic limestone occasionally interbanded with phyllite and development of organo sedimentary structure (stromatolites).

The Kanchenjunga Gneiss comprises mainly high-grade gneiss. The Chungthang gneiss is quartz-biotite gneiss. A streaky sheared granite gneiss known as "Lingtse Gneiss" occur as a NE-SW to N-S trending strip of rocks and forms a general line of separation between the Daling and high-grade Kanchenjunga Gneiss. The Tethyan sedimentaries, exposed in the northern part of Sikkim represent Everest Phyllites series (shale's/Phyllites), Mount Everest Limestone series, Lachi Formation (conglomerate with thick diamictite base) and Tso Lhamo Formation (calcareous shale, limestone band, calcareous sandstone).

At the contact of the rocks of Gorubathan Formation and Chungthang Formation, a thick horizon of streaky biotite granite gneiss is observed, which is described as Lingtse granite gneiss.

Gondwana Group of rocks are represented by a basal pebble slate (Ranjit Pebble Bed) followed by coal-bearing sandstone-shale horizons with occasional plant fossils equivalent to the Damuda Group of rocks of the Indian Peninsular shield.

The rocks of Buxa Formation occur as thrust wedges along the thrust contact of the rocks of Gorubathan Formation and Gondwanas. The boundary between Gondwanas and Dalings and between Dalings and Darjeeling group of rocks is tectonised and thrust.



## GEOLOGICAL AND GEOTECHNICAL INVESTIGATION REPORT

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The Generalised Stratigraphic succession Sikkim- Darjeeling Himalayas is given as under:

<b>Group/Formations</b>	<b>Lithology</b>	<b>Age</b>
Sub-aerial deposits	Debris and Overburden	Recent
Alluvial deposits	River Terraces	Quaternary
Siwalik Group	sandstone, conglomerate, siltstone, shale, claystone and limestone	Pleistocene - Mid-Miocene
-----Main Boundary Thrust-----		
Gondwana Group	Sandstone, shale, Coal with plant fossils, Lamprophyre	Permo-Carboniferous - Upper Permian
-----Thrust-----		
Buxa Formations	Dolomites, Ortho quartzite, Slate, Phyllites, Purple limestone	Meso – Neo Proterozoic
-----Thrust-----		
Daling Group	Phyllites, Quartzites, Chlorite Schist, quartz schist.	Proterozoic to Pre Cambrian
Darjeeling Gneiss	Biotite, Garnet	

### 2.2. Project geology

The Investigated area of the project is lying on the Eastern Himalaya, represents the Gorubathan Sub-group under the Daling Group of rocks ranging the geological age of Middle to Late Proterozoic age.

The rock type of this area is mainly chlorite quartz schist, chlorite schist, phyllite with or without sericite, quartz-sericite schist, sericite quartz schist, slaty phyllites, slates and quartzite.

### 3. SCOPE OF WORK

IRCON has awarded Arihant Drillings Private Limited to carry out geological and geotechnical investigations along the proposed railway track alignment. Addl. Geo-Technical Investigation for Sivok – Rangpo BG Railway Line project vide LOA no IRCON/2016/Sivok - Rangpo/Addl. GT Invest./58/675 dated on 28.02.2017.

The details of the scope of work are captioned as under:

1. Geotechnical Investigations:

- a. Drilling of Exploratory Drill Holes (40m Maximum).
  - b. In-situ Permeability tests in Overburdens and bedrock.
  - c. Collection of Rock Sample in Core boxes and Determination of RQD.
  - d. Standard Penetration Test (SPT).
  - e. Sample collection of disturbed soil samples
2. Submission of Geological and Geotechnical Reports.

This report consists of the Geological and Geotechnical data consisting of borehole logging, photographs, in-situ tests. The project consists of 4 nos of proposed boreholes completed in Melly Yard, Rongpo of East Sikkim.

The drill hole location plan of proposed "Sivok-Rongpo new BG railway line project" is given in plate no 1

The location (Co-ordinates) of drill holes, ground Elevations, total depth and water level are summarised in table 1 as below.

#### **4. EXPLORATION METHODOLOGY**

- NX size core drilling technique was adopted for the advancement of drill hole up to the explored depth. Drilling is done with standard mechanical feed rotary drilling machine as per IS: 6926-1973. In this method, the hole is advanced by rotating a system, consisting of a series of hollow drill rods to the bottom of which is attached a double/Triple tube core barrel with a diamond coring bit, by means of a diesel operated engine.
- When the rod with the coring bit is rotated, downward pressure is applied to the system to obtain penetration in the rocky strata and water under pressure was introduced into the bottom of the hole through the hollow drill rods. Water comes up through the annular space between the drill rods and the hole and is collected in the water sump, from where it is re-circulated. Water serves the dual function of cooling the bit as it enters the hole and carrying the cuttings from the bottom of the hole on its return journey to the surface as well as its colour also indicate a change in the layer during drilling.
- Seamless flush jointed steel casing of HX / NX sizes were used to prevent any caving and water loss from drill holes and those were inserted.
- Simultaneously with the advancement of drilling operations. Moreover, due to the collapsible nature of the subsurface formation, the holes were advanced by charging dense bentonite slurry to stabilize the walls of the drill holes.

- Standard Penetration Tests were conducted inside the holes wherever possible as per IS 2131-1981 “Method of standard penetration tests for soils”. The split spoon sampler used is of standard design and dimension. The spoon is advanced by driving with a drop hammer weighing 63.5 kg falling freely through a height of 75 cm. A record of the number of blows required to penetrate every 15 cm. to a depth of 45cm is kept. The number of blows required for the last 30 cm penetration of the split spoon sampler is recorded as ‘N’-value. On completion of the test, the sampler is lifted to the
- The ground opened and the specimen of the soil sample is stored in double polythene bags with the proper identification mark. The penetration number, ‘N’ has been shown against the corresponding depths in field bore/drill logs.
- Representative disturbed samples were collected regularly and wherever the stratum changed. These samples are taken from the split spoon samplers after standard penetration tests. These samples are labeled depth wise and used in the preparation of the bore/drill hole log and for general identification and classification purposes.
- Rock core samples were collected in standard NX size double/ triple tube core barrel and stored as per IS: 4464-1967 and IS: 4078-1967.

**5. SUMMARY OF GEOLOGICAL AND GEOTECHNICAL BORE HOLES:**

Based on core samples, drilling observations and in-situ tests performed in the drill holes, the subsurface geology, geotechnical conditions, Co-ordinates, ground Elevations, total depth and water level are summarised as below:

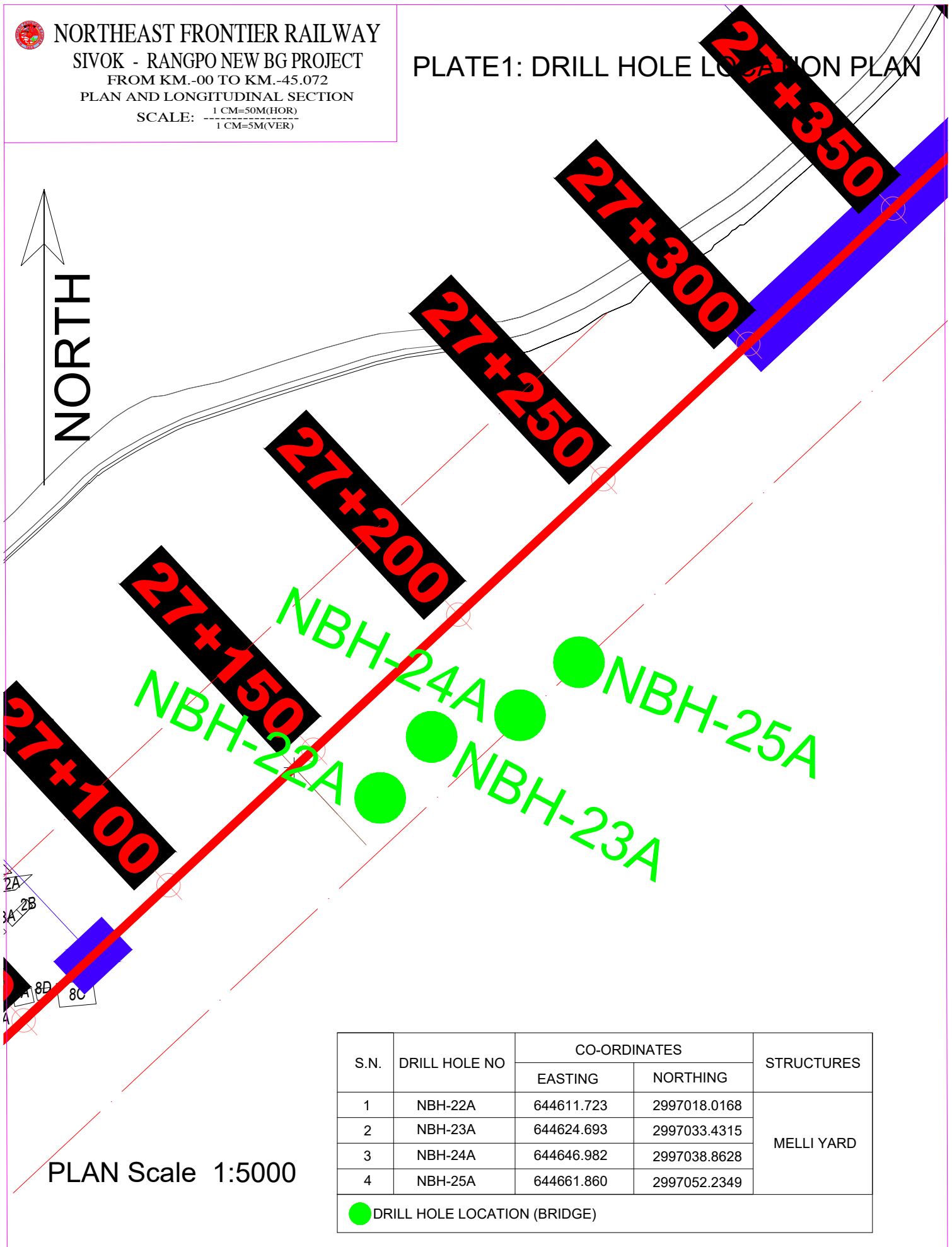
**SUMMARY OF BOREHOLES**

SN	Structure	Borehole no	Location Coordinate		Ground Elevation (m)	Depth Drilled (m)	Overburden Encountered From - to (depth) m	Overburden Characteristics	Bedrock Encountered from - to (depth) m	Bedrock Characteristics	Ground water depth (m) below ground level	Remarks
			Easting	Northing								
	1	2	3	4	5	6	7	8	6	7	8	9
1	MELLI YARD	NBH-22A	644611.723	2997018.0168	298.39	23	0.00 to 3.00	Brown colour top soil and pebbles of Quartzite.	3.00 to 23.00	weak to medium strong, Quartzitic Phyllite with irregular interbands of white coloured Quartzite,	N.E.	slightly weathered, intensely to moderately fractured
2		NBH-23A	644624.693	2997033.4315	311.02	35	0.00 to 8.00	Top soil, Boulders, cobbles, Pebbles and granules with clay material (6 to 8.30m) of Greenish grey to brown coloured, Quartzitic Phyllite and Quartzite.	8.00 to 35.00	weak to medium, strong Quartzitic Phyllite with irregular interbands of white coloured Quartzite	16.50	Highly to moderately weathered, highly to moderately fractured. Sheared mass encountered from 13.50 to 16.50m & 33.50 to 35.00 m
3		NBH-24A	644646.982	2997038.8628	309.67	15	0.00 to 2.50	Top soil, Pebbles and granules of Quartzitic Phyllite	2.50 to 15.00	Weak to medium strong, Quartzitic Phyllite with irregular interbands of white coloured Quartzite,	N.E.	Slightly to moderately & highly weathered, intensely to moderately fractured, highly fractured
4		NBH-25A	644661.860	2997052.2349	304.40	15	0.00 to 4.00	Top soil, Pebbles & granules of Quartzitic phyllite	4.00 to 15.00	Weak to medium strong rock, Quartzitic Phyllite with irregular interbands of white coloured Quartzite	N.E.	Intensely to very intensely & moderately fractured, fresh to slightly & moderately to highly weathered



**NORTHEAST FRONTIER RAILWAY**  
**SIVOK - RANGPO NEW BG PROJECT**  
 FROM KM.-00 TO KM.-45.072  
 PLAN AND LONGITUDINAL SECTION  
 SCALE:  $\frac{1 \text{ CM}=50\text{M(HOR)}}{1 \text{ CM}=5\text{M(VER)}}$

**PLATE1: DRILL HOLE LOCATION PLAN**



PLAN Scale 1:5000

S.N.	DRILL HOLE NO	CO-ORDINATES		STRUCTURES
		EASTING	NORTHING	
1	NBH-22A	644611.723	2997018.0168	MELLI YARD
2	NBH-23A	644624.693	2997033.4315	
3	NBH-24A	644646.982	2997038.8628	
4	NBH-25A	644661.860	2997052.2349	

DRILL HOLE LOCATION (BRIDGE)

# ANNEXURE –1

## STRUCTURE: MELLI YARD

GEOLOGICAL LOG, PHOTOGRAPHS AND PERMEABILITY TEST RESULTS  
OF DRILL HOLES: NBH-22A, NBH-23A, NBH-24A, NBH-25A AND LAB TEST  
REPORT OF CORE SAMPLES

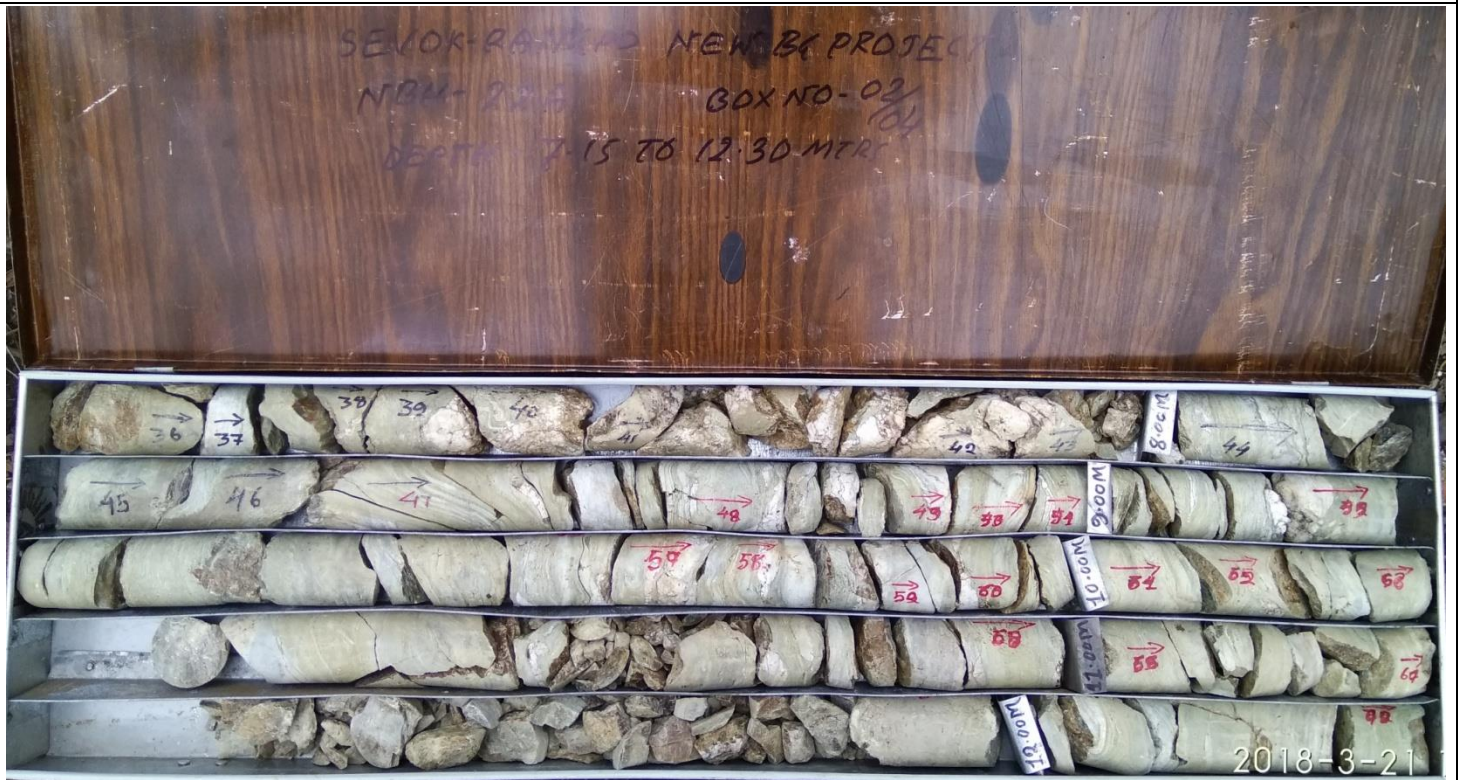




**NBH-22A, DEPTH 0.00 to 7.15m**

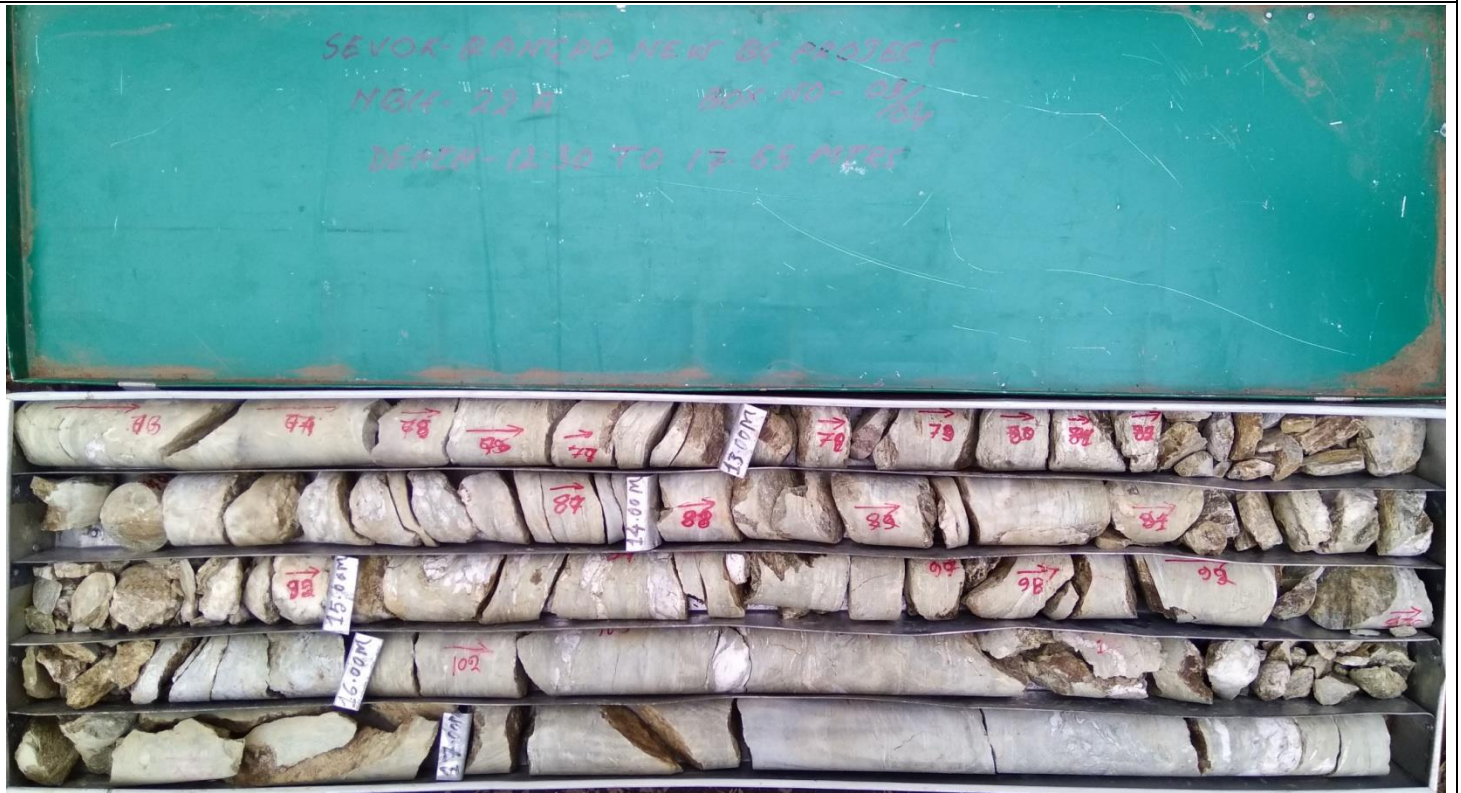


**NBH-22A, DEPTH 7.15 to 12.30m**





**NBH-22A, DEPTH 12.30 to 17.65m**



**NBH-22A, DEPTH 17.65 to 23.00m**





## SIVOK – RANGPO NEW BG RAILWAY LINE PROJECT

### WATER PERMEABILITY TEST

CLIENT	: IRCON INTERNATIONAL LTD.	PACKER TYPE	: Double
DRILLING AGENCY	: ARIHANT DRILLING PVT LTD.	DIAMETER OF HOLE	: NX(76 mm)
LOCATION / FEATURE	: MELLI YARD	TYPE OF DRILLING	: Diamond Core
BOREHOLE	: NBH-22A	PERIOD	: 13.03.2018
ANGLE OF THE HOLE	: 90° (Vertical)	TOTAL DEPTH OF THE HOLE	: 23.00m
GROUND ELEVATION	: 298.39m	SHEET	: 1/1
COLLAR ELEVATION	: 298.51m		

Meter Reading of Water Intake( Litres)				Water Intake Litres/Minute				Water Intake	GUAGE PRESSUR E	DEPTH OF GROUND WATER	HEIGHT OF WATER SWIVEL	*ACTUAL PRESSURE	PERMEABILITY	FLOW CHART	INTERPRETATION
INITIAL	After 5min.	After 10min.	After 15min.	First 5min.	Sec. 5min.	Third 5min.	Avg.	Lt./ min /m	kg/cm2	(m)	(m)	kg/cm2	IN LUGEON'S		

#### 1-Test Section 15.00m to 18.00 M

1280.00	1308.00	1338.00	1371.00	28.00	30.00	33.00	31.50	2.10	1.00	N.E	1.40	2.64	7.95		Laminar
1380.00	1420.00	1459.00	1499.00	40.00	39.00	40.00	39.50	2.63	2.00			3.64	7.23		7.67
1510.00	1568.00	1625.00	1684.00	58.00	57.00	59.00	58.00	3.87	3.00			4.64	8.33		
1690.00	1727.00	1769.00	1809.00	37.00	42.00	40.00	41.00	2.73	2.00			3.64	7.51		
1815.00	1844.00	1874.00	1902.00	29.00	30.00	28.00	29.00	1.93	1.00			2.64	7.32		





**NBH-23A, DEPTH 0.00 to 8.25m**



**NBH-23A, DEPTH 8.25 to 16.10m**





NBH-23A, DEPTH 16.10 to 22.25m



NBH-23A, DEPTH 22.25 to 27.45m





**NBH-23A, DEPTH 27.45 to 33.50m**



**NBH-23A, DEPTH 33.50 to 35.00m**



**IN-SITU CONSTANT HEAD PERMEABILITY (WATER PERCOLATION) TESTS DATA**

**DRILL HOLE : NBH-23A**  
**SHEET : 1 of 1**

1. PROJECT	: SIVOK – RANGPO NEW BG RAILWAY LINE PROJECT	5. COORDINATES	: N2997033.4315.E644624.6930
2. LOCATION/FEATURE	: MELLI / YARD	6. TOTAL DEPTH FROM ESL	: 30.00m
3. CLIENT	: IRCON INTERNATIONAL LTD.	7. GROUND LEVEL EL	: 311.02m
4. DRILLING AGENCY	: ARIHANT DRILLING PVT. LTD.	8. COLLAR EL	: 311.14m

Test No.	Depth of Test Section (m)	Dia. of Hole	Vaule of $C_1$		Average Time (min.)	Water Intake(L/5min)						Q=Average Constant Intake of Water(L/min.)	Depth of Ground Water Level(m)	Water Level Height above GL/(m)	Differential Head(H) (m)	COEFF. OF PERMEABILITY (k)		REMARKS
						1 <sup>st</sup> 5 min	2 <sup>nd</sup> 5 min	3 <sup>rd</sup> 5 min	4 <sup>th</sup> 5 min	5 <sup>th</sup> 5 min	Average of Last Two Readings					AS PER IS 5529-(PART-1)		
																cm/sec.	Lugeon	
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	3.00	HX	0.00606	$6.06 \times 10^{-3}$	5	31.00	28.00	30.00	26.00	32.00	29.00	5.80	N.E.	0.12	3.12	$11.2654 \times 10^{-3}$	1126.54	i) The H for test below W.T. = Depth of water in casing – Depth of GW Table.
2	6.00	NX	0.00795	$7.95 \times 10^{-3}$	5	26.00	24.00	25.00	27.00	25.00	26.00	5.20	N.E.	0.14	6.14	$6.7329 \times 10^{-3}$	673.29	
																		ii) The H for test above W.T. = WL in casing – Depth of test sec.
																		iii) The expression $K=C_1 \times Q/H$ where K= Permeability in cm/sec. Q= Constant rate of flow into hole in litre/min.



## GEOLOGICAL LOG OF DRILL HOLE

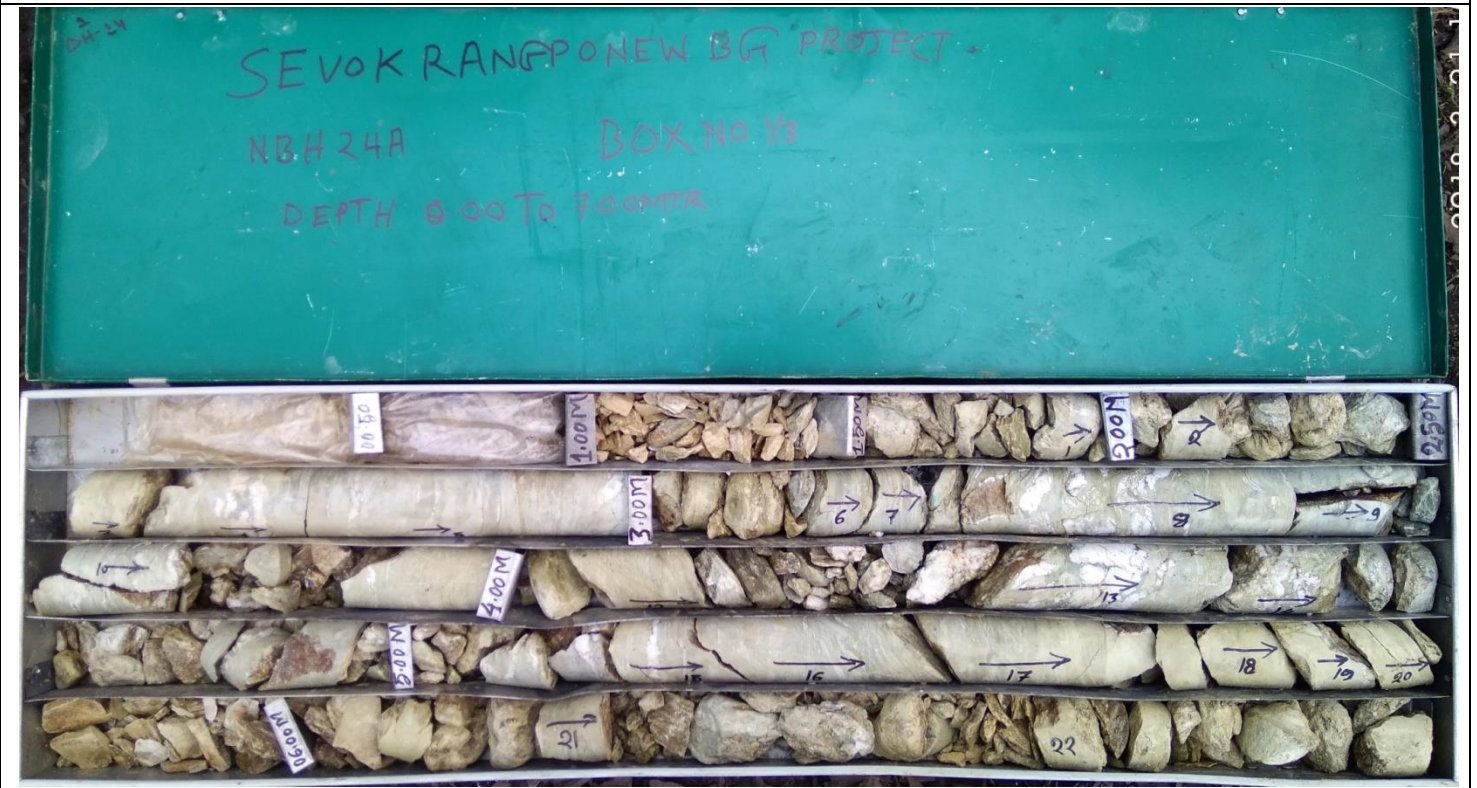
HOLE NO : NBH-24A  
SHEET NO : 1 of 1

PROJECT : <u>SIVOK-RANGPO NEW BG RAILWAY LINE PROJECT</u> LOCATION : <u>MELLI</u> STRUCTURE : <u>YARD</u> CLIENT : <u>IRCON INTERNATIONAL LTD.</u> DRILLING AGENCY : <u>ARIHANT DRILLINGS PVT.LTD.</u> GROUND ELEVATION : <u>309.67m</u> COLLER ELEVATION : <u>309.81m</u>	CO-ORDINATES : <u>N2997038.8628,E644646.9823</u> ANGLE WITH HORIZONTAL : <u>90°</u> BEARING OF HOLE : <u>VERTICAL</u> DEPTH OF HOLE : <u>15.00m</u> PERIOD OF EXECUTION : <u>15.03.2018 - 17.03.2018</u> TYPE OF CORE BARREL : <u>DOUBLE/TRIPLE TUBE</u> LOGGED BY : <u>AK.TOMAR</u>
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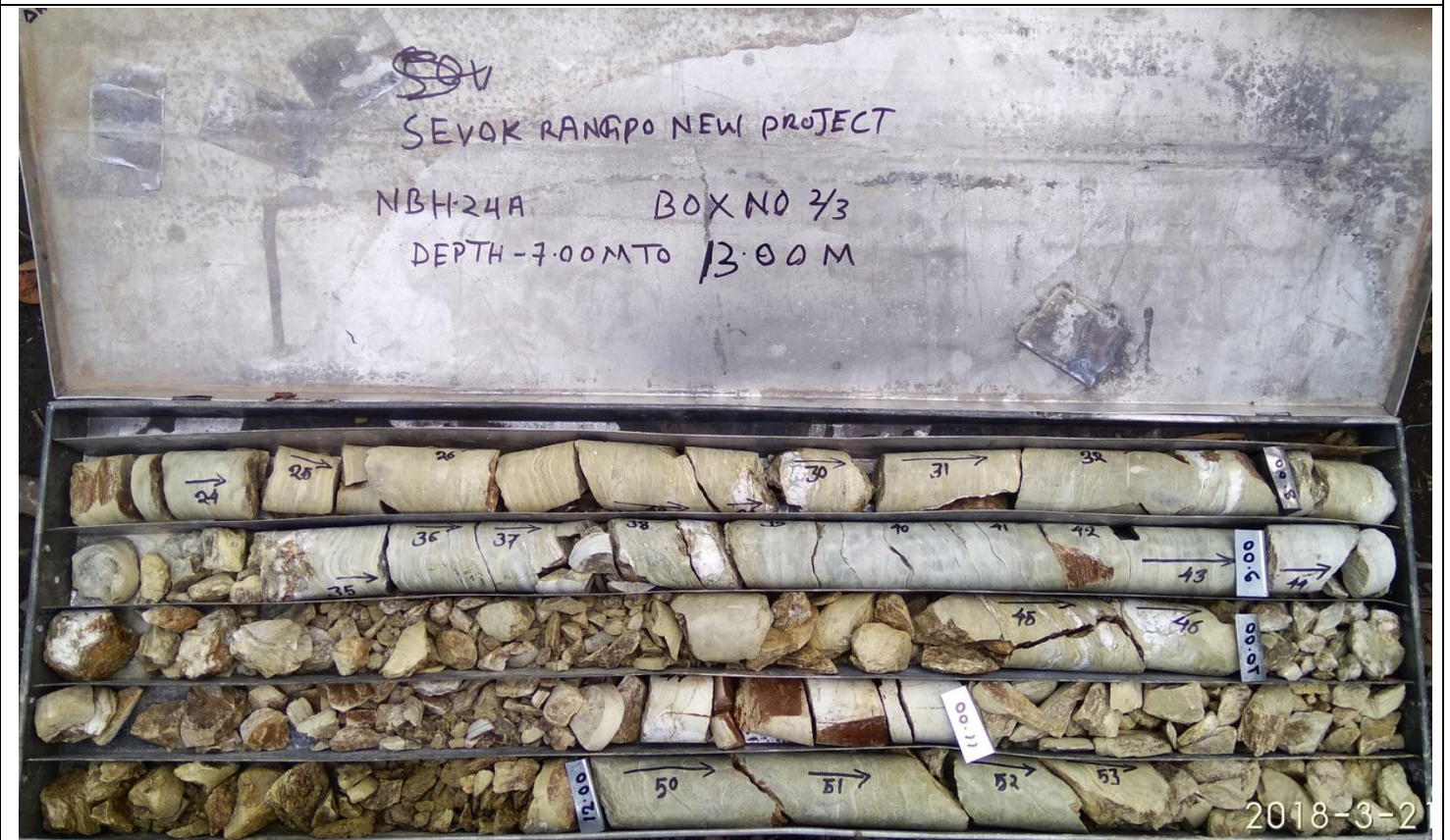
ELEVATION (m)	DEPTH (m)		LITHOLOGY	SIZE OF CORE PIECES	STRUCTURAL CONDITIONS	% OF CORE RECOVERY						RQD %	FRACTURE INDEX	SIZE OF CASING	SIZE OF HOLE	SIZE OF BIT	DEPTH OF GWMT (m)	DRILL WATER LOSS		PERMEABILITY	SPECIAL OBSERVATIONS AND INTERPRETATIONS				
	FROM	TO				DESCRIPTION	LOG	< 10mm	10 to 25 mm	25 to 75 mm	75 to 150 mm							> 150 mm	0-20			20-40	40-60	60-80	80-100
309.17	0.00	0.50	Brown coloured top soil	Overburden	Overburden																				
308.67	0.50	1.00																							
308.17	1.00	1.50				Pebbles and granules of Quartzitic Phyllite																			
307.67	1.50	2.00																							
307.17	2.00	2.50																							
306.67	2.50	3.00	Greenish grey coloured, fine grained-Quartzitic Phyllite with irregular interbands of white coloured Quartzite, slightly to moderately weathered, weak to medium strong, intensely to moderately and some portion is very intensely fractured.	FJ=35°/ Smooth, undulating, clay filled (Brownish due to weathering) with iron stained walls			1	1	1																
305.67	3.00	4.00			<10	<10	3	2	1																
304.67	4.00	5.00			>10	<10	4	1																	
303.67	5.00	6.00			>20	<10	5	2																	
302.67	6.00	7.00			>30	<10	2																		
301.67	7.00	8.00			<10	7	4																		
300.67	8.00	9.00					12	2																	
299.67	9.00	10.00			Quartzitic Phyllite with irregular interbands of white coloured Quartzite, moderately to highly weathered, weak to medium strong, very intensely to intensely fractured.	Discontinuity did not distinct			2	2															
298.67	10.00	11.00					>20	>10	4																
297.67	11.00	12.00					>20	>20																	
296.67	12.00	13.00	>20	>10			1	3																	
295.67	13.00	14.00	>20	>10			3	1																	
294.67	14.00	15.00	>10	<10			5	3																	

<b>Notation:-</b>		Overburden		Shear Zone	FJ=Foliation joint	GWT.=Ground Water Table.	SPT.=Standard Penetration Test	
		Quartzitic Phyllite		Quartzite	J=Other Joint	Sm=Smooth	R=Rough	
	Slightly fractured:Core recovered mostly in lengths from 30 to 100cm with few scattered lengths less than 30 cm or greater than 100cm .							
	Moderately fractured:Core recovered mostly in lengths from 10 to 30cm with most lengths about 20 cm				Very intensely fractured :Core recovered mostly as chips and fragments with a few scattered short core lengths.			
Intensely fractured : Lengths average from 3 to 10 cm with fragmented intervals. Core recovered mostly in lengths less than 10 cm.								

NBH-24A, DEPTH 0.00 to 7.00m



NBH-24A, DEPTH 7.00 to 12.75m





# NBH-24A, DEPTH 12.75 to 15.00m

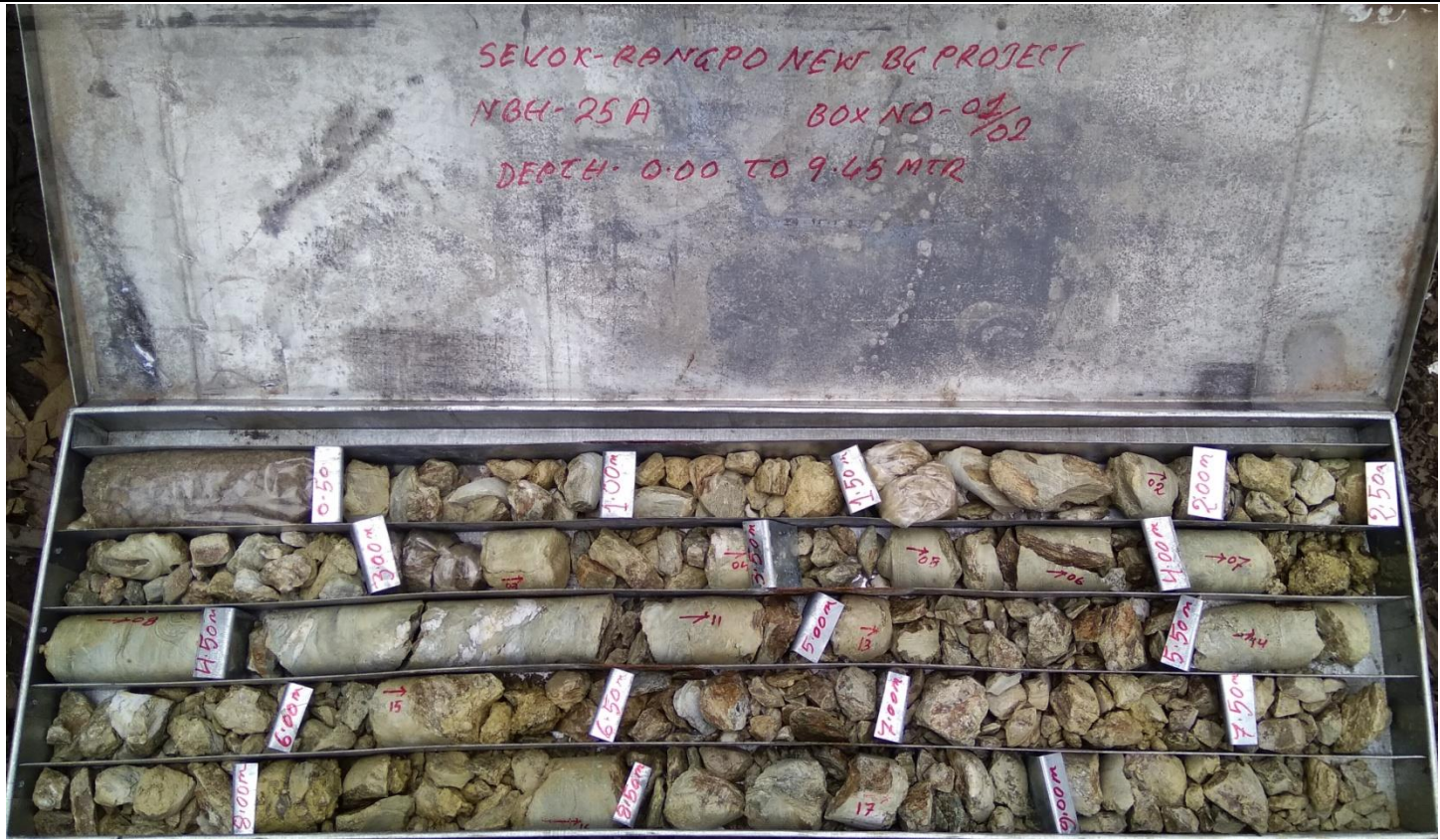




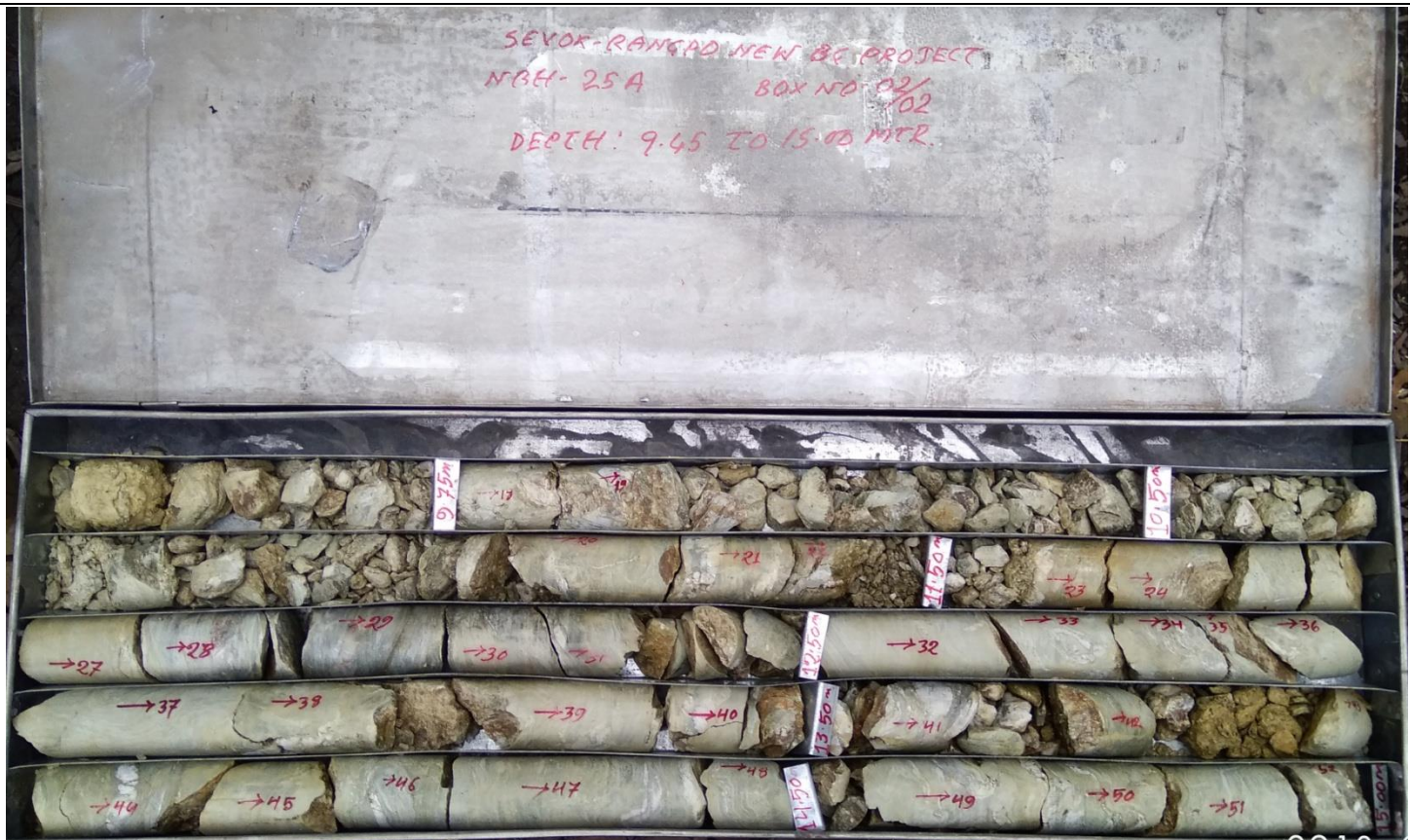




**NBH-25A, DEPTH 0.00 to 9.45m**



**NBH-25A, DEPTH 9.45 to 15.00m**







**TEST REPORT****A. Density, Porosity, Water Absorption and Specific gravity as per IS 13030:1991**

Sl. No.	Sample ID	Depth (m)	Bulk Density (g/cm <sup>3</sup> )	Dry Density (g/cm <sup>3</sup> )	Specific gravity	Water Absorption (%)
1	NBH-22A	03.00-04.00	2.694	2.674	2.73	0.72
2	NBH-23A	20.00-21.00	2.683	2.650	2.74	1.23
3	NBH-24A	12.00-13.00	2.661	2.628	2.72	1.26
4	NBH-25A	11.50-12.50	2.638	2.631	2.65	0.26

**B. Uniaxial Compressive Strength(Natural Condition) as per IS: 9143-1979 (Reaffirmed 2016)**

Sample No.	Source of Sample	Location	Depth (m)	Type of Machine Used	No. of Specimens Tested	Stress Rate (MPa/s)	Specimen No.	Lithological Description of Rock	Orientation of Loading Axis	Mode of Failure	Duration of Test (min)	Diameter (mm)	Height (mm)	UCS (MPa)
NBH-22A	Sevoke-Rangpo New BG Project	Melli Yard	16.00-17.00	500 kN CTM	1	0.5	104	Greenish grey colour. fine grain Quartzitic Phyllite with irregular inter band of white color quartzite	Vertical	Wedge Shear	1.0	51.82	99.95	30.020
NBH-23A		Melli Yard	20.00-21.00		1		55	Greenish grey colour. fine grain highly weathered Quartzitic Phyllite with irregular inter band of white color quartzite		Wedge Shear	0.3	51.64	100.41	9.363
NBH-24A		Melli Yard	5.00-6.00		1		16	Greenish grey colour. fine grain Quartzitic Phyllite with irregular inter band of white colour quartzite		Wedge Shear	0.8	51.59	88.89	23.397
NBH-25A		Melli Yard	12.50-13.50		1		37	Greenish grey colour. fine grain Quartzitic Phyllite with irregular inter band of white color quartzite		Wedge Shear	1.6	51.72	95.89	48.564



**C. Modulus of Elasticity & Poisson's Ratio(Natural Condition) as per IS:9221-1979**

Sample No.	Source of Sample	Location	Depth (m)	Type of Machine Used	No. of Specimens Tested	Stress Rate (MPa/s)	Specimen No.	Lithological Description of Rock	Orientation of Loading Axis	Mode of Failure	Duration of Test (min)	Diameter (mm)	Height (mm)	Modulus of Elasticity(Gpa)	Poisson's Ratio
								As per Client / Laboratory Observation (Visual Examination)							
NBH-22A	Sevoke-Rangpo New BG Project	Melli Yard	16.00-17.00	500 kN CTM	1	0.5	104	Greenish grey colour. fine grain Quartzitic Phyllitic with irregular inter band of white color quartzite	Vertical	Wedge Shear	1.0	51.82	99.95	27.2	0.24
NBH-23A		Melli Yard	20.00-21.00		1		55	Greenish grey colour. fine grain highly weathered Quartzitic Phyllitic with irregular inter band of white color quartzite		Wedge Shear					
NBH-24A		Melli Yard	5.00-6.00		1		16	Greenish grey colour. fine grain Quartzitic Phyllitic with irregular inter band of white colour quartzite		Wedge Shear					
NBH-25A		Melli Yard	12.50-13.50		1		37	Greenish grey colour. fine grain Quartzitic Phyllitic with irregular inter band of white color quartzite		Wedge Shear					

**D. Point Load Index Strength as per IS: 8764-1998 (Reaffirmed 2014)**

Sl.No.	Sample ID	Depth (m)	Source of Sample	Location	Specimen No.	Orientation of Loading Axis with respect to bedding planes	Rock Type As per Client / Lab (Visual Examination)	Width Perpendicular to the Loading Direction (W) (mm)	Distance between Platen Contact Points (D) (mm)	Point Load Index Strength $I_{s(50)}$ (MPa)	Remarks
14	NBH-22A	03.00 - 04.00	Sevoke- Rangpo New BG Project	Melli Yard	8	Horizontal	Quartzitic Phyllite	78.35	51.77	2.85	Diametrical
15	NBH-23A	20.00- 21.00			57			80.13	51.66	0.67	
16	NBH-24A	12.00- 13.00			51			75.8	51.6	1.6	
17	NBH-25A	11.50- 12.50			29			81.7	51.8	1.1	

**E. Brazilian Tensile Strength (Natural Condition) as per IS:10082-1981 (Reaffirmed 1996)**

Sample ID	Depth (m)	Source of sample	Location	Specimen No.	Rock Type (As per Client)	Diameter (mm)	Thickness (mm)	Tensile Strength (MPa)
NBH-22A	17.00-18.00	Sevoke-Rangpo New BG Project	Melli Yard	110	Quartetic Phyllite	51.79	29.85	3.45
NBH-23A	24.00-25.00			83	Quartetic Phyllite	51.12	27.61	1.02
NBH-24A	12.00-13.00			50	Quartetic Phyllite	51.74	29.52	2.10
NBH-25A	12.50-13.00			32	Quartetic Phyllite	51.74	27.47	4.30

**F. Triaxial Shear Strength (Natural Condition) as per IS: 13047-1991 (Reaffirmed 2016)**

Sample No.	Source of Sample	Location	Depth (m)	Moisture Content (%)	Specific Gravity	Porosity	Type of Machine Used	No. of Specimens Tested			Lithological Description of Rock Client / Laboratory Observation (Visual Examination)	Orientation of Loading Axis	Mode of Failure					c (MPa)	φ (°)					
								1	2	3			Wedge Shear Failure	Wedge Shear Failure	Wedge Shear Failure	Diameter (mm)	Height (mm)			Compressive Pressure (MPa)	Compressive Pressure (MPa)			
NBH-23A	Sevoke-Rangpo New BG Project	Melli Yard	24.00-25.00	-	-	-	500 kN Load frame	03	1	Greenish grey colour. fine grain highly weathered quartetic Phyllite with irregular interband of white color quartzite	Vertical	Wedge Shear Failure	50.61	50.86	51.38	5.884	64.38	7.845	17.93	1.20	23.68			
									2				51.75	51.90	51.79							51.94	51.90	51.87
									3				78.35	78.01	79.88							76.26	78.01	77.45
DH-22A	Sevoke-Rangpo New BG Project	Melli Yard	17.00-18.00	-	-	-	500 kN Load frame	03	1	Greenish grey colour. fine grain quartetic Phyllite with irregular interband of white color quartzite	Vertical	Wedge Shear Failure	50.61	50.86	51.38	5.884	64.38	7.845	17.93	1.20	23.68			
									2				51.75	51.90	51.79							51.94	51.90	51.87
									3				78.35	78.01	79.88							76.26	78.01	77.45
												2.21		35.35										



ANNEXURE-A  
Modulus of elasticity & Poisson's ratio Plots

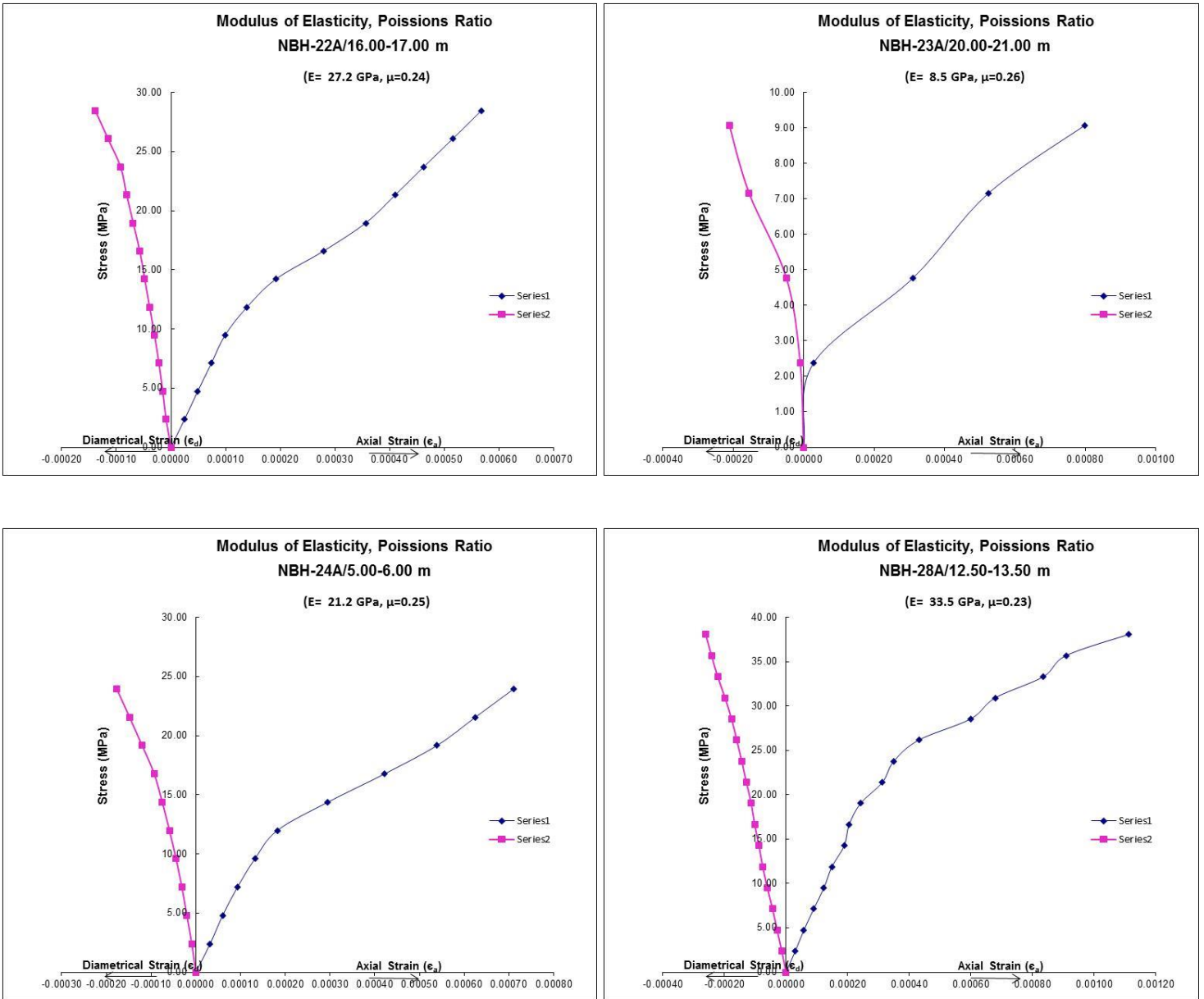
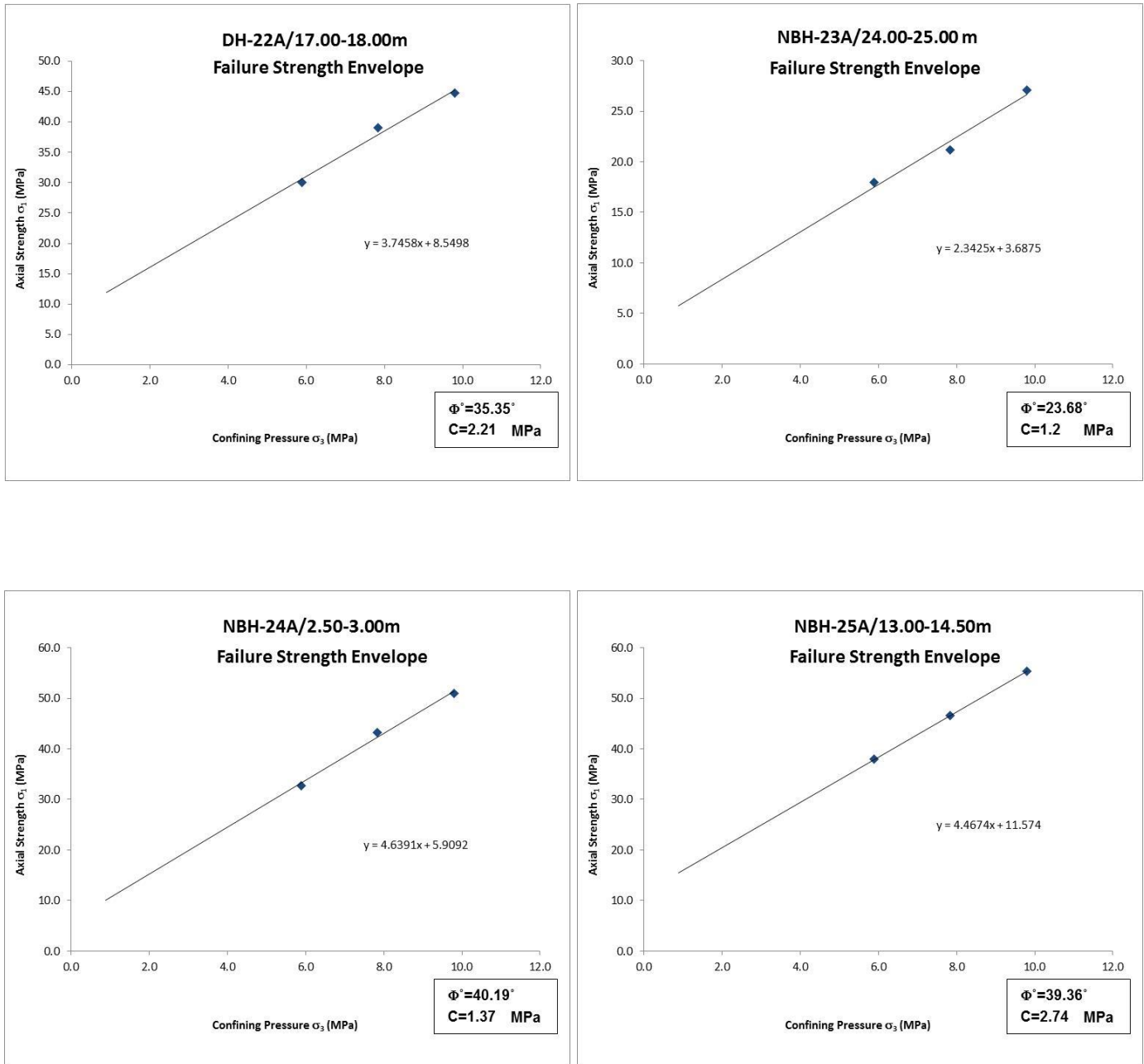


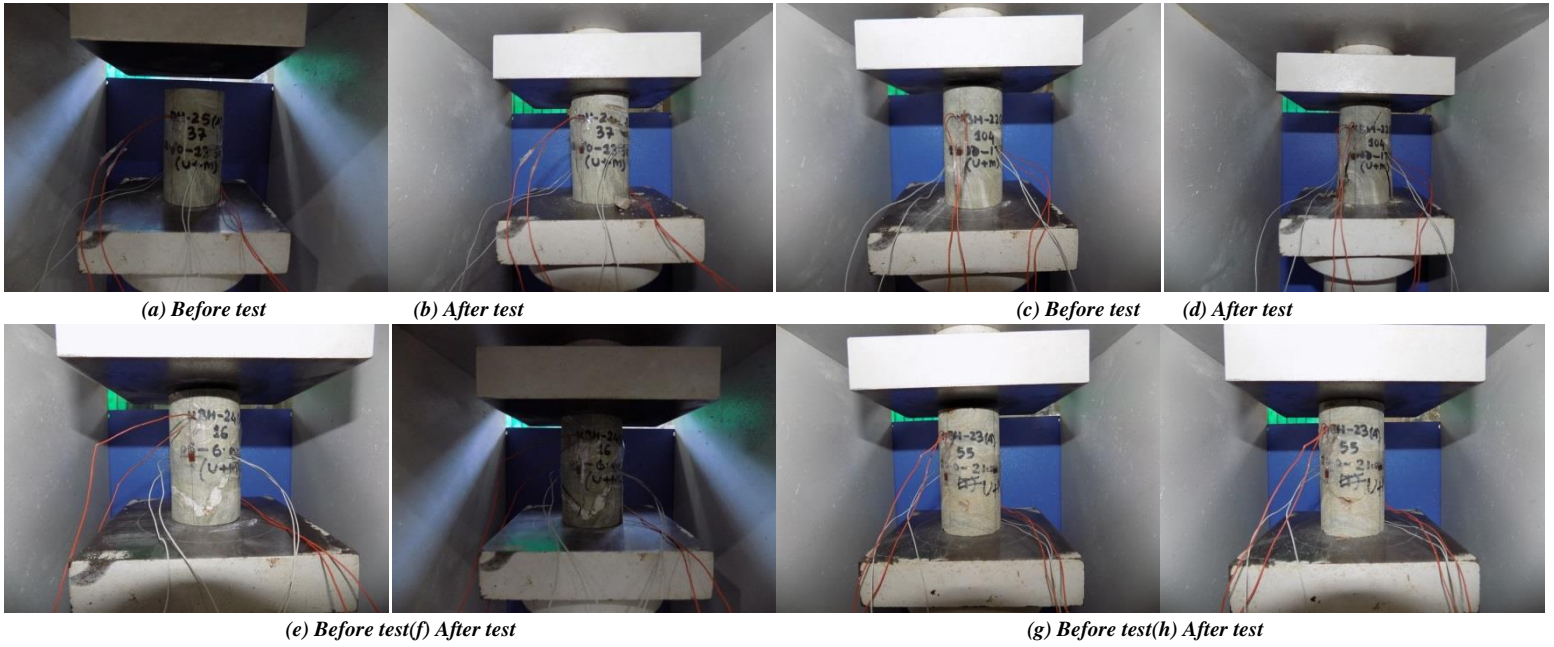
Fig. 1 Plots between Axial Stress and Axial Strain ( $\epsilon_a$ ) and Diametrical Strain ( $\epsilon_d$ ) for modulus of elasticity & Poisson's ratio

**ANNEXURE-B**  
**Triaxial Strength Plots**



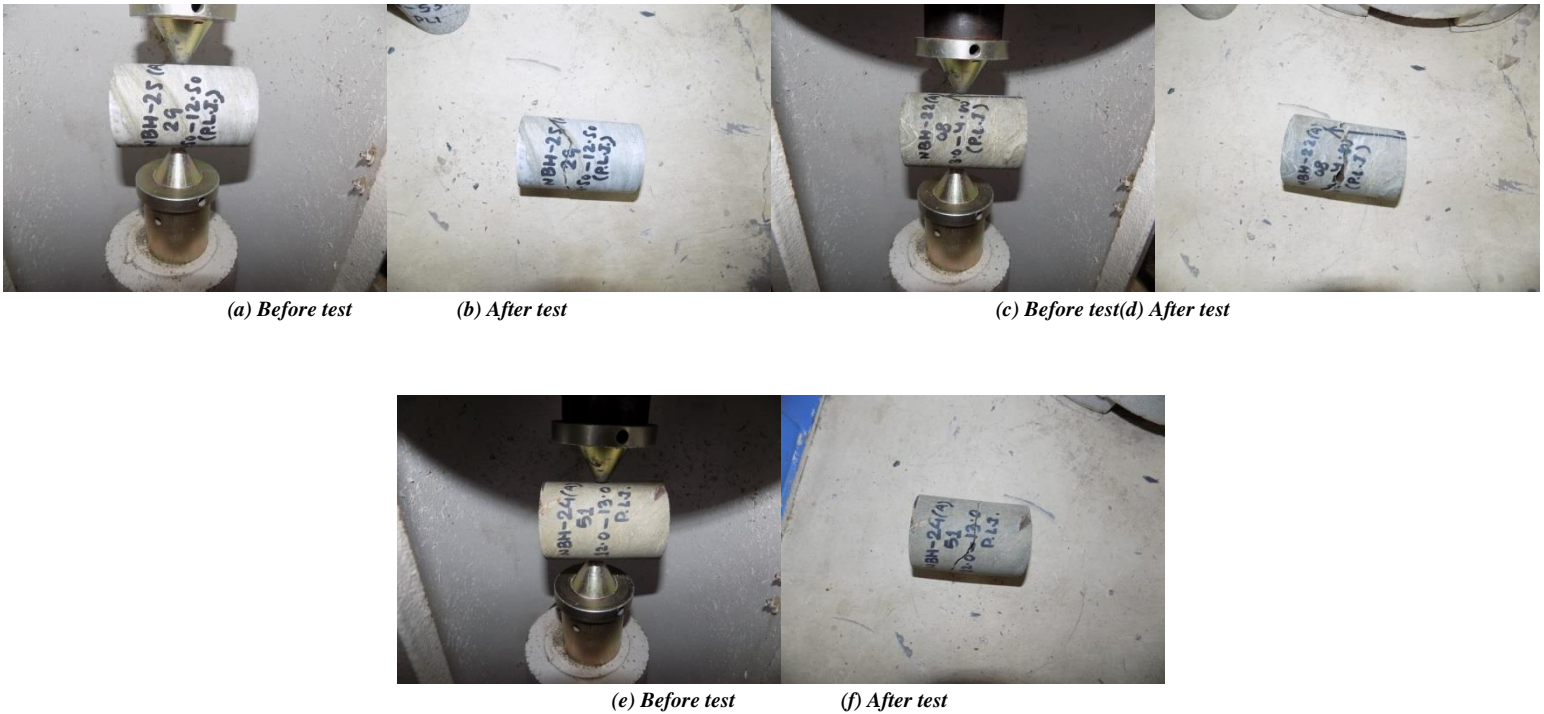
*Fig. 2 Plots between Axial Strength and Confining Pressure for Triaxial strength of rock Core samples*

**ANNEXURE-C**  
**UCS with Modulus of elasticity & Poisson's ratio Tested Sample**



*Fig:-3 UCS with modulus of elasticity and Poisson's ratio Tested Samples*

**ANNEXURE-D**  
**Point Load Index Strength Tested Samples**



*Fig:4 -Point Load Strength Index Tested Samples Photograph*

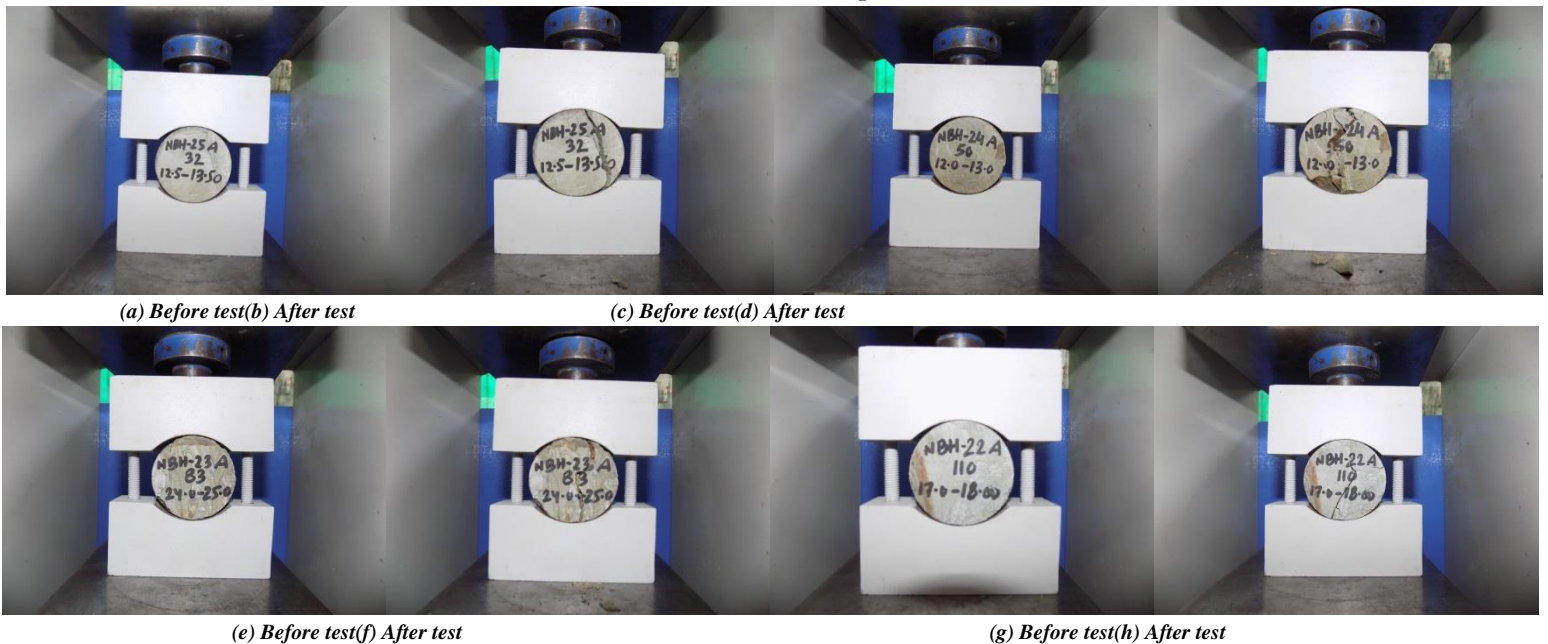


**ANNEXURE-E**  
**Triaxial Shear Strength Tested Samples**



**Fig:-5 Triaxial Shear Strength Tested Samples**

**ANNEXURE-F**  
**Tensile (Brazilian) Tested Samples**



**Fig: 6 -Brazilian Tensile Tested Samples Photograph**

## **Annexure-G (Petrography Analysis)**

### **INTRODUCTION:**

This report incorporates petrographic study of rock samples from Sevoke-Rangpo New BG Project. The rock sample was submitted by M/s Arihant Drillings Pvt. Ltd. on 09/07/2018 at the Aimil testing Laboratory, New Delhi office.

Petrography of rock sample has been carried out as per standard IS: 2386 (Pt-8)-1963 (Reaffirmed-1997)-“Petrographic Examination”.

Thin sections of the given sample were examined megascopically as well as under polarizing microscope with an aim to identify different mineral constituents, detrimental minerals, if any and photo-micrographed for documentation. The microscopic examination also includes study of micro-textures and alterations which have been observed between minerals grain boundaries.

The rock description given hereunder solely pertains to megascopic and microscopic study of two thin sections only without any feedback of the field description and name, keeping this in view it is suggested that given name of the rock type by laboratory studies should preferably not be matched with text book description of the rock. But it should be viewed in conjunction with alterations identified, if any, of the rock.

### **PETROGRAPHIC OBSERVATIONS AND INTERPRETATIONS**

#### **1. PETROGRAPHIC STUDY OF SAMPLE NO-1:**

Senders sample ID	: MELLI YARD/NBH-22A
Field name of sample, if any (assigned by the sender)	: Not specified by the sender
Nature of the sample	: Rock core
Location/ Depth of the sample	: 16.00-17.00m
Sample ID (ATES Lab)	: RC-842
Laboratory name of the sample (assigned by the present study)	: Quartzitic Phyllite

#### **Megascopic Study of the Sample (Study aid –naked eye & hand lens):**

The given rock sample is light dark grey in colour with intercalation of secondary white quartz. The rock is fine grained foliated, hard and compact and has medium specific gravity. The rock has thin encrustation on its outer surface.





Fig.-: Rock sample

Microscopic study of the sample (Study aids – Computer interfaced high resolution polarizing microscope with photographic attachment)

#### A. Mineralogical Content (V. E.):

Sl. No.	Mineralogical Content %					
	Quartz	Muscovite/ Sericite	Chlorite	Ferruginous Material	Strained quartz of total quartz present	Undulose Extinction angle
1	45-47	18-20	28-30	5-7	*8-10	*10-12
2	47-49	17-19	26-28	6-8	*8-10	*10-12

\*observations are recorded only on the grains which are relatively better developed.

#### B. Textures and Microstructures:

It is a fine to medium grained rock in which hazy individual mineral boundaries are identifiable under high magnification of x100 mgf. Most of the muscovite is altered to sericite and green coloured chlorite occurs as distributed throughout the rock. Grains of secondary quartz are present as irregular haphazard grains. Quartz grains in general occupy the foliation planes and are probably responsible for the strength of the rock. Foliation which is discernible in the hand specimen is more prominent in the thin section.

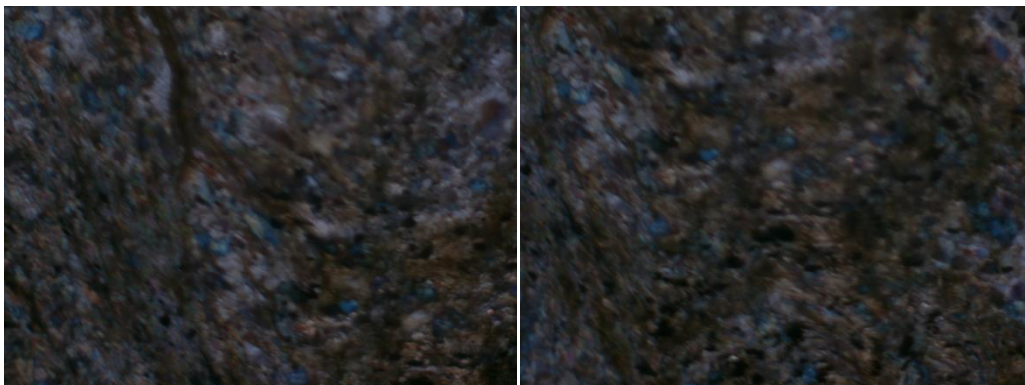


Fig.- Mgf: X100

Fig.- Mgf: X100

**2. PETROGRAPHIC STUDY OF SAMPLE NO-2:**

Senders sample ID	:	MELLI YARD/NBH-23 A
Field name of sample, if any (assigned by the sender)	:	Not specified by the sender
Nature of the sample	:	Rock core
Location/ Depth of the sample	:	24.00-25.00m
Sample ID (ATES Lab)	:	RC-847
Laboratory name of the sample (assigned by the present study)	:	Phyllitic Quartzite

**Megascopic Study of the Sample (Study aid –naked eye & hand lens):**

The given rock sample is off-white in colour with intercalation of secondary white quartz. The rock is medium to coarse grained, hard and compact and has medium specific gravity. The rock also show thin and crude foliation.



**Fig.-: Rock sample**

**Microscopic study of the sample (Study aids – Computer interfaced high resolution polarizing microscope with photographic attachment)****A. Mineralogical Content (V. E.):**

Sl. No.	Mineralogical Content %					
	Quartz	Muscovite/ Sericite	Chlorite	Ferruginous Material	Strained quartz of total quartz present	Undulose Extinction angle
1	59-61	12-14	22-24	3-5	*8-10	*10-12
2	58-60	14-16	20-22	4-6	*8-10	*10-12

\*observations are recorded only on the grains which are relatively better developed.

**B. Textures and Microstructures:**

It is a fine to medium grained rock in which foliation is defined by preferred orientation of muscovite and chlorite. At places quartz grains are stressed and occupy the parallelism with flaky minerals. Some quartz grains as well as flakes of mica are lying oblique to foliation of the rock. Quartz rich portions have some of the grains of quartz as secondary also and by and large the shape and size of the quartz grains varies. Grains of ferruginous material are randomly oriented and localized.

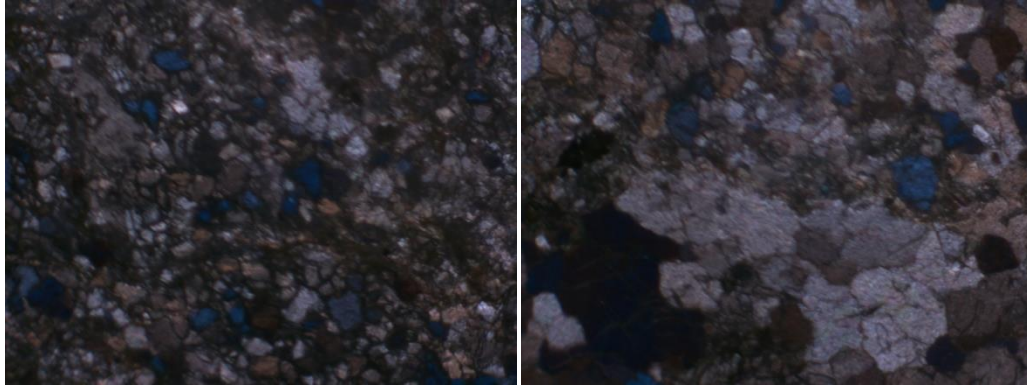


Fig.- Mgf: X100

Fig.- Mgf: X100

**3. PETROGRAPHIC STUDY OF SAMPLE NO-3:**

Senders sample ID	:	MELLI YARD/NBH-24 A
Field name of sample, if any (assigned by the sender)	:	Not specified by the sender
Nature of the sample	:	Rock core
Location/ Depth of the sample	:	12.00-13.00m
Sample ID (ATES Lab)	:	RC-855
Laboratory name of the sample (assigned by the present study)	:	Quartzitic Phyllite

**Megascopic Study of the Sample (Study aid –naked eye & hand lens):**

The given rock sample is light dark grey in colour with intercalation of secondary white quartz. The rock is fine grained foliated, hard and compact and has medium specific gravity. The rock has thin encrustation on its outer surface.



Fig.-: Rock sample

**Microscopic study of the sample (Study aids – Computer interfaced high resolution polarizing microscope with photographic attachment)**

**A. Mineralogical Content (V. E.):**

Sl. No.	Mineralogical Content %					
	Quartz	Muscovite/ Sericite	Chlorite	Ferruginous Material	Strained quartz of total quartz present	Undulose Extinction angle
1	47-49	18-20	28-30	3-5	*8-10	*10-12
2	46-48	16-18	30-32	4-6	*8-10	*10-12

\*observations are recorded only on the grains which are relatively better developed.

**B. Textures and Microstructures:**

It is a fine to medium grained rock in which hazy individual mineral boundaries are identifiable under high magnification of x100 mgf. Most of the muscovite is altered to sericite and green coloured chlorite occurs as distributed throughout the rock. Foliation which is discernible in the hand specimen is more prominent in the thin section. Grains of secondary quartz are present as irregular haphazard grains. Quartz grains in general occupy the foliation planes and are probably responsible for the strength of the rock.

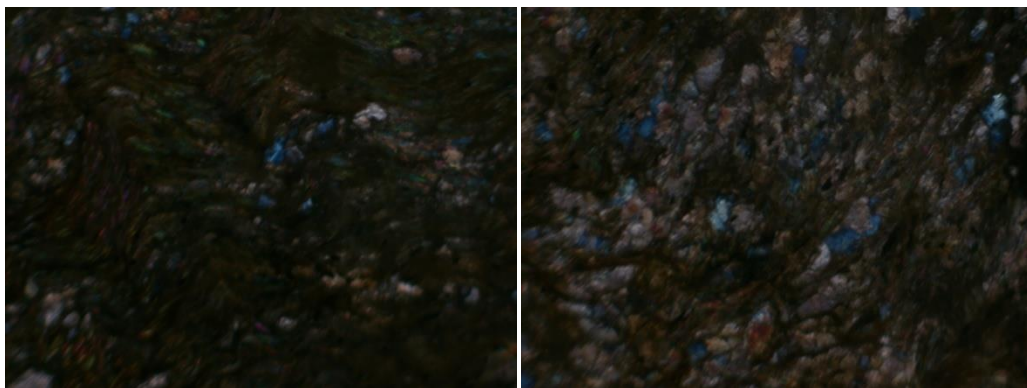


Fig.- Mgf: X100

Fig.- Mgf: X100

**4. PETROGRAPHIC STUDY OF SAMPLE NO-4:**

Senders sample ID : MELLI YARD/NBH-25 A  
 Field name of sample, if any : Not specified by the sender  
 (assigned by the sender)  
 Nature of the sample : Rock core  
 Location/ Depth of the sample : 12.50-13.50m  
 Sample ID (ATES Lab) : RC-858  
 Laboratory name of the sample :  
 (assigned by the present study)

**Megascopic Study of the Sample (Study aid –naked eye & hand lens):**

It is a fine grained rock, grey in colour with greenish tinge, characterized by thin phyllitic cleavage/foliation. The outer surface of the specimen has a sheen which may be occupied by fine grained mica/ sericite. It has a massive thin band of fine grained quartz, overall thinly foliated rock which has thin bands of quartz. The rock has medium specific gravity. The rock is so fine grained that no individual mineral grain is identified.



Fig.-: Rock sample

**Microscopic study of the sample (Study aids – Computer interfaced high resolution polarizing microscope with photographic attachment)****A. Mineralogical Content (V. E.):**

Sl. No.	Mineralogical Content %					
	Quartz	Muscovite/ Sericite	Chlorite	Ferruginous Material	Strained quartz of total quartz present	Undulose Extinction angle
1	47-49	20-22	26-28	3-5	*8-10	*10-12
2	43-45	21-23	28-30	4-6	*8-10	*10-12

\*observations are recorded only on the grains which are relatively better developed.



**B. Textures and Microstructures:**

It is a fine grained rock in which foliation is defined by preferred orientation of muscovite and chlorite. At places quartz grains are stressed and occupy the parallelism with flaky minerals. Some quartz grains as well as flakes of mica are lying oblique to foliation of the rock. The grains of secondary quartz are also seen at places, by and large the shape and size of the quartz grains varies. Grains of ferruginous material are randomly oriented and localized.

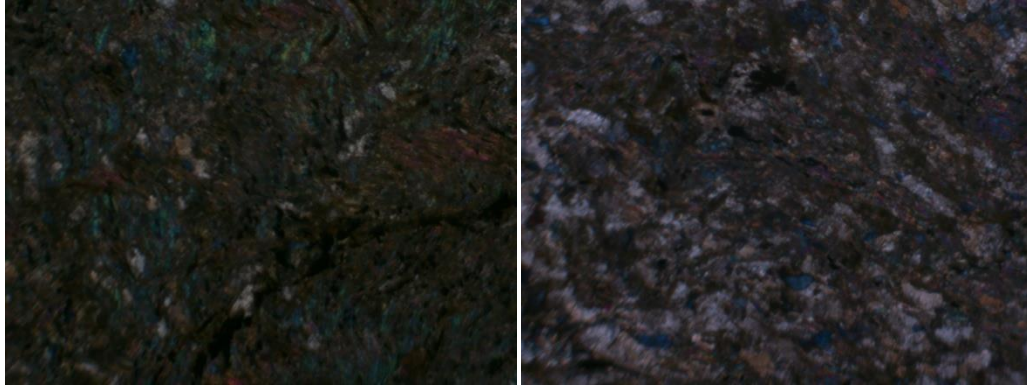


Fig.- Mgf: X100

Fig.- Mgf: X100