Analysis soil bearing capacity by plate load test

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Abstract: **The precise assessment of soil bearing capacity is critical in the design of stable foundations for road pavement and airfield projects. The plate load test serves as a rapid, straightforward, and cost-effective method for determining soil bearing capacity and unconfined compressive strength. This method effectively addresses design challenges associated with subgrade and subbase layers, particularly in scenarios where high wheel loads are anticipated due to heavy traffic during both the construction phase and the operational lifespan of the pavement. This study aims to investigate, analyses, and discuss the geotechnical behavior of soil layers through the following methods: (a) drilling two boreholes to the required depth to examine site stratigraphy and collect both disturbed and undisturbed soil samples for laboratory testing; (b) conducting laboratory tests on selected soil samples to ascertain relevant index and engineering properties of the strata; and (c) analyzing all field and laboratory data to formulate engineering recommendations. The comparison of bearing capacity values is presented, with a detailed discussion of the soil description included.**

Keywords: **Plate load test; Static load; Bearing capacity; engineering properties; Settlement; analyzing;**

1. INTRODUCTION

The bearing capacity and load-deformation behaviour of soil are essential factors in the geotechnical design of shallow foundations [1, 2]. Numerous established methods, including analytical, numerical, experimental, laboratory, and field tests, are available to determine the settlement and strength properties of soil [3, 4]. Historically, numerous researchers have focused specifically on either the ultimate bearing capacity or the settlement under service load when designing shallow foundations, as there is no standardised technique to adhere to [4–9]. When complete subsurface information is unavailable or to minimise extensive soil investigations in the field and laboratory tests, plate load tests (PLT) serve as an appropriate alternative for directly determining the bearing capacity of shallow foundations. Ahmed et al. (2009) asserted that the PLT can evaluate bearing capacity comparable to that obtained from laboratory tests of undisturbed soil collected from the same site, utilising the Meyerhof and modified Terzaghi equations [4]. Warmate reported that the ultimate bearing capacity of soil can be extrapolated from load settlement behaviour using PLT [5]. Additionally, PLT remains a direct, prompt, and reliable method for determining in situ characteristics and estimating the ultimate load-carrying capacity of soil at shallow depths [6–8]. Researchers conducted static PLT on various artificially enhanced soils [9–11] to analyse the load-carrying capacity and deformability of the soil-foundation system. It has been asserted that critical in situ factors, including the groundwater table location and matric suction, contribute to the variability of PLT results [12–15].

This study aims to investigate the stratigraphy of the site and to formulate geotechnical recommendations for the foundation design and construction of various structures along the proposed alignment.

The study was conducted in the following phases to achieve these objectives:

(a) Drilling two boreholes to the required depth to investigate site stratigraphy and collect disturbed and undisturbed soil samples for laboratory testing; (b) Testing selected soil samples in the laboratory to determine relevant index and engineering properties of the strata; and (c) Analysing all field and laboratory data to develop engineering recommendations for foundation design and construction.

2. SOIL BORINGS & SPT OF SITE LOCATION

2.1 Soil Borings & SPT: The borings were advanced using Rotary Drilling to the designated depth or until refusal, whichever occurred first. The work generally adhered to IS: 1892-1979. Standard Penetration Tests (SPT) are performed by attaching a split spoon sampler to 'A' rods and driving it to a depth of 45 cm using a 63.5 kg hammer that falls freely from a height of 75 cm. The tests were performed following IS: 2131-1981 standards. The number of blows required for each 15 cm of penetration of the split spoon sampler was documented. Figure1 shows site locations.

Fig.1 shows site locations

The impacts necessary to breach the first 15 cm of the split spoon for sampler seating are disregarded because of the potential presence of loose materials or cuttings resulting from the drilling process. The total number of blows necessary to penetrate the remaining 30 cm of the 45 cm split spoon sampler is referred to as the SPT value or the 'N' value. The ‘N’ values are provided for the soil profile associated with each borehole. The decision to cease additional boring penetration was made when the ‘N’ values surpassed 100.

2.2 Disturbed Sampling (Soil) in Boreholes: Disturbed soil obtained from the SPT sampler was preserved in polythene covers and transported to the laboratory. A supplementary polythene cover was supplied to mitigate moisture loss during transit.

2.3 Undisturbed Sampling (Soil) in Boreholes: Undisturbed samples were obtained using 100 mm diameter thin-walled 'Shelby' tubes, which were driven into the soil by light hammering with a 63.5 kg hammer, following the guidelines set forth in IS: 2132-1986. The tubes were sealed with wax at each end. The collection of undisturbed samples in refusal strata is virtually unfeasible. All samples were transported to the laboratory in Hyderabad for further examination and testing.

- Open (Isolated / Raft) foundation is recommended.

Table 1 Recommended SBC for Foundation depth Below Cellar Level

BH No’s.	Foundation depth Below Cellar Level, m	Resting in Strata	*Recommended SBC, T/m2
BH1 & BH2	1.00	Soft disintegrated Rock/ Weathered Rock	50
	1.50	Soft disintegrated Rock/ Weathered Rock	54

2.4 Groundwater: Groundwater levels were measured in the boreholes 24 hours post-drilling and sampling completion. Water levels are recorded on the individual soil profiles.

3. LABORATORY TESTS

Laboratory tests were conducted on selected soil samples, groundwater samples to determine its index and engineering properties. The testing procedures were in accordance with current applicable IS specifications. The following tests were conducted on selected samples recovered from the boreholes.

On Soil:

Name of Test	IS Code No.
Bulk Density	By Calculation

Grain size analysis	IS: 2720 (Part-4)-1985
Specific gravity	IS: 2720 (Part-3)-1980
Unconsolidated undrained Direct Shear Test	IS: 2720 (Part-13)-1986

On Rock:

Name of Test	IS Code No.
Bulk density	IS: 13030-1991
Specific Gravity	IS: 2720 (Part-3)-1980
Water absorption	IS: 13030-1991
Crushing strength	IS: 9143-1979

Site Stratigraphy: Based on the boring information, the following subsoil profile was inferred up to final depth of boreholes: Figure 2 shows Geotechnical Investigation for Proposed Commercial Building and Table 2 isted Strata Description for two bore holes.

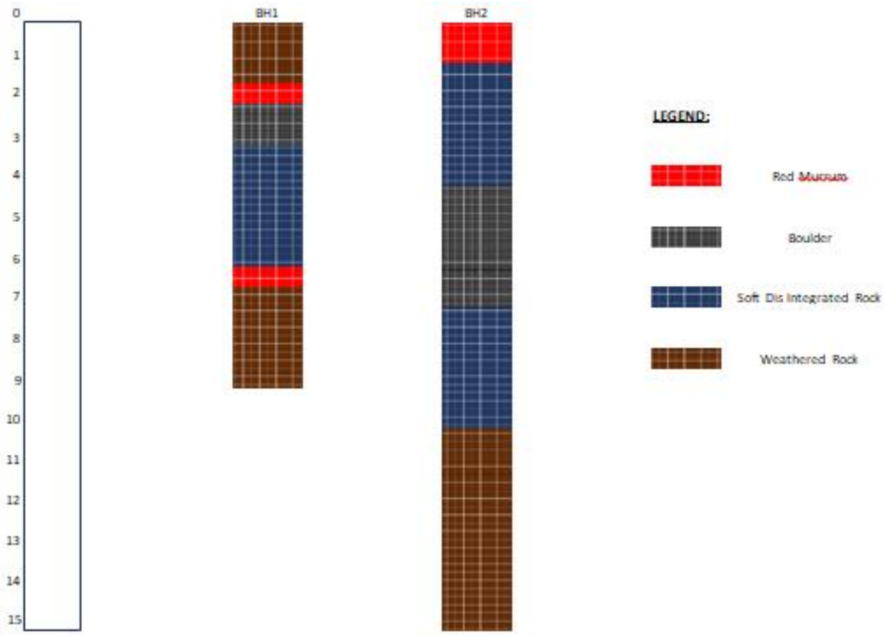

Fig. 2 Geotechnical Investigation for Proposed Commercial Building

Table 2 Strata Description for two bore holes

BH No.	Depth (m)		Strata Description
	From	To	
1	0.00	1.60	Weathered Rock
	1.60	2.00	Red Murrum
	2.00	3.00	Boulder
	3.00	6.00	Soft Disintegrated Rock
	6.00	9.00	Weathered Rock
2	0.00	1.00	Red Murrum
	1.00	4.00	Soft Disintegrated Rock
	4.00	7.00	Boulder
	7.00	10.00	Soft Disintegrated Rock
	10.00	15.00	Weathered Rock

Hydrogeology: Based on the measurements in the completed boreholes, water was not met at depth below existing ground level.

4. RESULTS AND DISCUSSION

BEARING CAPACITY ANALYSIS FOR SHALLOW FOUNDATIONS

The bearing capacity equation is as follows:

$$q_{net\ safe} = (1/FS)\{cN_c\zeta_c d_c + q(N_q-1)\zeta_q d_q + 0.5B\gamma N_\gamma \zeta_\gamma d_\gamma R_w\}$$

where:

$q_{net\ safe}$ = safe net bearing capacity q = overburden pressure

c = cohesion intercept B = Foundation width

□ = Bulk density of soil below founding level

R_w = Water table correction factor FS = Factor of safety

N_c, N_q, N□ = bearing capacity factors, which are a function of □

d_c, d_q, d□ = Depth factors

□c, □q, □□ = Shape factors

Soil parameters :

c =	0.00	T/m²	□ =	30.0	degrees	GENERAL SHEAR FAILURE c' =
	0.00	T/m²	□'=	21.1	degrees	LOCAL SHEAR FAILURE

Depth, m □

General Shear Failure :	N_c =	30.14	N_q =	18.40	N_γ =	22.40
Local Shear Failure :	N_c' =	15.87	N ' =	7.11	N ' =	6.24

Factor of safety = 3.0 as per IS 1904-1986

Bulk Density Profile

Depth, m		T/m³
0.0	4.0	1.62
4.0	7.0	1.65
7.0	10.0	1.68
10.0	15.0	1.72

SETTLEMENT ANALYSIS FOR SHALLOW FOUNDATIONS BASED ON N - VALUES

Analysis as per IS:8009(Part 1)-1976 , Clause 9.1.4

Design Water Table Depth : 0.0 m

R_w *factor*: Calculate (C) based on water table depth or

Fixed Value(V) for worst condition : c

Fox's Depth Factor to be considered ? Y

Depth to be ignored in Depth Factor Computation for loose soils, poorly compacted backfill, scour, etc.10.0m

Table 3 Computed Settlement

Foundation Width,m	Foundation Length,m	Foundation Depth,m	Shape	Design N-value	Net Allowable Bearing Pressure, T/m²	Settlement @ 1kg/cm² (as read off from graph), mm	R_w	Fox's Depth Factor, d_f	Rigidity Factor, d_r	Computed Settlement, mm
2.0	2.0	10.0	square	72.0	50.2	3.2	0.50	1.00	0.8	25.4
2.0	2.0	10.5	square	75.0	54.9	3.0	0.50	0.94	0.8	25.0

SBC CALCULATION'S ON ROCK CORE

Core Strength: Analysis has been carried out using the uniaxial compressive strength of rock cores based on spacing and opening of discontinuities of rock mass. The net safe allowable bearing pressures are specified in IS: 12070.

qs = qc * Nj where:

q = Safe Bearing Pressure (gross) T/m2

qc = average uniaxial compressive strength of rock cores T/m2 Nj empirical coefficient depending on the spacing of discontinuities. As per IS 12070-1987

For Open Foundation in rock mass

Safe Bearing Pressure, q = qc*N where

qc = avg uniaxial strength of rock cores = 680 kg/sq cm N = empirical coefficient for discontinuities =0.25

Factor of Safety, F = 3

q = 56 T/sq.m

Minimum SBC recommended in very Poor Rock Mass is = 40 T/sq.m (As IS 12070) Recommended SBC = 50 T/sq.m (As IS 12070)

Soil Profile	Project: Geotechnical Investigation for Proposed Commercial Building	BH.No: 1	TERMINATION DEPTH (M)	R.L
		WATER TABLE (M): 0.00	9.00	

N-Value	Depth (m)	Sample Type	SOIL DESCRIPTION	Grain Size Analysis Gravel %	Sand %	Silt %	Clay %	Atterberg Limits Liquid limit %	Plastic %	Plasticity Index %	Specific Gravity	Free swell Index	Bulk Density	Dry Density	Moisture Content	Confining Pressure Kg/cm2	Cohesion Intercept Kg/cm2	Angle of internal friction
	0.00 1.60	D/S	Weathered Rock															
	1.60 2.00	D/S	Red Murrum															
	2.00 3.00	D/S	Boulder															
>50	3.00 4.00	SPT	Soft Disintegrated Rock															
	4.00 5.00	D/S	Soft Disintegrated Rock															
>50	5.00 6.00	D/S SPT	Soft Disintegrated Rock	11	86	3	0	Non – Plastic			2.72	NP	2.11	1.92	10	-	0	31

Fig. 3 Geotechnical Investigation for Proposed Commercial Building for soil profile BH-1

Rock Profile	Project: Geotechnical Investigation for Proposed Commercial Building	BH. No: 1	TERMINATION DEPTH (m)	R.L
		Water level, m 0.00	9.00	
	Location See Fig.1	Type of Boring:		Rig:

Depth (m)	Drill Run (m)	Penetration	N-Value	Sample No	CR (%)	RQD (%)	Rock Description	Specific Gravity	Water Absorption (%)	UCS Strength Kg/cm2	Point Load Index Kg/cm2	Return Water Colour	Loss	Bits Used	Remarks
6.00															
7.00	1.00	Core Samples					Weathered Rock	2.75	0.34	680					
8.00	1.00	Core Samples					Weathered Rock								
9.00	1.00	Core Samples					Weathered Rock	2.76	0.29	720					

Fig. 4 Geotechnical Investigation for Proposed Commercial Building for rock profile BH-1

Soil Profile	Project: Geotechnical Investigation for Proposed Commercial Building	BH.No: 2	TERMINATION DEPTH (M)	R.L
		WATER TABLE (M): 0.00	15.00	

N-Value	Depth (m)	Sample Type	SOIL DESCRIPTION	Grain Size Analysis Gravel %	Sand %	Silt %	Clay %	Atterberg Limits Liquid limit %	Plastic %	Plasticity Index %	Specific Gravity	Free swell Index	Bulk Density	Dry Density	Moisture Content	Confining Pressure Kg/cm2	Cohesion Intercept Kg/cm2	Angle of internal friction
	0.00 1.00	D/S	Red Murrum															
>50	1.00 2.00	D/S SPT	Soft Disintegrated Rock															
	2.00 3.00	D/S	Soft Disintegrated Rock															
>50	3.00 4.00	D/S SPT	Soft Disintegrated Rock	9	89	2	0	Non- Plastic			2.73	NP	2.13	1.96	9	.	0	30
	4.00 5.00	D/S	Boulder															
	5.00 6.00	D/S	Boulder															
	6.00 7.00	D/S	Boulder															
>50	7.00 8.00	D/S SPT	Soft Disintegrated Rock															
	8.00 9.00	D/S	Soft Disintegrated Rock															
	9.00 10.00	D/S	Soft Disintegrated Rock	7	91	2	0	Non – Plastic			2.74	NP	2.17	2.01	8	-	0	32

Fig. 5 Geotechnical Investigation for Proposed Commercial Building for soil profile BH-2

Rock Profile		Project: Geotechnical Investigation for Proposed Commercial Building					BH. No: 2		TERMINATION DEPTH (m)			R.L			
							Water level, m 0.00		15.00						
				Location See Fig.1			Type of Boring:							Rig:	
Depth (m)	Drill Run (m)	Penetration	N-Value	Sample No	CR (%)	RQD (%)	Rock Description	Specific Gravity	Water Absorption (%)	UCS Strength Kg/cm2	Point Load Index Kg/cm2	Return Water Colour	Return Water Loss	Bits Used	Remarks
10.00															
11.00	1.00	Core Samples					Weathered Rock	2.76	0.35	690					
12.00	1.00	Core Samples					Weathered Rock								
13.00	1.00	Core Samples					Weathered Rock	2.77	0.32	760					
14.00	1.00	Core Samples					Weathered Rock								
15.00	1.00	Core Samples					Weathered Rock								

Fig. 6 Geotechnical Investigation for Proposed Commercial Building for rock profile BH-1

CONCLUSIONS

Drilled two boreholes to the required depth to examine site stratigraphy and collect both disturbed and undisturbed soil samples for laboratory testing; conducted laboratory tests on selected soil samples to ascertain relevant index and engineering properties of the strata; and analyzed all field and laboratory data to formulate engineering recommendations

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