5. DISCUSSION

5.01. PLATE LOAD TEST:

Five nos. (5) Plate Load Tests were conducted in the site (2 nos. are of routine type & the rest 3 nos. are of cyclic type) at specified depths using 450mm square plate Load (vs.) settlement plots is made to calculate Allowable Bearing Capacity, Young's modulus. The calculations are presented below separately.

DETERMINATION OF SAFE BEARING CAPACITY:

PLT – 02:

B_f = Width of footing = 2m (say), B_p = Size of test plate = 0.45m

S_f = Limiting Settlement of footing = 25mm and S_p = Settlement of test plate.

Now As per IS : 1888, in case of sandy soil, we can write $\frac{S_p}{S_f} = \left[\frac{B_p}{B_f} \times \frac{(B_f + 30)}{(B_p + 30)}\right]^2$

Hence, S_p = 11.90mm < 25mm

So, from load-settlement curve, safe load = 39.375 t/sqm, say 35 t/sqm

Based on the above data, the safe bearing capacity value for different footing size is presented below.

Test Location	Depth (M)	Recommended Safe Bearing Capacity, T/M^2			
		Foundation width = 1m	Foundation width = 2m	Foundation width = 3m	Foundation width = 4m
		S= 25mm	S= 25mm	S= 25mm	S= 25mm
PLT-02	3.00	35	35	35	35
PLT-04	3.00	40	40	35	35

Where S = limiting settlement

SUBGRADE MODULUS:

Subgrade Modulus is obtained from Plate Load Tests as K = P/S. Where P = Plate Load corresponding to settlement S under working load. The final results values are presented in a tabular form below.

Test No.	Depth (M)	Subgrade Modulus for Plate as per IS 9214, Kg/cm^3	Subgrade Modulus for Plate, correcting as per IS 9214, Kg/cm^3
PLT-02	3.00	17.28	7.24
PLT-04	3.00	6.16	4.55

The Subgrade modulus value is inversely proportional to the square root of the foundation area up to a base area of 10 sqm and then remains constant. The calculated subgrade modulus values for different foundation areas are presented afterwards.

PLATE LOAD TEST NO.02

Commenced on:28/02/2020
Completed on: 28/02/2020
Pit size: 3.00mX3.00mX3.00m(depth)
Load on pr.guage/divn.=10Kg/sq.cm
Load on jack/divn. = 0.709t
Plate size: 0.450mX0.450m
Load on plate/divn.=3.50 t/sq.m.
Test Type: Routine PLT

Co-ordinates:
E = 1196.000M.
N = 1353.000M.
RL = 153.655M.

S.W.L.= 2.50M.

EGL-0.80m:- Brownish grey, sandy silt. Obs. clay binder & organic matter.
0.80-2.60m:- Whitish grey, clayey silt with calcareous nodules & kankars.
2.60-3.00m:- Reddish grey, sandy silt with decomposed rock fragments.

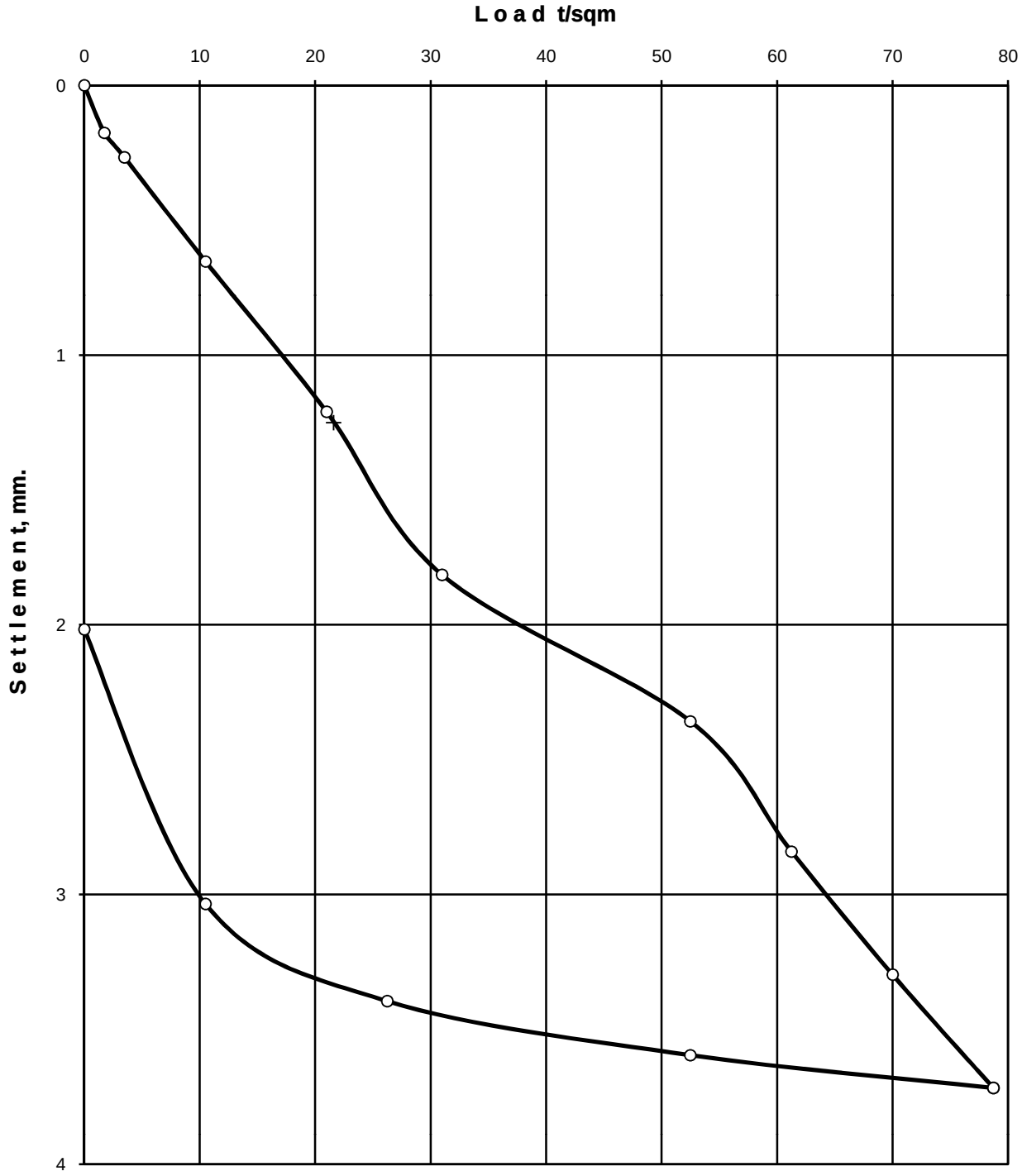


FIG. 3.1 LOAD VS SETTLEMENT GRAPH FOR PLT-02

PLATE LOAD TEST NO.04

Commenced on:23/05/2020
Completed on: 24/05/2020
Pit size: 3.00mX3.00mX3.00m(depth)
Load on pr.guage/divn.=10Kg/sq.cm
Load on jack/divn. = 0.709t
Plate size: 0.600mX0.600m
Load on plate/divn.=1.97 t/sq.m.
Test Type: Routine PLT

Co-ordinates:
E = 858.000M.
N = 1410.000M.
RL = 155.444M.

S.W.L.= Not found.

EGL-1.40m:- Reddish brown / brownish grey, clayey silt with sand & calcareous nodules.
1.40-2.20m:- Yellowish brown to brownish grey silty sand.
2.20-3.00m:- Brownish grey to reddish brown, silty sand with decomposed rock fragments.

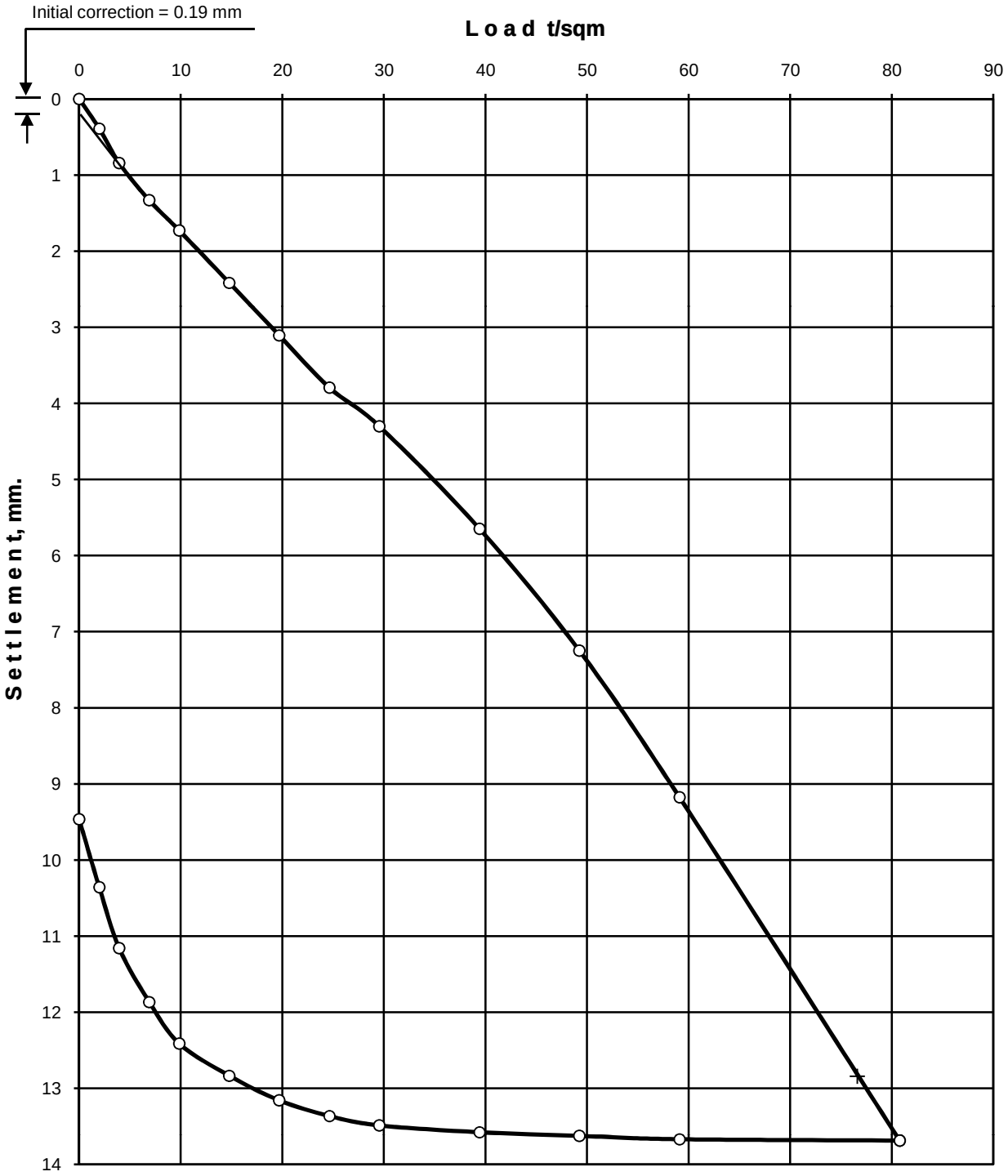


FIG. 3.2 LOAD VS SETTLEMENT GRAPH FOR PLT-04

CYCLIC PLATE LOAD TEST NO.01

Commenced on: 15/03/2020
Completed on: 15/03/2020
Pit size: 3.00mX3.00mX2.00m (depth)
Load on pr.guage/divn. = 10Kg/sq.cm
Load on jack/divn. = 0.709t
Plate size: 0.60m X 0.60m
Load on plate/divn. = 1.97t/sq.m.
Test Type: Cyclic PLT

Co-ordinates:
E = 851.000m.
N = 1405.000m.
RL = 154.672 m.

S.W.L. = Not Found

Description of Soil :-

(EGL-0.50)m:- Brownish grey clayey silty sand mixed with kankar & gravel.

(0.50-2.00)m:- Reddish brown clayey silt with traces of sand. Obs. pieces of gravel.

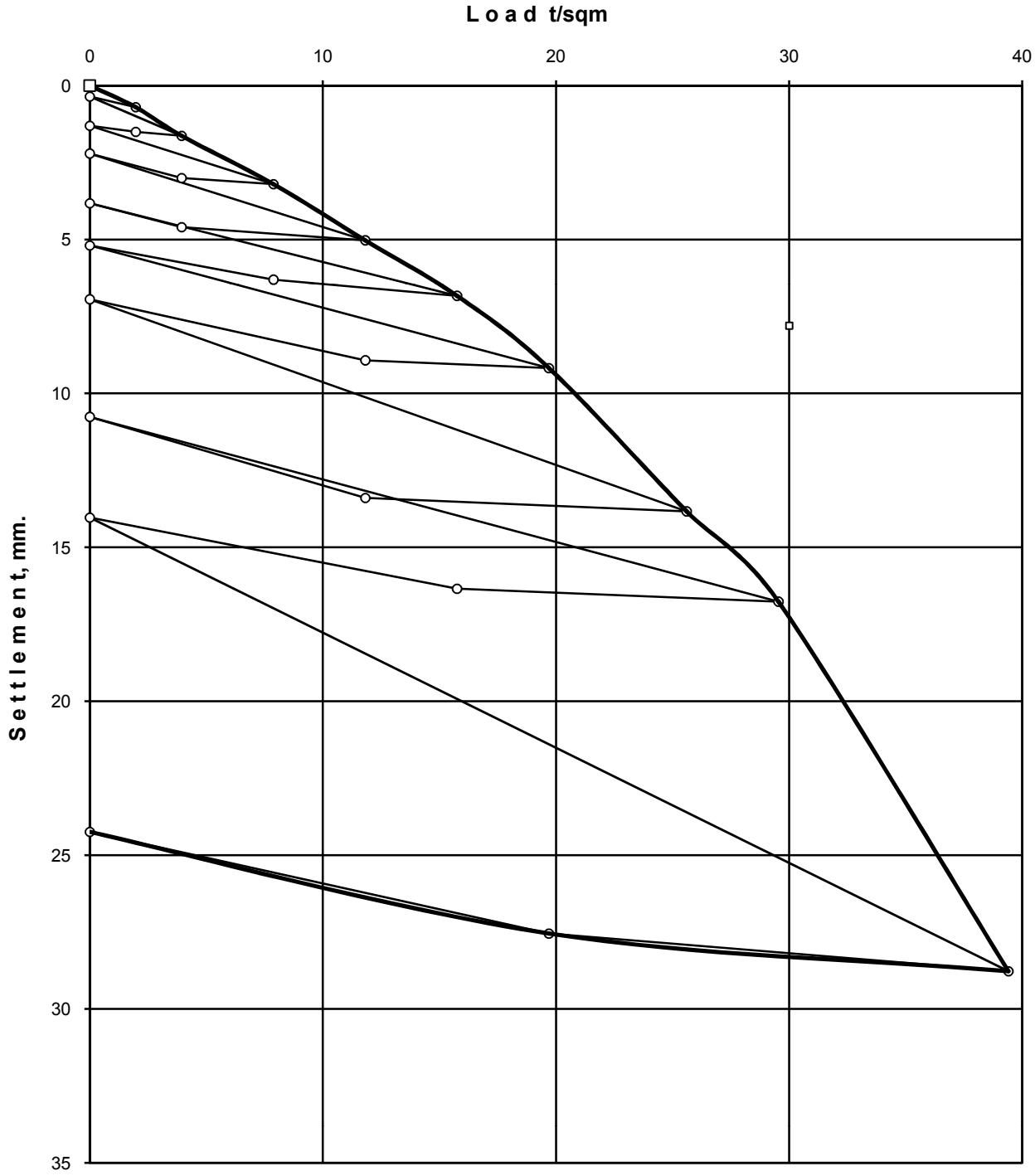


FIG. 3.3 LOAD VS SETTLEMENT GRAPH FOR CPLT-01

CYCLIC PLATE LOAD TEST NO.02

Commenced on: 13/03/2020
Completed on: 14/03/2020
Pit size: 3.00mX3.00mX3.00m (depth)
Load on pr.guage/divn. = 10Kg/sq.cm
Load on jack/divn. = 0.709t
Plate size: 0.60m X 0.60m
Load on plate/divn. = 1.97t/sq.m.
Test Type: Cyclic PLT

Co-ordinates:
E = 1040.000m.
N = 1400.000m.
RL = 154.267 m.

S.W.L. = 2.55m

Description of Soil :-

(EGL-1.30)m:- Brownish grey clayey silt with traces of sand. Obs. kankar

(1.30-3.00)m:- Light yellowish brown silty fine sand / sandy silt. Obs. decomposed rock dust.

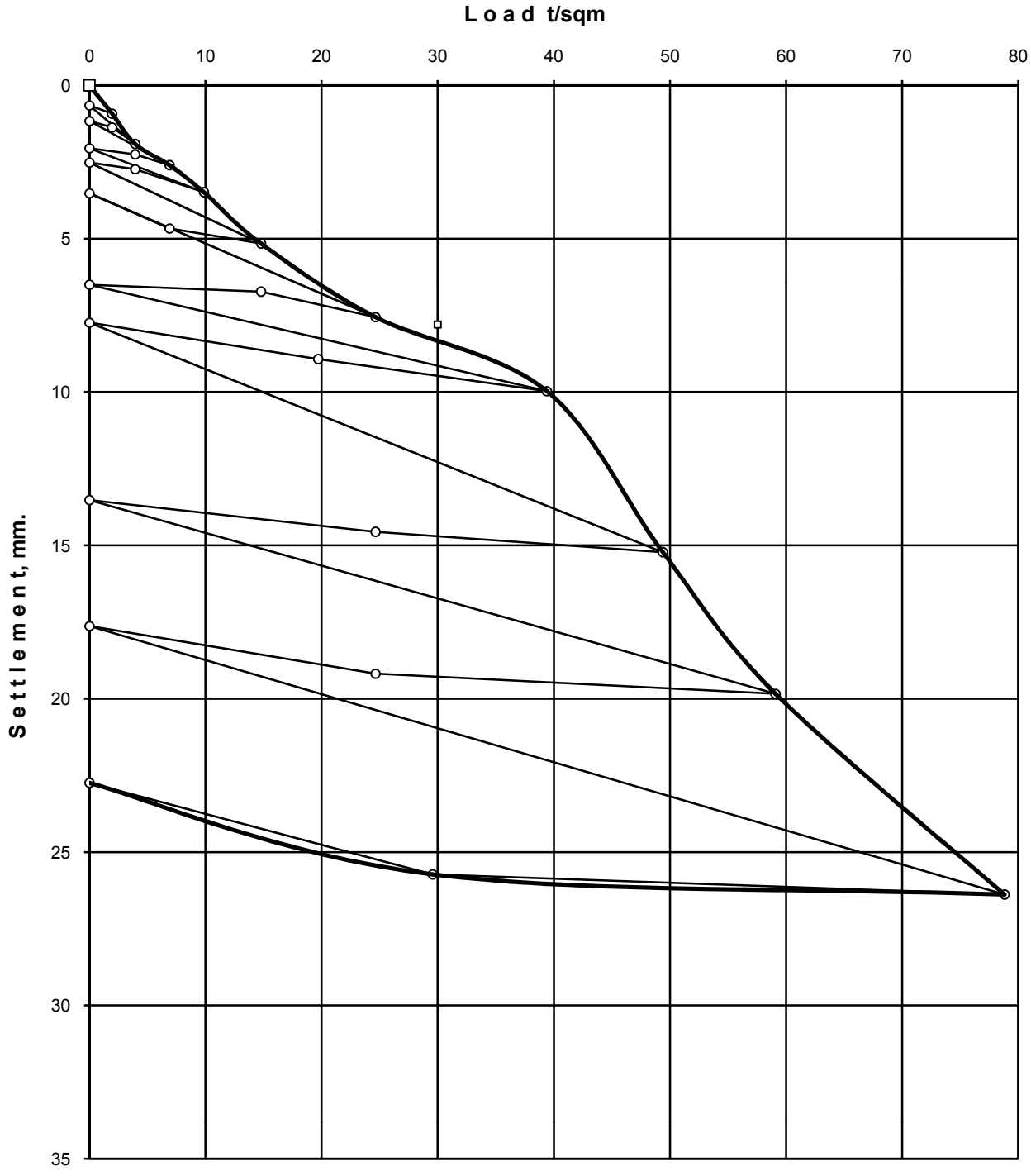


FIG. 3.4 LOAD VS SETTLEMENT GRAPH FOR CPLT-02

CYCLIC PLATE LOAD TEST NO.03

Commenced on: 11/03/2020
Completed on: 12/03/2020
Pit size: 3.00mX3.00mX2.00m (depth)
Load on pr.guage/divn. = 10Kg/sq.cm
Load on jack/divn. = 0.709t
Plate size: 0.60m X 0.60m
Load on plate/divn. = 1.97t/sq.m.
Test Type: Cyclic PLT

Co-ordinates:
E = 1234.000m.
N = 1478.000m.
RL = 155.681 m.

S.W.L. = Not Found

Description of Soil :-

(EGL-1.00)m:- Brownish grey silty sand with clay. Obs. kankar & gravel.

(0.50-2.00)m:- Reddish brown sandy silt. Obs. kankar

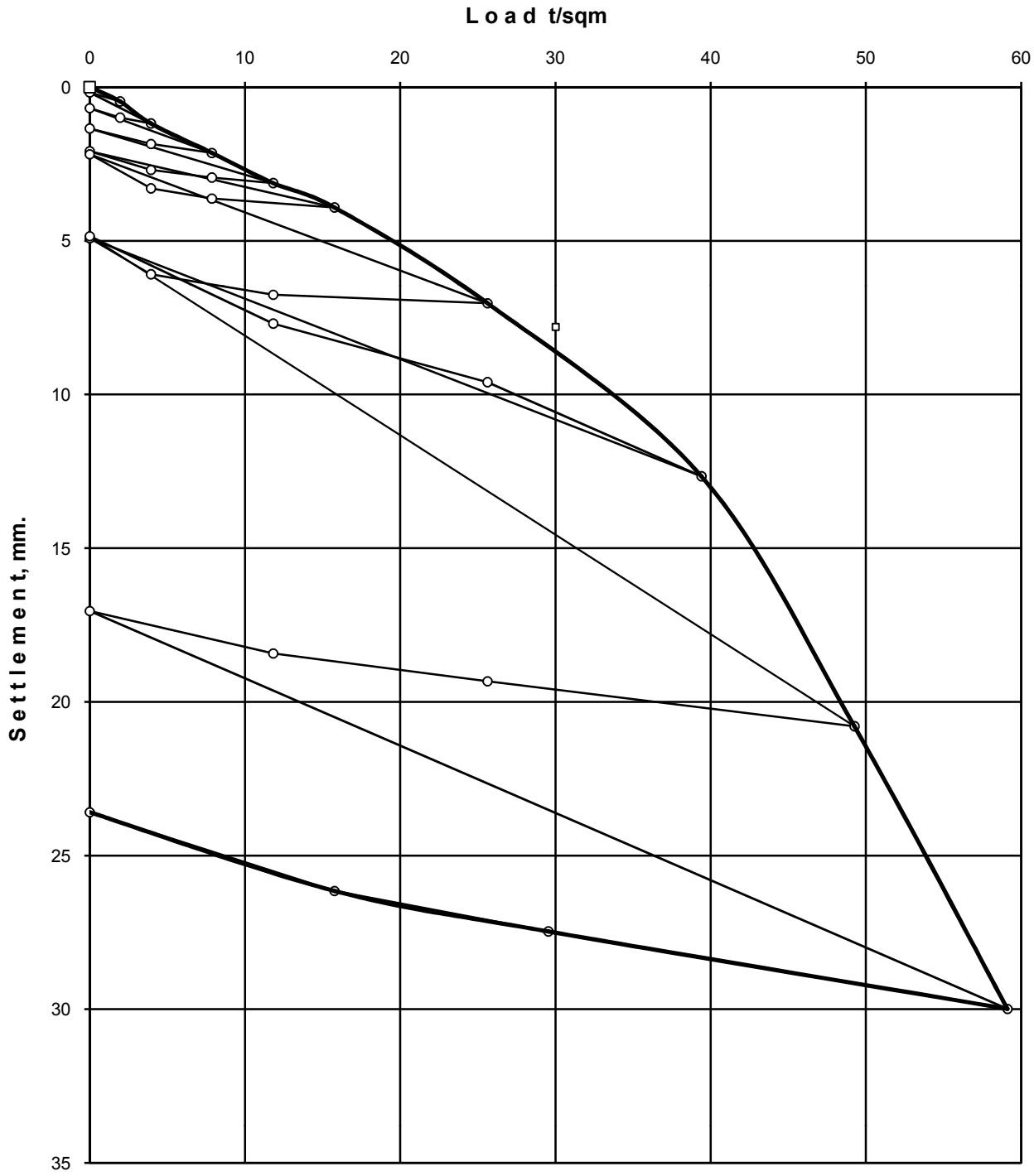


FIG. 3.5 LOAD VS SETTLEMENT GRAPH FOR CPLT-03

Test No.	Depth (M)	Subgrade Modulus, (kg/cucm)			
		Foundation Area = 1 sqm	Foundation Area = 4 sqm	Foundation Area = 5 sqm	Foundation Area = 10 sqm or above
PLT-02	3.00	3.26	1.63	1.46	1.03
PLT-04	3.00	2.73	1.37	1.22	0.86

Sample Calculation of Subgrade Modulus for foundation area 4 Sq.m for PLT-02

For Plate

Safe Load, corresponding to 1.25mm settlement = 21.60 t/sqm

Subgrade Modulus for Plate, K = P/S = 21.60/1.25 = 17.28 Kg/cm^3

Applying correction for plate bending, as per Clause 5.1.3 & Fig.5 of IS:9214, corrected Subgrade Modulus = 13.03 Kg/cm^3

Since the test was conducted on 450mm square plate (i.e. smaller than 75cm dia,), corrected Subgrade Modulus as per Clause 5.1.1 & Fig.3 of IS: 9214 = 13.03 / 1.80 = 7.24 Kg/cm3

For Foundation

Corrected Subgrade Modulus of plate = 7.24 Kg/cm^3

Area of plate = 45 x 45 sq.cm = 0.45 x 0.45 sq.m

Area of footing = 4 sq.m

Subgrade Modulus of foundation = 7.24 x $\sqrt{(0.45x0.45)/4}$ Kg/cm^3 = 1.63 Kg/cm^3

ELASTIC COMPRESSION:

For Cyclic Plate Load Tests, after application of each load increment and full stabilisation of plate settlement, the applied load was reduced to zero and the settlement records were noted till full stabilisation. Thereafter, the next load increment was applied.

The elastic rebounds at these load intensities are calculated from the field data and are graphically presented in graph (Ref. fig. no. 3.06 – 3.08). The coefficient of elastic uniform compression, C_u is obtained as $C_u = P / S_e$ (kg/cucm).

CPLT- 1:

From the load vs elastic rebound plot, the slope of the trend line = C_u = (20-10)/(2.30-1.15) = 8.70 kg/cucm

Now, for a foundation size of 10 sqm (3m x 3.33m, say), the corresponding value will be,

C_{u10sqm} = 8.70 x $\sqrt{[(0.600 \times 0.600) / 10]}$ = 1.65 kg/cucm

Test No.	Depth (M)	C_u (kg/cucm)	$C_{u\ (10sqm\ fdn.size)}$ (kg/cucm)
CPLT-01	2.00	8.70	1.65
CPLT-02	3.00	20.83	3.95
CPLT-03	2.00	12.82	2.43

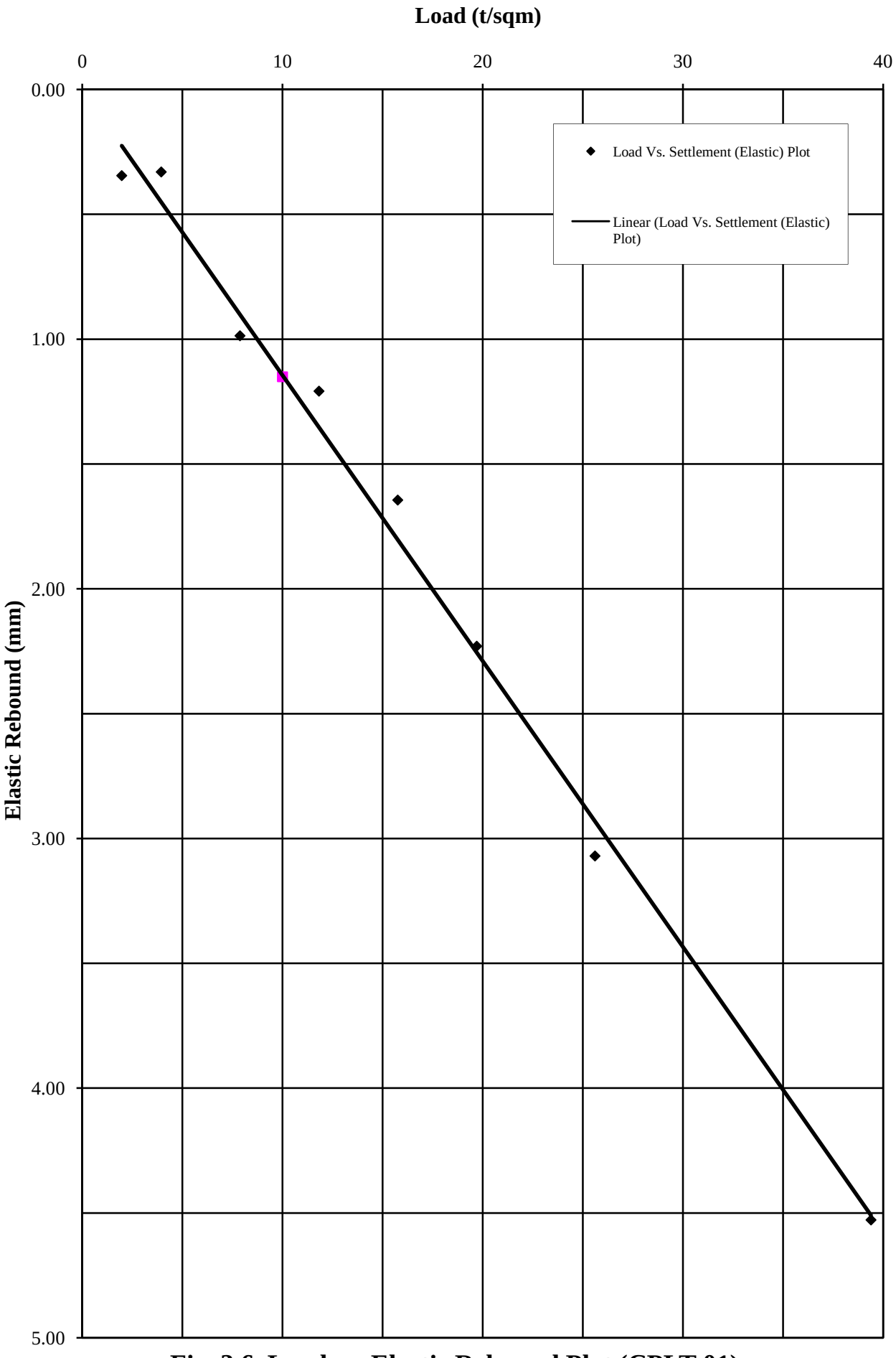


Fig. 3.6. Load vs. Elastic Rebound Plot (CPLT-01)
as per IS 5249 : 1992, Pg - 6

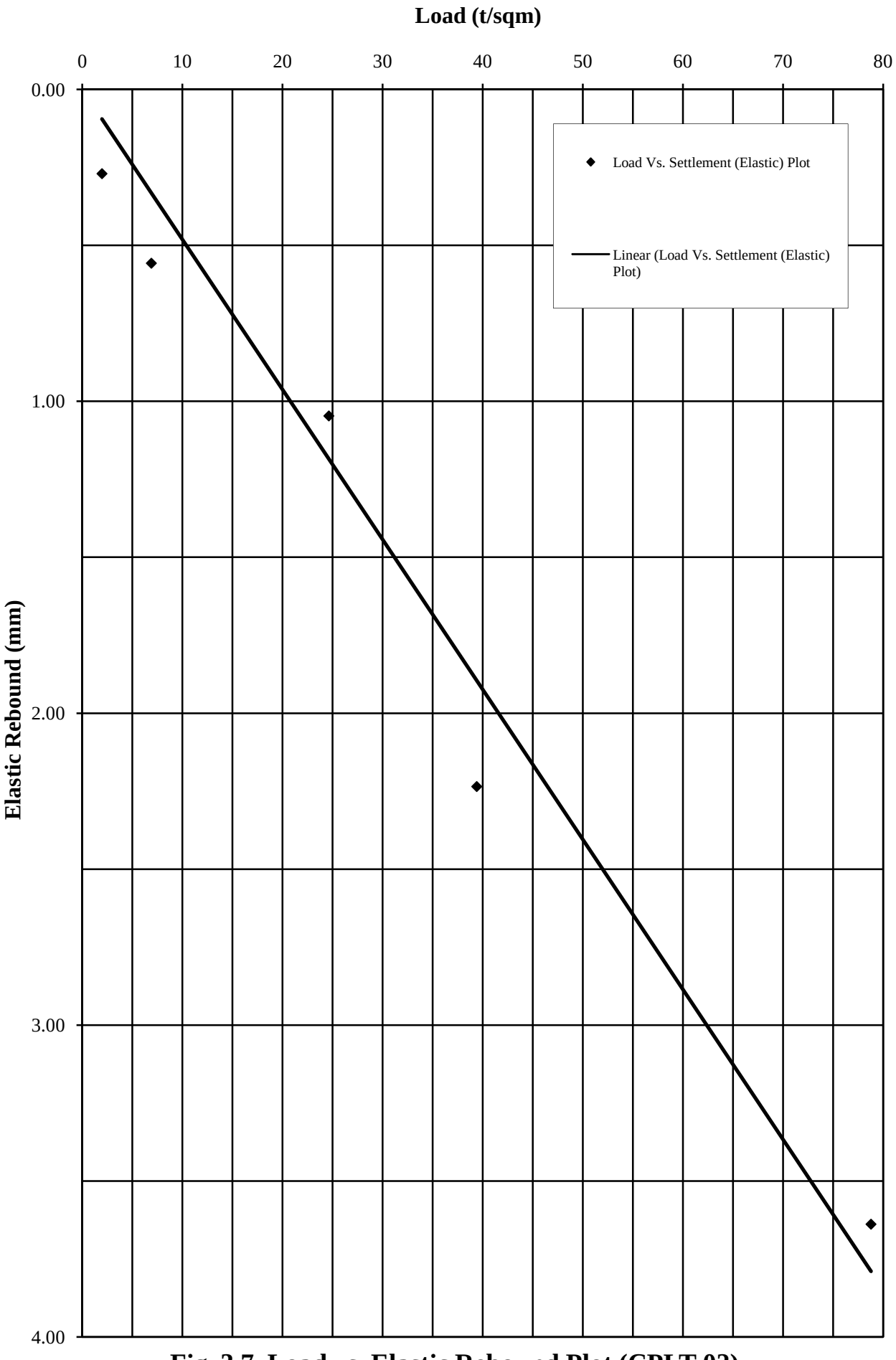


Fig. 3.7. Load vs. Elastic Rebound Plot (CPLT-02)
as per IS 5249 : 1992, Pg - 6

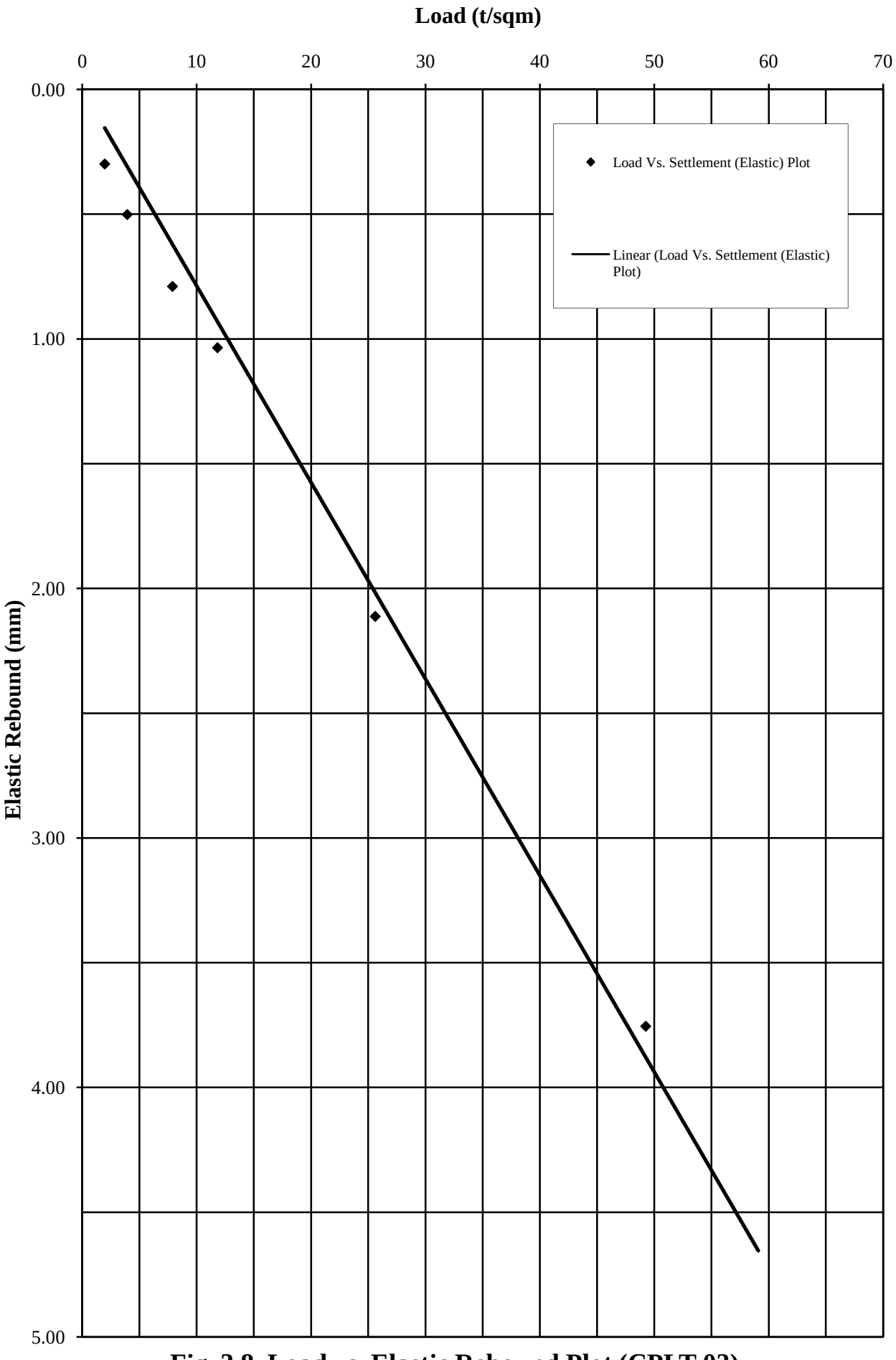


Fig. 3.8. Load vs. Elastic Rebound Plot (CPLT-03)
as per IS 5249 : 1992, Pg - 6

5.02. CHOICE OF FOUNDATION AND FOUNDING LEVEL:

Considering the nature of the subsoil and the type of structures to be constructed at the present site, it is suggested to go for open foundation. The determination of bearing capacity is presented below.

5.03. DETERMINATION OF BEARING CAPACITY AROUND BOOSTER FAN STAGE-1 (BH-17):

Let us place the foundation at 2.00m below NGL i.e. 5.495m below EGL i.e. 3.80m below FGL (where, NGL = 153.700 M, FGL = 155.500 M)

Founding level falls inside Stratum -III.

This layer consists of hard silty clay.

Average N = 61, corresponding cohesion from N value = 2.26 kg/sqcm

Considering the above, use C = 1.50 kg/sqcm & $\Phi = 0°$ for bearing capacity calculation.

EVALUATION OF STRENGTH AND DEFORMATION PARAMETERS:

For Stratum III

Total soil modulus, $E_s = 4.4 \times N = 268.400$ kg/sqcm

[Ref. to "History of Soil penetration testing" by B. B. Broms & N. Flodin in "Penetration Testing 1988", ISPOT-1: vol.1, p – 185]

Undrained Young's modulus, $E_u = K \times C = 500 \times 1.5 = 750$ kg/sqcm

Again, $1/E_s = 1/E_u + 1/E_d$ giving drained young's modulus, $E_d = 417.98$ kg/sqcm

Now, we have, $E_d = E_u/3 = 250$ kg/sqcm

[Refer to "Cone Penetration Testing" by A.C.Meigh, pp. No. – 53]

Considering the above, let us use $E_d = 330$ kg/sqcm

From E_d, $m_{vc} = 1/G.E_d = 0.0055$ sqcm/kg [Geological Factor, G = 0.55 & μ = 0.35]

Again from SPT "N", $m_{vc} = 1/5N = 0.0033$ sqcm/kg

[Refer to "Standard Penetration Test, State-of-the-art-Report" by Ivan K. Nixon in "Penetration testing 1" Edited by A.Verrujt, F.L.beringen & E.H.De Leeuw, pp. No. 11]

Thus average $m_{vc} = [0.0055 + 0.0033]/2 = 0.0044$ sqcm/kg

For Stratum V & VI

After that rock layer was encountered. Settlement of rock may be neglected. However, to be in the conservative side, use a lowest probable Young's modulus, E_s for layer V & VI = 2000 kg/sqcm & 4000 kg/sqcm respectively.

CALCULATION OF NET SAFE BEARING CAPACITY:

The Net Ultimate Bearing Capacity is given as:

$$q_{nu} = C.N_c.S_c.D_c + q.N_q.S_q.D_q + 0.5\gamma.B.N_\gamma.S_\gamma.D_\gamma - q$$

Where,

N_c, N_q and N_γ are bearing capacity factors,
S_c, S_q and S_γ are shape factors,
D_c, D_q and D_γ are depth factors,

And

C = Cohesion
q = Overburden pressure,
B = Width of foundation,
γ = Effective density below foundation.

For 6m x 12m Footing Placed at 2.00m below NGL

Cohesion, C = 15.00 t/sqm
Using ϕ = 0 degree, the bearing capacity factors are:

N_c = 5.14
N_q = 1.00
N_γ = 0.00

Use,

Depth of Foundation = D_f = 2 M (Below Natural Ground level)
Width of Foundation = B = 6 M
Length of Foundation = L = 12 M

Overburden Pressure = q =2.000 (Depth) x 0.90 (Submerged density) = 1.80 t/sqm (Assuming the ground water table is flushing with the ground level)

The Shape factors are [IS:6403 - 1981]

S_c = 1.10 S_q = 1.10 S_γ = 0.80

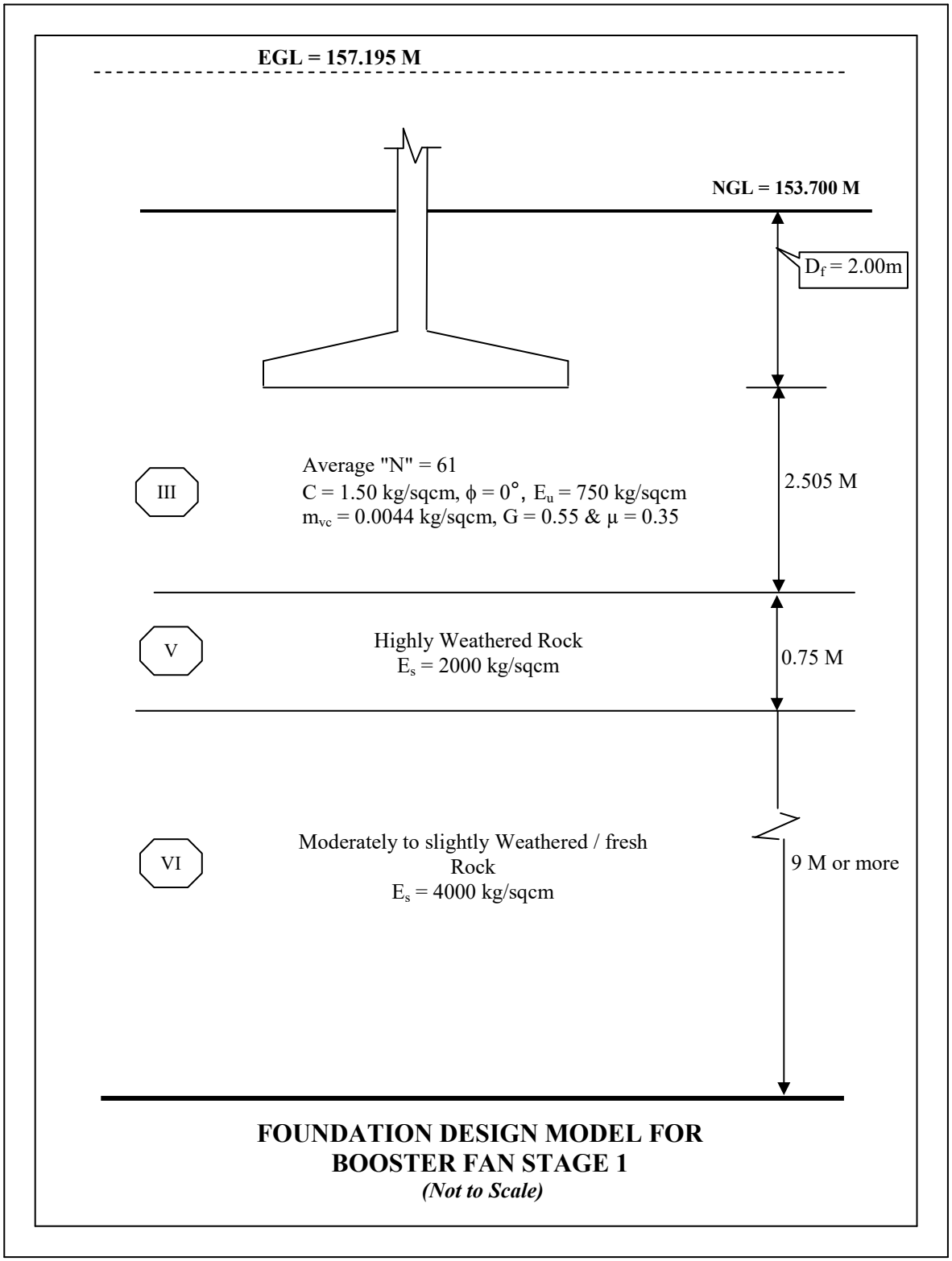
The Depth factors are [IS:6403 - 1981]

D_c = 1.07 D_q = 1.00 D_γ = 1.00

Computed Net Ultimate Bearing Capacity = 90.72 t/sqm

Using a factor of safety of 2.5, Net Safe Bearing Capacity = 36.29 t/sqm

The above bearing capacity should be checked against settlement criteria.



FOUNDATION DESIGN MODEL FOR BOOSTER FAN STAGE 1

(Not to Scale)

SETTLEMENT CALCULATION

Settlement Analysis

A) General Data:

Width of foundation =	6.00	m
Length of foundation =	12.00	m
Depth of foundation =	2.00	m from NGL
Net Base Pressure =	3.6	kg/sqcm

B) Subsoil Properties:

Layer - III			Layer - V			Layer - VI		
Young's Modulus =	750	kg/sqcm	Young's Modulus =	2000	kg/sqcm	Young's Modulus =	4000	kg/sqcm
Poisson Ratio, μ =	0.35		Poisson Ratio, μ =	0.25		Poisson Ratio, μ =	0.25	
Top of Stratum =	2.00	m	Top of Stratum =	4.51	m	Top of Stratum =	5.26	m
End of Stratum =	4.51	m	End of Stratum =	5.26	m	End of Stratum =	14.00	m
Geological factor, G =	0.55		Geological factor, G =	1.00		Geological factor, G =	1.00	
m_{vc} =	0.0044	sqcm/kg	m_{vc} =	0.0000	sqcm/kg	m_{vc} =	0.0000	sqcm/kg

C) Calculation of Immediate Settlement:

Settlement at center			*Settlement at center*			*Settlement at center*		
M = L' / B' =	2.000		M = L' / B' =	1.705		M = L' / B' =	1.648	
N = H / B' =	0.835		N = H / B' =	0.176		N = H / B' =	1.890	
I_1 =	0.095		I_1 =	0.006		I_1 =	0.277	
I_2 =	0.105		I_2 =	0.038		I_2 =	0.094	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.143	$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.031	$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.340
Immediate settlement S_i =		0.725 cm	Immediate settlement S_i =		0.052 cm	Immediate settlement S_i =		0.271 cm
$[q_o \times B' \times (1-\mu^2) \times m \times I_s] / E_s$			$[q_o \times B' \times (1-\mu^2) \times m \times I_s] / E_s$			$[q_o \times B' \times (1-\mu^2) \times m \times I_s] / E_s$		

Settlement at corner			*Settlement at corner*			*Settlement at corner*		
M = L' / B' =	2.00		M = L' / B' =	1.71		M = L' / B' =	1.648	
N = H / B' =	0.418		N = H / B' =	0.088		N = H / B' =	0.945	
I_1 =	0.028702		I_1 =	0.001		I_1 =	0.119	
I_2 =	0.074917		I_2 =	0.021		I_2 =	0.103	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.063	$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.015	$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.188
Immediate settlement S_i =		0.160 cm	Immediate settlement S_i =		0.013 cm	Immediate settlement S_i =		0.075 cm

Average S_i for Stratum III=	4.43 mm	Average S_i for Stratum V=	0.33 mm	Average S_i for Stratum VI=	1.73 mm
Total immediate settlement =	6.48 mm	(for all the three layers)			

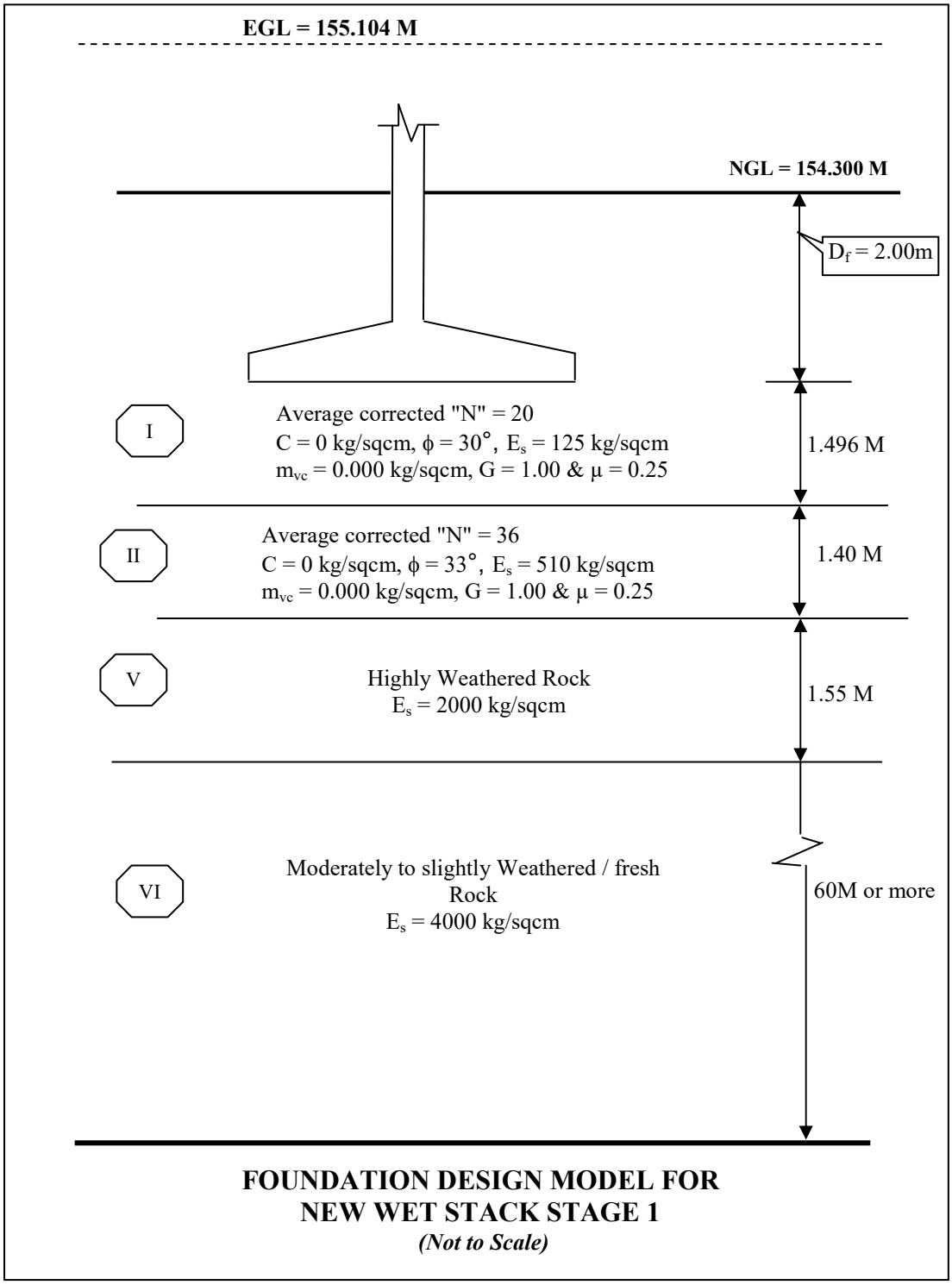
D) Calculation of Consolidation Settlement:

Strata	From (M)	To (M)	Thickness (M)	Mid depth (M)	Δ P (kg/sqcm)	m_{vc}, sqcm/kg	G	S_c (cm)
Layer - III	2.00	3.25	1.25	0.63	3.10	0.0044	0.55	0.94
	3.25	4.51	1.25	1.88	2.37	0.0044	0.55	0.72
Hence, Total Consolidation Settlement =								16.58 mm

So, Total Settlement =	23.05 mm	
Fox's Depth correction Factor =	0.94	
Applying Rigidity correction Factor =	0.80	
Corrected total settlement =	**17.31 mm**	**< 25 mm**

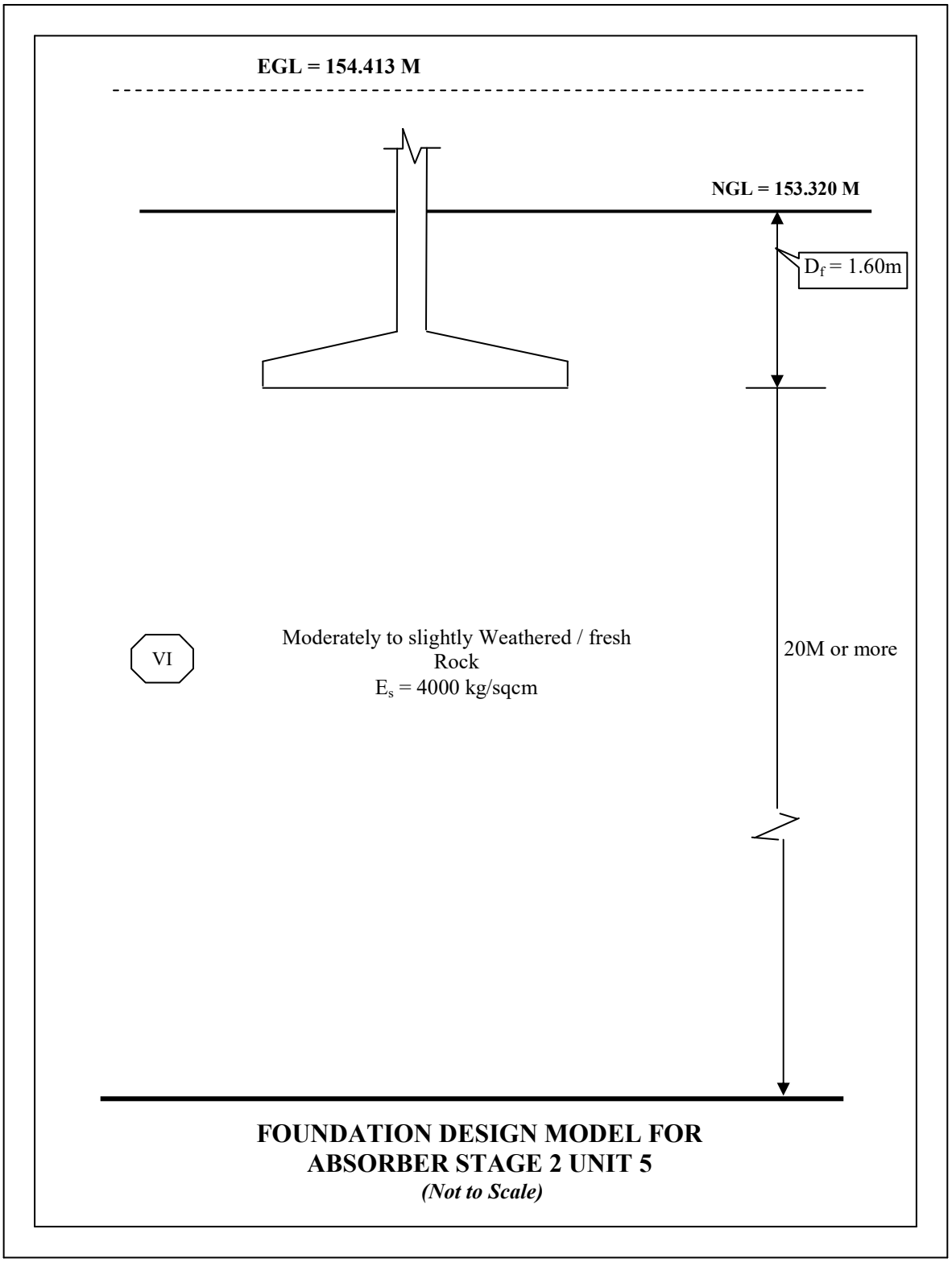
The calculated settlement is well within permissible limit. However, let us restrict the bearing capacity to 8 t/sqm at 2.00m below NGL (as per technical specification).

Based on the above, the structure wise recommended bearing capacity values have been presented in Sec. 5.04.



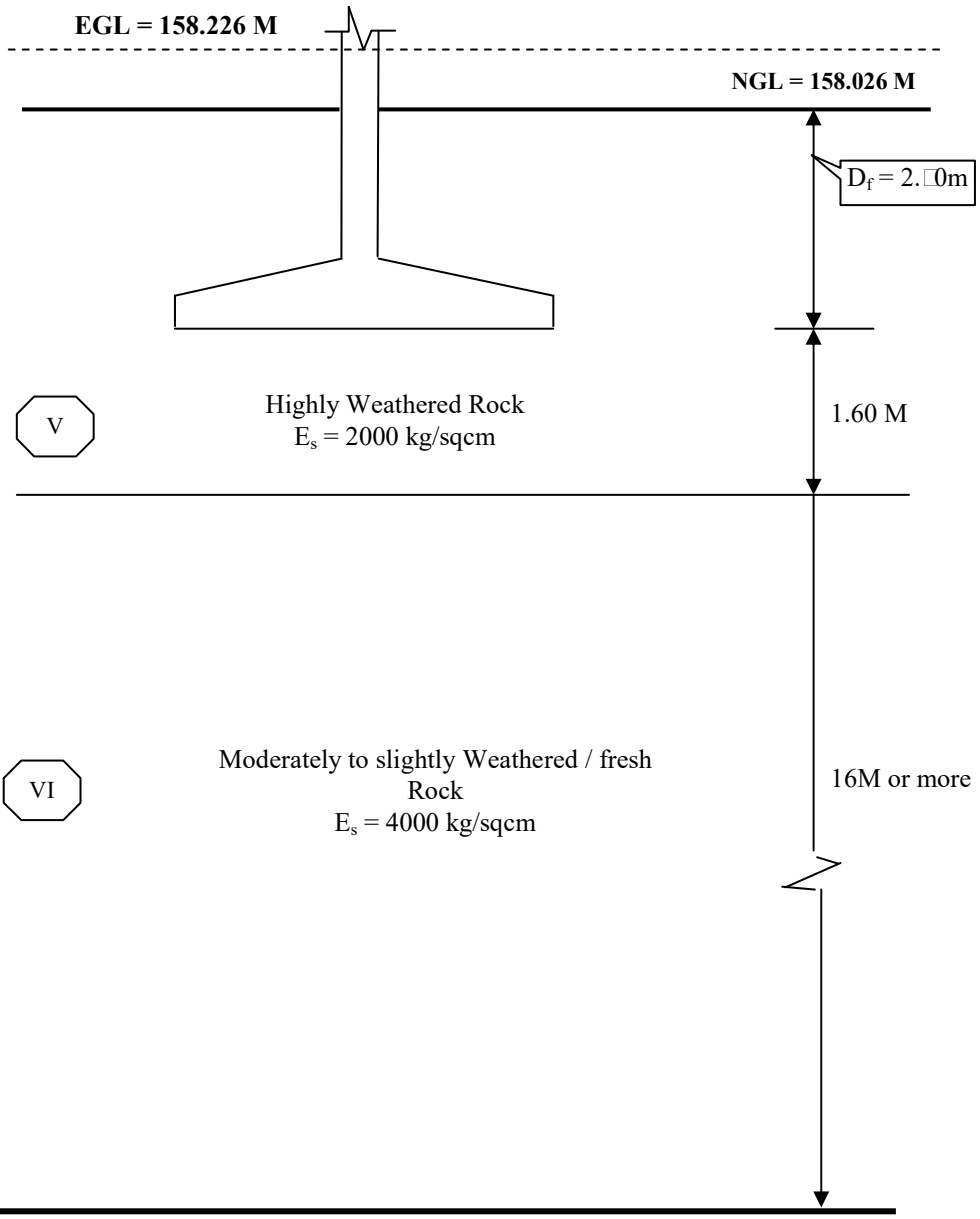
FOUNDATION DESIGN MODEL FOR NEW WET STACK STAGE 1

(Not to Scale)



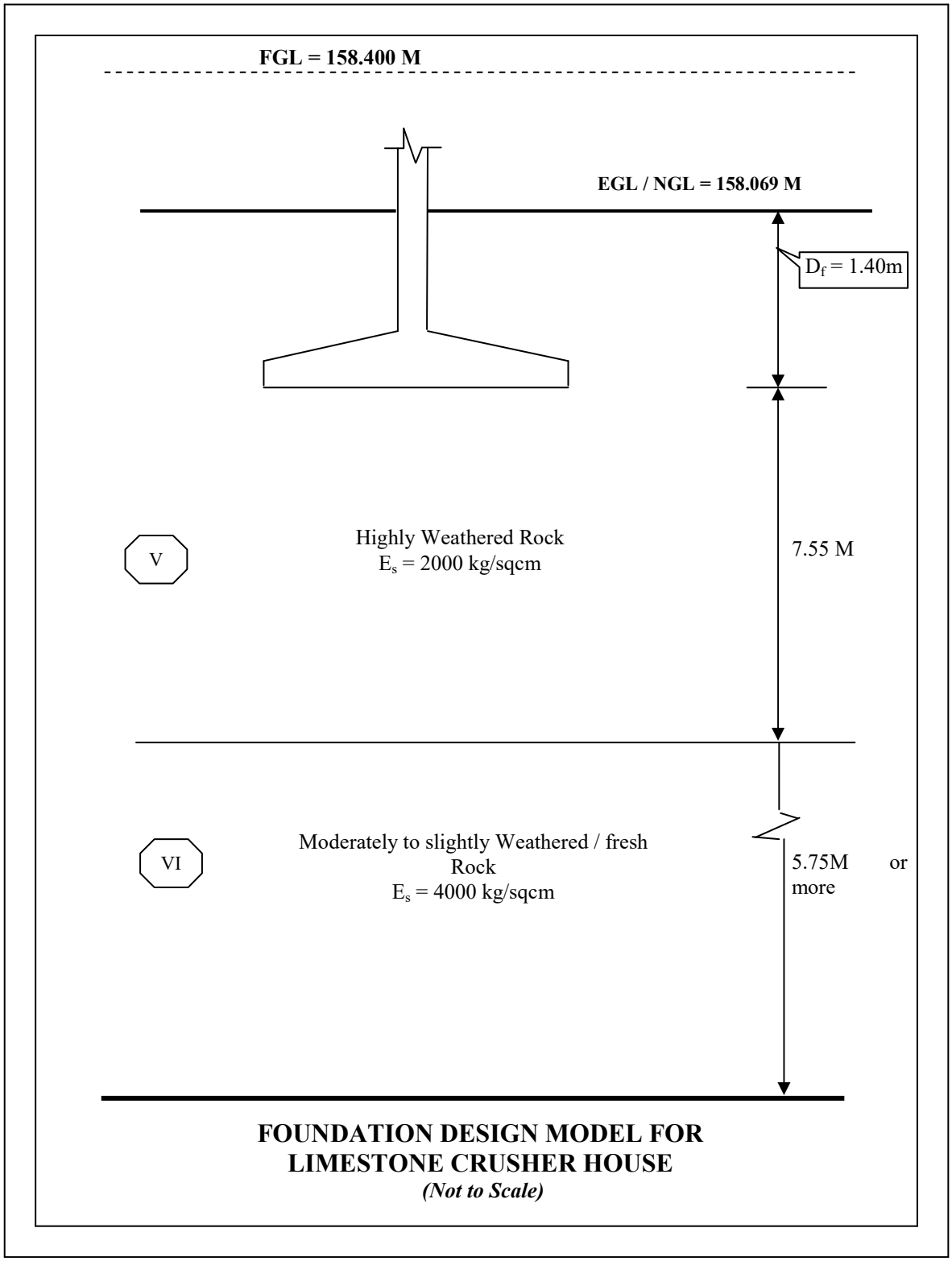
FOUNDATION DESIGN MODEL FOR ABSORBER STAGE 2 UNIT 5

(Not to Scale)



FOUNDATION DESIGN MODEL FOR BALL MILL BUILDING

(Not to Scale)



FOUNDATION DESIGN MODEL FOR LIMESTONE CRUSHER HOUSE

(Not to Scale)

5.04. RECOMMENDATION

Name of Structure	Borehole Location	Average EGL (M)	Natural Ground Level (M)	FGL (M)	Founding RL (M)	D_f below NGL (M)	D_f below FGL (M)	Size of foundation (m)	NABC (t/sqm)			
									S = 12mm	S = 25mm	S = 40mm	S = 75mm
New Wet Stack-Stage 1	BH-12 & 13	155.160	154.300	155.500	152.300	2.00	3.20	36.5 dia	--	--	--	12
					151.300	3.00	4.20	36.5 dia	--	--	--	15
					150.300	4.00	5.20	36.5 dia	--	--	--	18
					149.500	4.80	6.00	36.5 dia	--	--	--	29
					148.500	5.80	7.00	36.5 dia	40	--	--	--
Absorber, RC Pumps & Oxidation Blower House - Stage 1	BH-14 & 15	155.831	155.170	155.500	154.170	1.00	1.33	B upto 6	--	--	--	--
								B>6	--	--	--	--
					153.170	2.00	2.33	B upto 6	--	8	10	--
								B>6	--	--	--	12
					152.170	3.00	3.33	B upto 6	--	10	12	--
								B>6	--	--	--	15
					151.170	4.00	4.33	B upto 6	--	14	16	--
								B>6	--	--	--	18
					150.500	4.67	5.00	B upto 6	--	26	26	--
								B>6	--	--	--	26
					150.000	5.17	5.50	B upto 6	--	29	29	--
								B>6	--	--	--	29
					149.500	5.67	6.00	B upto 6	40	--	--	--
								B>6	40	--	--	--
Booster Fans - Stage 1	BH-16	155.966	155.170	155.500	154.170	1.00	1.33	B upto 6	--	--	--	--
								B>6	--	--	--	--
					153.170	2.00	2.33	B upto 6	--	8	10	--
								B>6	--	--	--	12
					152.170	3.00	3.33	B upto 6	--	10	12	--
								B>6	--	--	--	15
					151.170	4.00	4.33	B upto 6	--	14	16	--
								B>6	--	--	--	18
					150.500	4.67	5.00	B upto 6	--	26	26	--
								B>6	--	--	--	26
					150.000	5.17	5.50	B upto 6	--	29	29	--
								B>6	--	--	--	29
					149.500	5.67	6.00	B upto 6	40	--	--	--
								B>6	40	--	--	--
Booster Fans - Stage 1	BH-17	157.195	153.700	155.500	152.700	1.00	2.80	B upto 6	--			--
								B>6	--	--	--	
					151.700	2.00	3.80	B upto 6	--	8	10	--
								B>6	--	--	--	12
					150.700	3.00	4.80	B upto 6	--	10	12	--
								B>6	--	--	--	15
					149.700	4.00	5.80	B upto 6	--	14	16	--
								B>6	--	--	--	18
					149.000	4.70	6.50	B upto 6	--	26	26	--
								B>6	--	--	--	26
					148.600	5.10	6.90	B upto 6	40	--	--	--
								B>6	40	--	--	--
Duct-Stage 1	BH-18	154.110	153.110	154.110	152.110	1.00	2.00	B upto 6	--	--	--	--
								B>6	--	--	--	--
					151.110	2.00	3.00	B upto 6	--	8	10	--
								B>6	--	--	--	12
					150.110	3.00	4.00	B upto 6	--	10	12	--
								B>6	--	--	--	15
					149.110	4.00	5.00	B upto 6	40	--	--	--
								B>6	40	--	--	--
					148.810	4.30	5.30	B upto 6	45	--	--	--
								B>6	45	--	--	--
Duct-Stage 2 (Unit #4)	BH-20	151.370	151.370	151.370	150.370	1.00	1.00	B upto 6	--	--	--	--
								B>6	--	--	--	
					149.370	2.00	2.00	B upto 6	--	8	10	--
								B>6	--	--	--	12
					148.370	3.00	3.00	B upto 6	--	10	12	--
								B>6	--	--	--	15
					147.370	4.00	4.00	B upto 6	--	14	16	--
								B>6	--	--	--	18
					146.800	4.57	4.57	B upto 6	--	26	26	--
								B>6	--	--	--	26
Duct-Stage 2 (Unit #4)	BH-21	154.359	153.400	154.359	152.400	1.00	1.96	B upto 6	--	--	--	--
								B>6	--	--	--	--
					151.400	2.00	2.96	B upto 6	--	8	10	--
								B>6	--	--	--	12
					150.700	2.70	3.66	B upto 6	40	--	--	--
								B>6	40	--	--	--
					150.300	3.10	4.06	B upto 6	45	--	--	--
								B>6	45	--	--	--
Booster Fan - Stage 2 (Unit #4)	BH-22	155.308	154.100	155.000	153.100	1.00	1.90	B upto 6	--	--	--	--
								B>6	--	--	--	--
					151.500	2.60	3.50	B upto 6	40	--	--	--
								B>6	40	--	--	--
Booster Fan - Stage 2 (Unit #4)	BH-23 & 24	155.774	154.100	155.000	153.100	1.00	1.90	B upto 6	--	--	--	--
								B>6	--	--	--	--
					152.100	2.00	2.90	B upto 6	--	8	10	--
								B>6	--	--	--	12

Name of Structure	Borehole Location	Average EGL (M)	Natural Ground Level (M)	FGL (M)	Founding RL (M)	D_f below NGL (M)	D_f below FGL (M)	Size of foundation (m)	NABC (t/sqm)			
									S = 12mm	S = 25mm	S = 40mm	S = 75mm
Booster Fan - Stage 2 (Unit #4)	BH-23 & 24	155.774	154.100	155.000	151.100	3.00	3.90	B upto 6	--	10	12	--
								B>6	--	--	--	15
					150.100	4.00	4.90	B upto 6	--	14	16	--
								B>6	--	--	--	18
					149.500	4.60	5.50	B upto 6	--	26	26	--
								B>6	--	--	--	26
					148.100	6.00	6.90	B upto 6	40	--	--	--
								B>6	40	--	--	--
ACW & DMCW Pump Shed	BH-25	156.754	156.330	155.000	154.000	2.33	1.00	B upto 6	--	--	--	--
								B>6	--	--	--	--
					153.000	3.33	2.00	B upto 6	--	8	10	--
								B>6	--	--	--	12
					152.600	3.73	2.40	B upto 6	40	--	--	--
								B>6	40	--	--	--
Compressor House	BH-26	156.774	154.970	155.000	153.970	1.00	1.03	B upto 6	--	--	--	--
								B>6	--	--	--	--
					152.970	2.00	2.03	B upto 6	--	8	10	--
								B>6	--	--	--	12
					152.170	2.80	2.83	B upto 6	40	--	--	--
								B>6	40	--	--	--
					151.770	3.20	3.23	B upto 6	45	--	--	--
								B>6	45	--	--	--
Stage-II	BH-27	155.359	154.359	155.000	153.359	1.00	1.64	B upto 6	--	--	--	--
								B>6	--	--	--	--
					152.359	2.00	2.64	B upto 6	--	8	10	--
								B>6	--	--	--	12
					151.759	2.60	3.24	B upto 6	40	--	--	--
								B>6	40	--	--	--
					151.359	3.00	3.64	B upto 6	45	--	--	--
								B>6	45	--	--	--
New Wet Stack - Stage 2 (Unit #5)	BH-28	155.497	154.740	155.000	150.500	4.24	4.50	35m dia	40	--	--	--
					150.000	4.74	5.00	35m dia	45	--	--	--
Pipe & Cable Rack	BH-29	155.242	154.542	155.000	153.542	1.00	1.46	B upto 6	--	--	--	--
								B>6	--	--	--	--
					152.542	2.00	2.46	B upto 6	--	8	10	--
								B>6	--	--	--	12
					151.642	2.90	3.36	B upto 6	40	--	--	--
								B>6	40	--	--	--
					151.242	3.30	3.76	B upto 6	45	--	--	--
								B>6	45	--	--	--
FGD control room	BH-30	155.231	154.910	155.000	153.910	1.00	1.09	B upto 6	--	--	--	--
								B>6	--	--	--	--
					152.910	2.00	2.09	B upto 6	--	8	10	--
								B>6	--	--	--	12
					151.610	3.30	3.39	B upto 6	40	--	--	--
								B>6	40	--	--	--
					151.210	3.70	3.79	B upto 6	45	--	--	--
								B>6	45	--	--	--
Booster Fan - Stage 2 (Unit #5)	BH-31 & 32	155.008	153.520	155.000	151.220	2.30	3.78	B upto 6	30	--	--	--
								B>6	30	--	--	--
					150.820	2.70	4.18	B upto 6	40	--	--	--
								B>6	40	--	--	--
Booster Fan - Stage 2 (Unit #5)	BH-33 & 34	153.851	153.125	155.000	152.125	1.00	2.88	B upto 6	--	--	--	--
								B>6	--	--	--	--
					151.125	2.00	3.88	B upto 6	--	8	10	--
								B>6	--	--	--	12
					149.975	3.15	5.03	B upto 6	40	--	--	--
								B>6	40	--	--	--
					149.575	3.55	5.43	B upto 6	45	--	--	--
								B>6	45	--	--	--
Duct-Stage 2 (Unit #5)	BH-35	152.396	151.396	152.396	150.396	1.00	2.00	B upto 6	--	--	--	--
								B>6	--	--	--	--
					149.796	1.60	2.60	B upto 6	40	--	--	--
								B>6	40	--	--	--
					149.396	2.00	3.00	B upto 6	45	--	--	--
								B>6	45	--	--	--
Duct Near Chimney Stage 2 (Unit #6)	BH-36	151.888	151.188	151.888	150.188	1.00	1.70	B upto 6	--	--	--	--
								B>6	--	--	--	--
					149.188	2.00	2.70	B upto 6	--	8	10	--
								B>6	--	--	--	12
					148.788	2.40	3.10	B upto 6	40	--	--	--
								B>6	40	--	--	--
					148.388	2.80	3.50	B upto 6	45	--	--	--
								B>6	45	--	--	--
Duct-Stage 2 (Unit #6)	BH-37	151.837	151.837	151.837	150.837	1.00	1.00	B upto 6	--	--	--	--
								B>6	--	--	--	--
					149.737	2.10	2.10	B upto 6	40	--	--	--
								B>6	40	--	--	--
					149.337	2.50	2.50	B upto 6	45	--	--	--
								B>6	45	--	--	--

Name of Structure	Borehole Location	Average EGL (M)	Natural Ground Level (M)	FGL (M)	Founding RL (M)	D_f below NGL (M)	D_f below FGL (M)	Size of foundation (m)	NABC (t/sqm)			
									S = 12mm	S = 25mm	S = 40mm	S = 75mm
Booster Fan - Stage 2 (Unit #6)	BH-38 & 39	154.678	153.363	155.000	152.363	1.00	2.64	B upto 6	--	--	--	--
								B>6	--	--	--	
					151.363	2.00	3.64	B upto 6	--	8	10	--
								B>6	--	--	--	12
					150.363	3.00	4.64	B upto 6	--	10	12	--
								B>6	--	--	--	15
					149.863	3.50	5.14	B upto 6	40	--	--	--
								B>6	40	--	--	--
					149.463	3.90	5.54	B upto 6	45	--	--	--
								B>6	45	--	--	--
Booster Fan - Stage 2 (Unit #6)	BH-40 & 41	155.044	154.200	155.000	153.200	1.00	1.80	B upto 6	--	--	--	--
								B>6	--	--	--	
					151.700	2.50	3.30	B upto 6	30	--	--	--
								B>6	30	--	--	--
					151.300	2.90	3.70	B upto 6	40	--	--	--
								B>6	40	--	--	--
Near FGD control room	BH-42	155.5020	155.260	155.000	154.000	1.26	1.00	B upto 6	--	--	--	--
								B>6	--	--	--	
					153.000	2.26	2.00	B upto 6	--	8	10	--
								B>6	--	--	--	12
					152.400	2.86	2.60	B upto 6	30	--	--	--
								B>6	30	--	--	--
					152.000	3.26	3.00	B upto 6	40	--	--	--
								B>6	40	--	--	--
Pipe & Cable Rack	BH-43	155.742	155.290	155.000	154.000	1.29	1.00	B upto 6	--	--	--	--
								B>6	--	--	--	
					153.100	2.19	1.90	B upto 6	30	--	--	--
								B>6	30	--	--	--
					152.700	2.59	2.30	B upto 6	40	--	--	--
								B>6	40	--	--	--
RC Pumps & Absorber - Stage 2 (Unit #5)	BH-44	154.413	153.320	155.000	151.720	1.60	3.28	B upto 6	30	--	--	--
								B>6	30	--	--	--
					151.320	2.00	3.68	B upto 6	40	--	--	--
								B>6	40	--	--	--
Duct Near Chimney Stage 2 (Unit #5)	BH-45	151.830	151.173	151.830	150.173	1.00	1.66	B upto 6	--	--	--	--
								B>6	--	--	--	
					149.273	1.90	2.56	B upto 6	40	--	--	--
								B>6	40	--	--	--
					148.873	2.30	2.96	B upto 6	45	--	--	--
								B>6	45	--	--	--
Duct Near Chimney Stage 2 (Unit #4)	BH-46	151.926	151.326	151.926	150.326	1.00	1.60	B upto 6	--	--	--	--
								B>6	--	--	--	
					149.326	2.00	2.60	B upto 6	--	8	10	--
								B>6	--	--	--	12
					148.326	3.00	3.60	B upto 6	40	--	--	--
								B>6	40	--	--	--
					147.926	3.40	4.00	B upto 6	45	--	--	--
								B>6	45	--	--	--
Duct Near Chimney Stage 1	BH-47	152.086	152.086	152.086	149.086	3.00	3.00	B upto 6	--	10	12	--
								B>6	--	--	--	15
					148.086	4.00	4.00	B upto 6	--	14	16	--
								B>6	--	--	--	18
					145.000	7.09	7.09	B upto 6	--	26	26	--
								B>6	--	--	--	26
Limestone Slurry Storage Tank	BH-48	158.737	158.420	159.000	156.620	1.80	2.38	B upto 6	30	--	--	--
								B>6	30	--	--	--
					156.220	2.20	2.78	B upto 6	40	--	--	--
								B>6	40	--	--	--
Ball Mill Building	BH-49	158.226	158.026	159.000	155.826	2.20	3.17	B upto 6	30	--	--	--
								B>6	30	--	--	--
					155.426	2.60	3.57	B upto 6	40	--	--	--
								B>6	40	--	--	--
Gypsum dewatering building	BH-50	157.111	157.090	158.300	156.090	1.00	2.21	B upto 6	--	--	--	--
								B>6	--	--	--	
					154.990	2.10	3.31	B upto 6	30	--	--	--
								B>6	30	--	--	--
					154.590	2.50	3.71	B upto 6	40	--	--	--
								B>6	40	--	--	--
	BH-51	159.272	156.980	158.300	155.980	1.00	2.32	B upto 6	30	--	--	--
								B>6	30	--	--	--
Hydrocyclone Feed Tank, Waste Water & Filtrate Water tank	BH-52 & 53	158.465	157.538	158.300	156.538	1.00	1.76	B upto 6	--	--	--	--
								B>6	--	--	--	
					155.438	2.10	2.86	B upto 6	30	--	--	--
								B>6	30	--	--	--
					155.038	2.50	3.26	B upto 6	40	--	--	--
								B>6	40	--	--	--
New wet stack stage II (Unit 6)	BH-54	157.782	154.182	155.000	152.182	2.00	2.82	35m dia	40	--	--	--
					151.782	2.40	3.22	35m dia	45	--	--	--
Absorber stage II (Unit 6)	BH-55	155.242	155.100	155.000	154.000	1.10	1.00	B upto 6	--	--	--	--
								B>6	--	--	--	
					153.000	2.10	2.00	B upto 6	--	8	10	--
								B>6	--	--	--	12

Name of Structure	Borehole Location	Average EGL (M)	Natural Ground Level (M)	FGL (M)	Founding RL (M)	D_f below NGL (M)	D_f below FGL (M)	Size of foundation (m)	NABC (t/sqm)			
									S = 12mm	S = 25mm	S = 40mm	S = 75mm
Absorber stage II (Unit 6)	BH-55	155.242	155.100	155.000	152.000	3.10	3.00	B upto 6	--	10	12	--
								B>6	--	--	--	15
					151.100	4.00	3.90	B upto 6	40	--	--	--
								B>6	40	--	--	--
New wet stack stage II (Unit 4)	BH-56	155.208	155.208	155.000	153.000	2.21	2.00	35m dia	--	--	--	12
					152.000	3.21	3.00	35m dia	--	--	--	15
					151.000	4.21	4.00	35m dia	--	--	--	18
					150.000	5.21	5.00	35m dia	--	--	--	26
					149.100	6.11	5.90	35m dia	40	--	--	--
Absorber stage II (Unit 4)	BH-57	154.427	154.227	155.000	153.227	1.00	1.77	B upto 6	--	--	--	--
								B>6	--	--	--	
					152.227	2.00	2.77	B upto 6	--	8	10	--
								B>6	--	--	--	12
					151.027	3.20	3.97	B upto 6	40	--	--	--
								B>6	40	--	--	--
					150.627	3.60	4.37	B upto 6	45	--	--	--
								B>6	45	--	--	--
Duct-Stage 1	BH-58	152.163	151.600	152.163	150.600	1.00	1.56	B upto 6	--			--
								B>6	--	--	--	
					149.600	2.00	2.56	B upto 6	--	8	10	--
								B>6	--	--	--	12
					148.600	3.00	3.56	B upto 6	--	10	12	--
								B>6	--	--	--	15
					147.600	4.00	4.56	B upto 6	--	14	16	--
								B>6	--	--	--	18
					147.000	4.60	5.16	B upto 6	--	26	26	--
								B>6	--	--	--	26
					146.000	5.60	6.16	B upto 6	40	--	--	--
								B>6	40	--	--	--
--	BH-59	156.882	156.282	156.882	155.282	1.00	1.60	B upto 6	--	--	--	--
								B>6	--	--	--	--
					154.282	2.00	2.60	B upto 6	30	--	--	--
								B>6	30	--	--	--
					153.882	2.40	3.00	B upto 6	40	--	--	--
								B>6	40	--	--	--
Pipe & Cable Rack	BH-60	155.700	154.400	155.700	153.400	1.00	2.30	B upto 6	--	--	--	--
								B>6	--	--	--	
					152.500	1.90	3.20	B upto 6	25	--	--	--
								B>6	25	--	--	--
					152.100	2.30	3.60	B upto 6	40	--	--	--
								B>6	40	--	--	--
Pipe & Cable Rack	BH-61	157.178	156.450	157.178	154.950	1.50	2.23	B upto 6	25	--	--	--
								B>6	25	--	--	--
					154.550	1.90	2.63	B upto 6	40	--	--	--
								B>6	40			
Gypsum Belt Conveyor	IBH-12	158.199	158.140	158.300	156.140	2.00	2.16	B upto 6	--	8	10	--
								B>6	--	--	--	12
					155.140	3.00	3.16	B upto 6	--	10	12	--
								B>6	--	--	--	15
					154.000	4.14	4.30	B upto 6	--	29	29	--
								B>6	--	--	--	29
					153.500	4.64	4.80	B upto 6	30	--	--	--
								B>6	30	--	--	--
	IBH-13	161.054	160.560	158.300	156.900	3.66	1.40	B upto 6	30	--	--	--
								B>6	30	--	--	--
					156.500	4.06	1.80	B upto 6	40	--	--	--
								B>6	40	--	--	--
Pipe & Cable Rack	IBH-14	156.185	156.185	156.185	155.185	1.00	1.00	B upto 6	--	--	--	--
								B>6	--	--	--	
					154.085	2.10	2.10	B upto 6	30	--	--	--
								B>6	30	--	--	--
					153.685	2.50	2.50	B upto 6	40	--	--	--
								B>6	40	--	--	--
LTP-1	IBH-15	157.218	157.218	158.400	154.618	2.60	3.78	B upto 6	30	--	--	--
								B>6	30	--	--	--
					154.218	3.00	4.18	B upto 6	40	--	--	--
								B>6	40	--	--	--
	IBH-16	158.106	154.506	158.400	153.906	0.60	4.49	B upto 6	30	--	--	--
								B>6	30	--	--	--
					153.506	1.00	4.89	B upto 6	40	--	--	--
								B>6	40	--	--	--
LBC-1A/B	IBH-17	158.121	156.621	158.400	156.021	0.60	2.38	B upto 6	30	--	--	--
								B>6	30	--	--	--
					155.621	1.00	2.78	B upto 6	40	--	--	--
								B>6	40	--	--	--
	IBH-18	158.663	158.663	158.400	156.400	2.26	2.00	B upto 6	30	--	--	--
								B>6	30	--	--	--
					156.000	2.66	2.40	B upto 6	40	--	--	--
								B>6	40	--	--	--
Limestone Crusher House	IBH-19	158.069	158.069	158.400	156.669	1.40	1.73	B upto 6	30	--	--	--
								B>6	30	--	--	--
					156.269	1.80	2.13	B upto 6	40	--	--	--
								B>6	40	--	--	--

Name of Structure	Borehole Location	Average EGL (M)	Natural Ground Level (M)	FGL (M)	Founding RL (M)	D_f below NGL (M)	D_f below FGL (M)	Size of foundation (m)	NABC (t/sqm)			
									S = 12mm	S = 25mm	S = 40mm	S = 75mm
Limestone Crusher House	IBH-20	159.227	159.710	158.400	157.600	2.11	0.80	B upto 6	30	--	--	--
								B>6	30	--	--	--
					157.200	2.51	1.20	B upto 6	40	--	--	--
								B>6	40	--	--	--
Limestone Storage Silo	IBH-21	159.298	159.000	159.000	157.800	1.20	1.20	B upto 6	30	--	--	--
								B>6	30	--	--	--
					157.400	1.60	1.60	B upto 6	40	--	--	--
								B>6	40	--	--	--
	IBH-22	158.956	157.700	159.000	157.100	0.60	1.90	B upto 6	30	--	--	--
								B>6	30	--	--	--
					156.700	1.00	2.30	B upto 6	40	--	--	--
								B>6	40	--	--	--

Note:

1. NSBC = Net Safe Bearing Capacity, NABC = Net Allowable Bearing Capacity, EGL = Existing Ground Level, FGL = Finished Ground Level
2. S = Limiting Settlement.
3. However for foundation placed inside rock, permissible settlement is considered as 12mm irrespective of type of foundation.
4. The roads, ground floor slabs, trenches, pipe pedestals, channels/drains and staircase foundation with foundation loading intensity less than 4 t/sqm may be supported on open / shallow foundations resting on virgin / controlled compacted filled up soil.
5. In case any loose pocket is observed at the founding level, then the same should be excavated out and the same shall be filled up with PCC.

DETERMINATION OF BEARING CAPACITY AROUND WET STACK STAGE-1 (BH-12):

Let us place the foundation at 3.00m below NGL i.e. 3.804m below EGL i.e. 4.20m below FGL (where, NGL = 154.300 M, FGL = 155.500 M)

Founding level falls inside Stratum –I i.e. medium dense sand layer.

Design "N" = 22

After correcting for Overburden Pressure and Dilatancy, Final Corrected "N" = 20

Considering the above, use C = 0 kg/sqcm & Φ = 30° for bearing capacity calculation.

Assume size of foundation = 36.50m dia

So, equivalent width of foundation = 32.35m

EVALUATION OF STRENGTH AND DEFORMATION PARAMETERS:

For Stratum I

Treating the sand to be normally consolidated sand, E_s = 5(N+15) = 175 kg/sqcm

Treating the sand to be silty sand, E_s = 3(N+6) = 78 kg/sqcm

Thus average E_s = 127 kg/sqcm

Use E_s = 125 kg/sqcm, G = 1.00, μ = 0.25

For Stratum II

The Average field "N" = 53

After correction factor for Overburden Pressure and Dilatancy, Final Corrected "N" = 36

Treating the sand to be normally consolidated sand, E_s = 5(N+15) = 255 kg/sqcm

Treating the sand to be over consolidated sand, E_s = 400+10.5N = 778 kg/sqcm

Thus average E_s = 517 kg/sqcm

Use E_s = 510 kg/sqcm, G = 1.00, μ = 0.25

For Stratum V & VI

After that rock layer was encountered. Settlement of rock may be neglected. However, to be in the conservative side, use a lowest probable Young's modulus, E_s for layer V & VI = 2000 kg/sqcm & 4000 kg/sqcm respectively.

Considering General Shear Failure:

Cohesion, C = 0.00 t/sqm

Using ϕ = 36 degree, the bearing capacity factors are:

N_c = 50.59

N_q = 37.75

N_γ = 56.31

Use,

Depth of Foundation = D_f = 3 M (Below Natural Ground level)

Diameter of Foundation = B = 36.5 M

Overburden Pressure = q =3.000 (Depth) x 0.90 (Submerged density) = 2.70 t/sqm (Assuming the ground water table is flushing with the ground level)

The Shape factors are [IS:6403 - 1981]

S_c = 1.30 S_q = 1.20 S_γ = 0.60

The Depth factors are [IS:6403 - 1981]

D_c = 1.03 D_q = 1.02 D_γ = 1.02

Computed Net Ultimate Bearing Capacity = 685.48 t/sqm

Using a factor of safety of 2.5, Net Safe Bearing Capacity = 274.19 t/sqm

Considering Local Shear Failure:

$\Phi = 28°$, $\Phi' = \tan^{-1}(2/3 \times \tan 28°) = 19°$

Computed Net Ultimate Bearing Capacity = 212.64 t/sqm

Using a factor of safety of 2.5, Net Safe Bearing Capacity = 85.06 t/sqm

Therefore, interpolated SBC for Φ of 30° = [85.06 + {(30-28) / (36-28)} x (274.19-85.06)] = 132.34 t/sqm.

The above bearing capacity should be checked against settlement criteria. This is shown below.

Settlement Analysis

A) General Data:

Equ. Width of foundation =	32.35	m
Equ. Length of foundation	32.35	m
Depth of foundation =	3.00	m from NGL
Net Base Pressure =	13.2	kg/sqcm

B) Subsoil Properties:

Layer - I			**Layer - II**		
Young's Modulus =	125	kg/sqcm	Young's Modulus =	510	kg/sqcm
Poisson Ratio, μ =	0.25		Poisson Ratio, μ =	0.25	
Top of Stratum =	3.00	m	Top of Stratum =	3.50	m
End of Stratum =	3.50	m	End of Stratum =	4.90	m
Geological factor, G =	1.00		Geological factor, G =	1.00	
m_{vc} =	0.0000	sqcm/kg	m_{vc} =	0.0000	sqcm/kg

C) Calculation of Immediate Settlement:

Settlement at center

M = L' / B' =	1.000		M = L' / B' =	1.000	
N = H / B' =	0.031		N = H / B' =	0.085	
I_1 =	0.000		I_1 =	0.002	
I_2 =	0.007		I_2 =	0.020	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.005	$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.0147
Immediate settlement S_i =		3.327 cm	Immediate settlement S_i =		2.2864 cm
$[q_o \times B' \times (1-\mu^2) \times m \times I_s] / E_s$			$[q_o \times B' \times (1-\mu^2) \times m \times I_s] / E_s$		

Settlement at corner

M = L' / B' =	1.00		M = L' / B' =	1.00	
N = H / B' =	0.015		N = H / B' =	0.043	
I_1 =	0.000053		I_1 =	0.000	
I_2 =	0.003780		I_2 =	0.010	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.003	$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.0072
Immediate settlement S_i =		0.826 cm	Immediate settlement S_i =		0.5612 cm

Average S_i for Stratum I= 20.77 mm

Average S_i for Stratum II= 14.238 mm

Layer - V

Young's Modulus =	2000	kg/sqcm
Poisson Ratio, μ =	0.25	
Top of Stratum =	4.90	m
End of Stratum =	6.45	m
Geological factor, G =	1.00	
m_{vc} =	0.0000	sqcm/kg

Settlement at center

M = L' / B' =	1.000	
N = H / B' =	0.091	
I_1 =	0.002	
I_2 =	0.021	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.016
Immediate settlement S_i =		0.595 cm
$[q_o \times B' \times (1- \mu^2) \times m \times I_s] / E_s$		

Settlement at corner

M = L' / B' =	1.000	
N = H / B' =	0.045	
I_1 =	0.000	
I_2 =	0.011	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.008
Immediate settlement S_i =		0.146 cm

Average S_i for Stratum V= 3.71 mm

Layer - VI

Young's Modulus =	4000	kg/sqcm
Poisson Ratio, μ =	0.25	
Top of Stratum =	6.446	m
End of Stratum =	67.70	m
Geological factor, G =	1.00	
m_{vc} =	0.0000	sqcm/kg

Settlement at center

M = L' / B' =	1.000	
N = H / B' =	3.422	
I_1 =	0.385	
I_2 =	0.043	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.413
Immediate settlement S_i =		7.498 cm
$[q_o \times B' \times (1- \mu^2) \times m \times I_s] / E_s$		

Settlement at corner

M = L' / B' =	1.000	
N = H / B' =	1.711	
I_1 =	0.252	
I_2 =	0.070	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =		0.299
Immediate settlement S_i =		2.710 cm

Average S_i for Stratum VI= 51.04 mm

Total immediate settlement = 89.75 mm (for all the four layers)

So, Total Settlement =	89.75 mm
Fox's Depth correction Factor =	0.98
Applying Rigidity correction Factor :	0.80
Corrected total settlement =	**70.66 mm**

The calculated settlement is well within permissible limit. However, let us restrict the bearing capacity to 15 t/sqm for 3.00m below NGL.

DETERMINATION OF BEARING CAPACITY AROUND ABSORBER STAGE-2 (BH-44):

Let us place the foundation at 1.60m below NGL i.e. 2.693m below EGL i.e. 3.280m below FGL (where, NGL = 143.320 M, FGL = 155.000 M)

Founding level falls inside Stratum –VI i.e. moderately to slightly weathered rock layer.

Weathered rock layer was encountered with moderate core recovery and almost nil RQD. The intermediate geo-material like disintegrated weathered or very soft rock may be treated as soil. Now from literature we know that the c and ϕ values of a rock specimen is in the range of c = 35 to 175 kg/sqcm and ϕ is seldom less than 40 degree [Bowles, J. E., Foundation Analysis and Design, pp-278, 5th Edition]. When the rock is fractured so that good intact core is not recovered, it is the cohesion value that will be missed. The friction value will remain in tact.

However, to be in the safer side, a lowest probable ϕ of 37° is used for further design.

Assume size of foundation = 6m x 12m

Cohesion, C = 0.00 t/sqm

Using ϕ = 37 degree, the bearing capacity factors are:

N_c = 55.63

N_q = 42.92

N_γ = 66.19

Use,

Depth of Foundation = D_f = 1.6 M (Below Natural Ground level)

Width of Foundation = B = 6 M

Length of Foundation = L = 12 M

Overburden Pressure = q =1.600 (Depth) x 0.90 (Submerged density) = 1.44 t/sqm (Assuming the ground water table is flushing with the ground level)

The Shape factors are [IS:6403 - 1981]

S_c = 1.10 S_q = 1.10 S_γ = 0.80

The Depth factors are [IS:6403 - 1981]

D_c = 1.11 D_q = 1.05 D_γ = 1.05

Computed Net Ultimate Bearing Capacity = 220.80 t/sqm

Using a factor of safety of 2.5, Net Safe Bearing Capacity = 88.32 t/sqm

The above bearing capacity should be checked against settlement criteria.

Young's modulus, E_s for layer VI = 4000 kg/sqcm

A) General Data:

Width of foundation =	6.00	m
Length of foundation =	12.00	m
Depth of foundation =	1.60	m below NGL
Net Base Pressure =	8.8	kg/sqcm

B) Subsoil Properties:

Layer - VI

Young's Modulus =	4000	kg/sqcm
Poisson Ratio, μ =	0.25	
Top of Stratum =	1.60	m
End of Stratum =	13.60	m
Geological factor, G =	1.00	
m_{vc} =	0.0000	sqcm/kg

C) Calculation of Immediate Settlement:

Settlement at center

M = L' / B' = 2.000

N = H / B' = 4.000

I_1 = 0.476

I_2 = 0.069

$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ = 0.522

Immediate settlement S_i = 1.292 cm

$[q_o \times B' \times (1- \mu^2) \times m \times I_s] / E_s$

Settlement at corner

M = L' / B' = 2.00

N = H / B' = 2.000

I_1 = 0.289087

I_2 = 0.102416

$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ = 0.357

Immediate settlement S_i = 0.442 cm

Average S_i for Stratum VI= 8.67 mm

Total immediate settlement = 8.67 mm

So, Total Settlement = 8.67 mm

Fox's Depth correction Factor = 0.953

Applying Rigidity correction Factor 0.80

Corrected total settlement = 6.61 mm

The calculated settlement is well within permissible limit. However, let us restrict the bearing capacity to 30t/sqm for 1.60m below NGL.

DETERMINATION OF BEARING CAPACITY AROUND BALLMILL BUILDING (BH-49):

Let us place the foundation at 2.20m below NGL i.e. 2.40m below EGL i.e. 3.17m below FGL (where, NGL = 158.026 M, FGL = 159.000 M)

Founding level falls inside Stratum V i.e. highly to moderately weathered rock layer.

Weathered rock layer was encountered with moderate core recovery and almost nil RQD. The intermediate geo-material like disintegrated weathered or very soft rock may be treated as soil. Now from literature we know that the c and ϕ values of a rock specimen is in the range of c = 35 to 175 kg/sqcm and ϕ is seldom less than 40 degree [Bowles, J. E., Foundation Analysis and Design, pp-278, 5th Edition]. When the rock is fractured so that good intact core is not recovered, it is the cohesion value that will be missed. The friction value will remain in tact.

However, to be in the safer side, we treat it as dense/very dense sand and a lowest probable ϕ of 37° is used for further design.

Assume size of foundation = 10m x 20m

Cohesion, C = 0.00 t/sqm

Using ϕ = 37 degree, the bearing capacity factors are:

N_c = 55.63

N_q = 42.92

N_γ = 66.19

Use,

Depth of Foundation = D_f = 2.2 M (Below Natural Ground level)

Width of Foundation = B = 10 M

Length of Foundation = L = 20 M

Overburden Pressure = q =2.200 (Depth) x 0.90 (Submerged density) = 1.98 t/sqm (Assuming the ground water table is flushing with the ground level)

The Shape factors are [IS:6403 - 1981]

S_c = 1.10 S_q = 1.10 S_γ = 0.80

The Depth factors are [IS:6403 - 1981]

D_c = 1.09 D_q = 1.04 D_γ = 1.04

Computed Net Ultimate Bearing Capacity = 344.43 t/sqm

Using a factor of safety of 2.5, Net Safe Bearing Capacity = 137.77 t/sqm

The above bearing capacity should be checked against settlement criteria.

Young's modulus, E_s for layer V & VI = 2000 kg/sqcm & 4000 kg/sqcm respectively.

Settlement Analysis

A) General Data:

Width of foundation =	10.0	m
Length of foundation =	20.0	m
Depth of foundation =	2.20	m below NGL
Net Base Pressure =	9.0	kg/sqcm

B) Subsoil Properties:

Layer - V

Young's Modulus =	2000	kg/sqcm
Poisson Ratio, μ =	0.25	
Top of Stratum =	2.20	m
End of Stratum =	3.96	m
Geological factor, G =	1.00	
m_{vc} =	0.0000	sqcm/kg

Layer - VI

Young's Modulus =	4000	kg/sqcm
Poisson Ratio, μ =	0.25	
Top of Stratum =	3.96	m
End of Stratum =	22.20	m
Geological factor, G =	1.00	
m_{vc} =	0.0000	sqcm/kg

C) Calculation of Immediate Settlement:

Settlement at center

M = L' / B' =	2.000	
N = H / B' =	0.353	
I_1 =	0.021	
I_2 =	0.067	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =	0.066	
Immediate settlement S_i = $[q_o \times B' \times (1-\mu^2) \times m \times I_s] / E_s$	0.553	cm

Settlement at center

M = L' / B' =	1.850	
N = H / B' =	3.100	
I_1 =	0.409	
I_2 =	0.078	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =	0.461	
Immediate settlement S_i = $[q_o \times B' \times (1-\mu^2) \times m \times I_s] / E_s$	1.786	cm

Settlement at corner

M = L' / B' =	2.00	
N = H / B' =	0.176	
I_1 =	0.005457	
I_2 =	0.038617	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =	0.031	
Immediate settlement S_i =	0.132	cm

Settlement at corner

M = L' / B' =	1.85	
N = H / B' =	1.550	
I_1 =	0.223	
I_2 =	0.106	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =	0.294	
Immediate settlement S_i =	0.570	cm

Average S_i for Stratum V= 3.42 mm

Total immediate settlement = 15.20 mm

Average S_i for Stratum VI= 11.78 mm

(for both the layer)

So, Total Settlement = 15.20 mm

Fox's Depth correction Factor = 0.964

Applying Rigidity correction Factor : 0.80

Corrected total settlement = 11.72 mm

The calculated settlement is well within permissible limit. However, let us restrict the bearing capacity to 30t/sqm for 2.20m below NGL.

DETERMINATION OF BEARING CAPACITY AROUND LIMESTONE CRUSHER HOUSE (IBH-19):

Let us place the foundation at 1.40m below NGL i.e. 1.40m below EGL i.e. 1.731m below

FGL (where, NGL = 158.069 M, FGL = 158.400 M)

Founding level falls inside Stratum V i.e. highly to moderately weathered rock layer.

Use C = 0 kg/sqcm & ϕ = 37º

Assume size of foundation = 6m x 12m

Cohesion, C = 0.00 t/sqm
Using ϕ = 37 degree, the bearing capacity factors are:
N_c = 55.63
N_q = 42.92
N_γ = 66.19
Use,
Depth of Foundation = D_f = 1.4 M (Below Natural Ground level)
Width of Foundation = B = 6 M
Length of Foundation = L = 12 M
Overburden Pressure = q =1.400 (Depth) x 0.90 (Submerged density) = 1.26 t/sqm (Assuming the ground water table is flushing with the ground level)
The Shape factors are [IS:6403 - 1981]
S_c = 1.10 S_q = 1.10 S_γ = 0.80
The Depth factors are [IS:6403 - 1981]
D_c = 1.09 D_q = 1.05 D_γ = 1.05
Computed Net Ultimate Bearing Capacity = 210.68 t/sqm
Using a factor of safety of 2.5, Net Safe Bearing Capacity = 84.27 t/sqm

The above bearing capacity should be checked against settlement criteria.

Young's modulus, E_s for layer V & VI = 2000 kg/sqcm & 4000 kg/sqcm respectively.

Settlement Analysis

A) General Data:

Width of foundation =	6.0	m
Length of foundation =	12.0	m
Depth of foundation =	1.4	m below NGL
Net Base Pressure =	8.4	kg/sqcm

B) Subsoil Properties:

Layer - V

Young's Modulus =	2000	kg/sqcm
Poisson Ratio, μ =	0.25	
Top of Stratum =	1.40	m
End of Stratum =	8.75	m
Geological factor, G =	1.00	
m_{vc} =	0.0000	sqcm/kg

Layer - VI

Young's Modulus =	4000	kg/sqcm
Poisson Ratio, μ =	0.25	
Top of Stratum =	8.75	m
End of Stratum =	13.40	m
Geological factor, G =	1.00	
m_{vc} =	0.0000	sqcm/kg

C) Calculation of Immediate Settlement:

Settlement at center

M = L' / B' =	2.000	
N = H / B' =	2.450	
I_1 =	0.346	
I_2 =	0.094	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =	0.408	
Immediate settlement S_i = $[q_o \times B' \times (1-\mu^2) \times m \times I_s] / E_s$	1.930	cm

Settlement at corner

M = L' / B' =	2.00	
N = H / B' =	1.225	
I_1 =	0.165667	
I_2 =	0.111044	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =	0.240	
Immediate settlement S_i =	0.566	cm

Average S_i for Stratum V=	12.48	mm
Total immediate settlement =	13.73	mm
So, Total Settlement =	13.73	mm
Fox's Depth correction Factor =	0.961	
Applying Rigidity correction Factor :	0.80	
Corrected total settlement =	**10.55**	**mm**

Settlement at center

M = L' / B' =	1.449	
N = H / B' =	0.697	
I_1 =	0.076	
I_2 =	0.092	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =	0.138	
Immediate settlement S_i = $[q_o \times B' \times (1-\mu^2) \times m \times I_s] / E_s$	0.202	cm

Settlement at corner

M = L' / B' =	1.45	
N = H / B' =	0.348	
I_1 =	0.022	
I_2 =	0.065	
$I_s = I_1 + \{(1-2\mu) / (1-\mu)\} I_2$ =	0.065	
Immediate settlement S_i =	0.048	cm

Average S_i for Stratum VI=	1.25	mm
(for both the layer)		

The calculated settlement is well within permissible limit. However, let us restrict the bearing capacity to 30t/sqm for 1.40m below NGL.

5.05. SWELLING CHARACTERISTICS:

The swelling pressure and Free Swell Index tests were performed on a few samples and the test results are presented at the end of the Appendix. The average swelling pressure and Free Swell Index as found from the tests are 0.052kg/sqcm and 9.03% respectively.

5.06. FIELD PERMEABILITY TEST RESULTS:

Field permeability test was conducted at different depths by falling head and double packer method and the test results are presented below. Sample calculations are also enclosed at the end of the Appendix.

Test Locations	Type of Test	Depth of Test (M)	Permeability (cm/sec)
BH-01	Falling Head	0.80 – 1.50	3.269×10^{-5}
	Falling Head	2.70 – 3.50	2.650×10^{-5}
	Falling Head	4.80 – 5.60	1.951×10^{-5}
	Double Packer	7.50 – 9.00	1.138×10^{-4}
	Double Packer	11.70 – 12.50	1.299×10^{-4}
BH-16	Falling Head	0.80 – 1.30	1.587×10^{-6}
	Falling Head	2.70 - 3.40	2.665×10^{-6}
	Falling Head	4.80 – 5.50	1.623×10^{-5}
	Double Packer	7.50 – 9.00	7.790×10^{-5}
	Double Packer	11.50 – 13.00	6.164×10^{-5}
BH-28	Falling Head	0.80 – 1.50	1.857×10^{-5}
	Falling Head	2.80 – 3.60	1.547×10^{-5}
	Double Packer	4.50 – 6.00	1.600×10^{-4}
	Double Packer	7.50 – 9.00	1.052×10^{-4}
	Double Packer	11.00 – 12.50	7.000×10^{-5}
BH-38	Falling Head	0.50 – 1.20	2.647×10^{-5}
	Falling Head	2.50 – 3.30	2.626×10^{-5}
	Double Packer	4.50 – 6.00	1.748×10^{-4}
	Double Packer	7.50 – 9.00	1.480×10^{-4}
	Double Packer	11.50 – 13.00	6.116×10^{-5}
IBH-06	Falling Head	0.80 – 1.50	3.065×10^{-5}
	Falling Head	2.70 – 3.40	6.817×10^{-5}
	Falling Head	4.30 – 5.00	3.394×10^{-5}

5.08. STANDARD PROCTOR COMPACTION & CBR TEST:

Standard Proctor Compaction tests were carried out in the laboratory to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). Thereafter, CBR (4 days soaked) tests were carried out on the samples prepared at 95% of MDD. The test results and graphs are presented in the Appendix.

5.09. CHEMICAL TESTS:

Chemical tests were performed on few soil and water samples for determining the pH value, Sulphate, Chloride content etc.

CHEMICAL TEST RESULTS ON SOIL SAMPLES:-

BH/Sample No.	Depth (m)	pH value	Sulphate as SO_3 (%)	Chloride as Cl (%)	Organic Matter (%)	Carbonate as Co_3 (%)
BH-02 / UDS01	2.50	7.23	0.060	0.026	0.3648	15.048
BH-05 / DS02	1.00	8.41	B.D.L.*	0.007	0.1890	7.284
BH-15 / UDS01	2.50	7.32	B.D.L.*	0.012	0.9915	23.256
BH-16 / UDS01	2.50	7.43	B.D.L.*	0.010	1.2481	19.380
BH-32 / DS01	0.50	7.67	B.D.L.*	0.006	0.8685	6.372
BH-47 / DS02	1.00	7.66	B.D.L.*	0.006	0.3825	5.004
IBH-11 / SPT03	4.50	7.95	0.050	0.008	0.1035	5.232
CHST03 / SPT01	1.50	7.60	0.050	0.012	0.2564	4.092

CHEMICAL TEST RESULTS ON WATER SAMPLES:-

BH/Sample No.	Depth (M)	pH value	Sulphate as (mg/litre)	Chloride as (mg/litre)	Organic Matter (mg/litre)	Carbonate (mg/litre)	Nitrate (mg/litre)
BH-15	4.80	6.98	120	78	8.78	14	0.12
BH-23	3.15	7.03	60	34	6.59	16	0.10
BH-43	3.65	6.99	60	36	6.59	14	0.12
IBH-09	5.45	7.14	120	119	10.98	15	0.14

Note: * - **B.D.L.** = **B**elow **D**etection **L**imit (i.e. below 0.050%)

It is seen that the values are on a safer side and so no special cement will be required for foundation concrete. **Either Ordinary Portland cement or Portland slag cement or Portland Pozzolana cement can be used for the purpose.**

5.10. SUITABILITY OF EXISTING SOIL FOR FILLING AND BACK-FILLING:

The subsoil at the site is inorganic in nature & consists of silty sand / silty clay (CI type soil) with sand having low swelling properties. The swelling pressure also varies from 0.01 kg/sqcm to 0.07 kg/sqcm. So, the soil can be used for filling and backfilling purposes with necessary compaction as required. The soil can be easily compacted and will easily attain an average dry density (by standard proctor) of 1.80 gm/cc and above.

5.11. SUITABILITY OF SOIL FOR CONSTRUCTION OF ROADS & PAVEMENT:

In the laboratory, standard proctor compaction tests were performed, using samples collected at a depth varying from 1.00-3.00m below ground level. The MDD ranges between 1.755 gm/cc to 1.866 gm/cc.

Laboratory CBR tests were performed on remoulded soil samples (compacted at 95% of MDD) under soaked (4days soaking) condition. The CBR values are in the range of 6% to 12% for soaked condition. For design of pavement, a lowest probable of 6% may be used.