ANNEXURE - III

Bearing capacity factors :

ϕ	30.00
N_c	30.14
N_q	18.40
N_γ	22.40

ϕ'	21.15
N'_c	16.18
N'_q	7.38
N'_γ	6.65

Shape factors :

S.no.	Width(m)	S_c	S_q	S_γ
1	1.20	1.00	1.00	1.00
2	1.20	1.00	1.00	1.00
3	1.20	1.00	1.00	1.00
4	1.20	1.00	1.00	1.00

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	1.20	1.43	1.22	1.22
2	3.00	1.20	1.87	1.43	1.43
3	4.50	1.20	2.30	1.65	1.65
4	6.00	1.20	2.73	1.87	1.87

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1- \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	1.20	0.00	0.50
2	3.00	1.20	-1.25	0.50
3	4.50	1.20	-2.50	0.50
4	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	SBC in (t/m^2)		
			General shea	Local shear	Actual
1	1.50	1.20	19.79	6.88	19.79
2	3.00	1.20	23.31	8.10	23.31
3	4.50	1.20	26.83	9.33	26.83
4	6.00	1.20	30.36	10.55	30.36

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ANNEXURE - IV

Settlement Calculation for Cohesionless Soil As per IS 8009 (Part 1)	
Location	Minor Bridge No. 368
Chainage	332/15-17
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	20.00
Average N value	18.16
Settlement for 10 t/m2 (mm)	13.40
Total Settlement (mm)	26.80
Depth Correction	0.83
Rigidity Correction	0.8
Corrected Total Settlement (mm)	17.8

Footing Depth (m)	3.00
SBC (t/m2)	23.00
Average N value	20.00
Settlement for 10 t/m2 (mm)	13.00
Total Settlement (mm)	29.90
Depth Correction	0.73
Rigidity Correction	0.8
Corrected Total Settlement (mm)	17.5

Footing Depth (m)	4.50
SBC (t/m2)	26.00
Average N value	27.00
Settlement for 10 t/m2 (mm)	11.00
Total Settlement (mm)	28.60
Depth Correction	0.675
Rigidity Correction	0.8
Corrected Total Settlement (mm)	15.4

Footing Depth (m)	6.00
SBC (t/m2)	28.00
Average N value	27.00
Settlement for 10 t/m2 (mm)	11.00
Total Settlement (mm)	30.80
Depth Correction	0.63
Rigidity Correction	0.8
Corrected Total Settlement (mm)	15.5

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CHAPTER - 17

"Minor Bridge No. 367",

Location – Existing Km. - 332/01-03

17.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x1.2x1.2

17.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL of existing GL shown in **FIGURE-1**.

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ≥18.00m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 1.50	Sandy Silt with Clay	Loose
	1.50 to 3.00	Sandy Silt with Clay	Medium Dense
	3.00 to 9.00	Silty Sand	Medium Dense
	9.00 to 12.00	Silty Sand	Dense

17.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.20	0.0020	0.0012	NIL	0.0010	0.029
	4.50	9.00	0.012	0.0021	NIL	0.0013	0.037

17.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	4.50	NIL

17.5 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	6.00
	3.00	12.00
	4.50	14.00
	6.00	16.00

17.6 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.

17.7 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 4.50m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.

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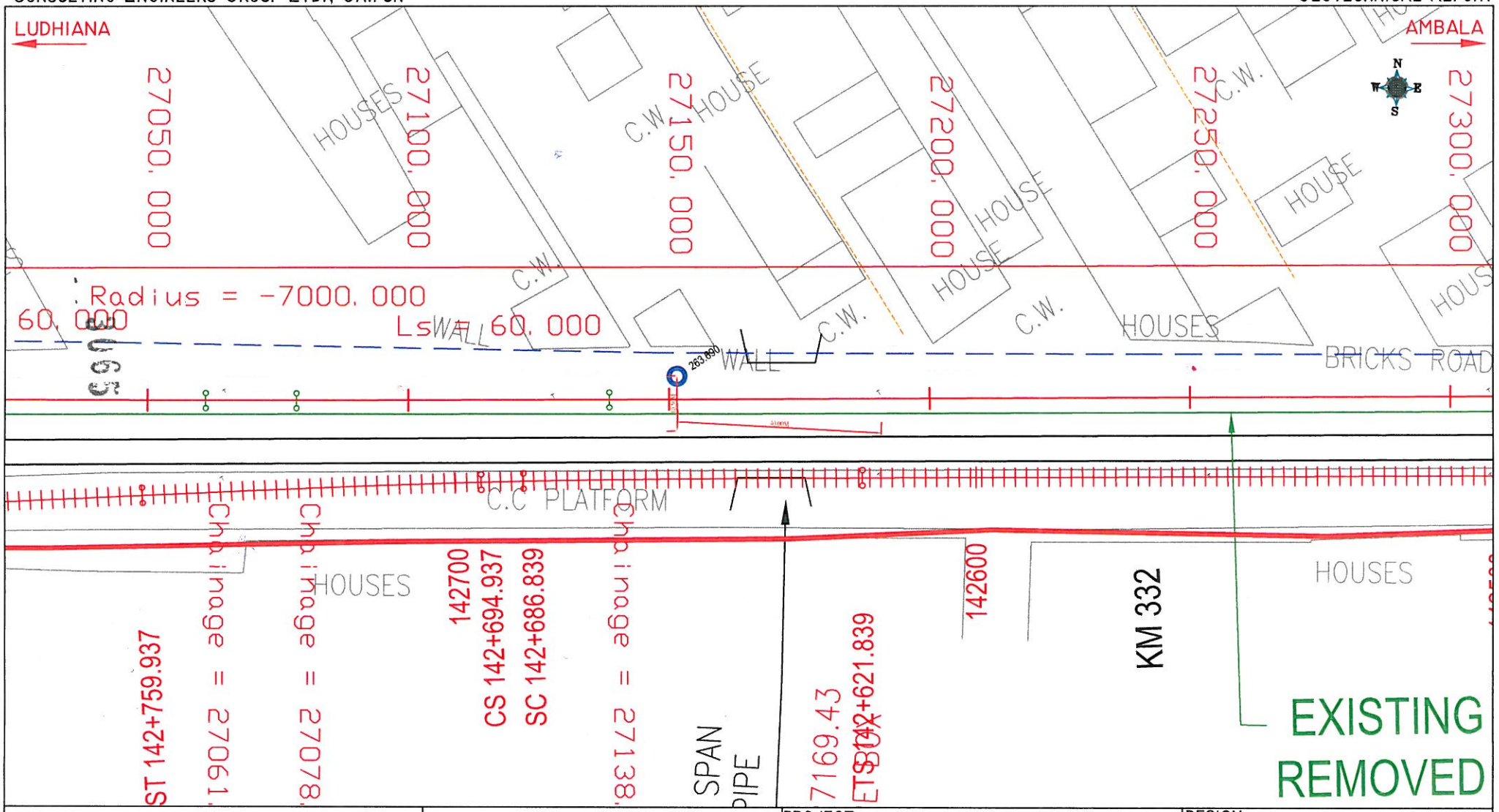

ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 332/1-3	RL OF BH-I = 263.690	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1(LHS) FOR MINOR BRIDGE No. 367 AT CHAINAGE 332/1-3

Project :	Chainage 332/1-3 Bridge No. 367			Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
				03.06.2009 to 03.06.2009	1	1 (LHS)	below 18.00 m.	12.00mtr	263.690

Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel									Gravity	c kg/cm^2	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Sandy Silt with Clay	12.36	61.70	20.68	2.19	0.68	2.39	0	30	20	10	-	-	-	-	-	-
1.50	11	1.45	15.95	Sandy Silt with Clay	10.15	59.44	23.46	1.47	1.51	3.97	0.00	25	16	9	-	-	-	-	-	-
3.00	20	1.22	24.40	Silty Sand	1.51	19.02	76.19	1.94	0.14	1.20	0.00	22	NIL	NP	-	-	-	-	-	-
4.50	UDS	-	-	Silty Sand	4.21	13.31	80.52	1.18	0.78	0.00	0.00	29	NIL	NP	1.76	9.60	1.61	2.64	0.00	27.50
6.00	28	0.98	27.44	Silty Sand	1.18	25.03	71.68	1.46	0.33	0.32	0.00	23	NIL	NP	-	-	-	-	-	-
9.00	31	0.85	26.35	Silty Sand	0.00	5.77	86.77	7.36	0.05	0.05	0.00	22	NIL	NP	-	-	-	-	-	-
12.00	38	0.75	28.50	Silty Sand	1.36	5.22	89.94	3.48	0.00	0.00	0.00	26	NIL	NP	-	-	-	-	-	-

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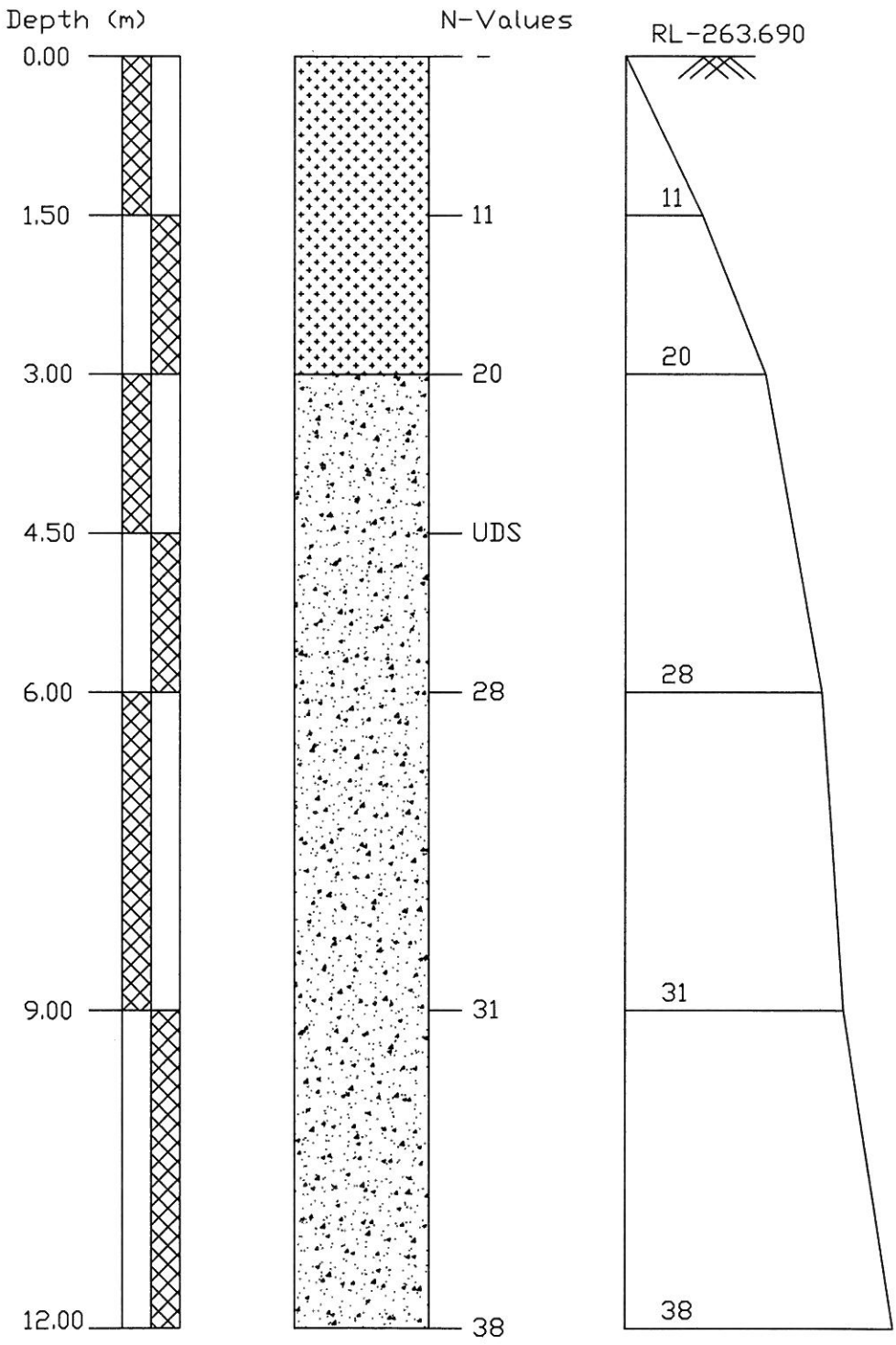
BORELOG OF BH–1(LHS) AT EXISTING KM–332/1–3 FOR MINOR BRIDGE NO.–367,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SANDY SILT WITH CLAY
	SILTY SAND

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 332/1-3 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Continuous Strip | 1

Angle of internal friction (ϕ°)	22.00
Cohesion (c in t/m2)	0.11
Void ratio (e)	0.63
Direction of load with vertical ($^\circ$)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.76
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)
1	1.50	1.20

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	22.00
N_c	17.19
N_q	8.10
N_γ	7.59

ϕ'	15.15
N'_c	11.09
N'_q	4.01
N'_γ	2.73

Shape factors :

S.no.	Width(m)	S_c	S_q	S_γ
1	1.20	1.00	1.00	1.00

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	1.20	1.37	1.19	1.19

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1- \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	1.20	0.00	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	SBC in (t/m^2)		
			General shea	Local shear	Actual
1	1.50	1.20	8.17	3.37	6.25

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 332/1-3 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Continuous Strip | **1**

Angle of internal friction (ϕ °)	27.50
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.63
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.76
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)
1	3.00	1.20
2	4.50	1.20
3	6.00	1.20

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	27.50
N_c	25.43
N_q	14.53
N_γ	16.64

ϕ'	19.23
N'_c	14.24
N'_q	6.02
N'_γ	4.97

Shape factors :

S.no.	Width(m)	S_c	S_q	S_γ
1	1.20	1.00	1.00	1.00
2	1.20	1.00	1.00	1.00
3	1.20	1.00	1.00	1.00

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	3.00	1.20	1.82	1.41	1.41
2	4.50	1.20	2.24	1.62	1.62
3	6.00	1.20	2.65	1.82	1.82

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1-\alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	3.00	1.20	-1.25	0.50
2	4.50	1.20	-2.50	0.50
3	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	SBC in (t/m^2)		
			General shea	Local shear	Actual
1	3.00	1.20	17.13	6.05	12.70
2	4.50	1.20	19.62	6.94	14.55
3	6.00	1.20	22.12	7.82	16.40

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ANNEXURE - IV

Settlement Calculation for Cohesionless Soil As per IS 8009 (Part 1)	
Location	Minor Bridge No. 367
Chainage	332/1-3
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	6.00
Average N value	15.95
Settlement for 10 t/m2 (mm)	15.80
Total Settlement (mm)	9.48
Depth Correction	0.83
Rigidity Correction	0.8
Corrected Total Settlement (mm)	6.3

Footing Depth (m)	3.00
SBC (t/m2)	12.00
Average N value	24.00
Settlement for 10 t/m2 (mm)	10.00
Total Settlement (mm)	12.00
Depth Correction	0.73
Rigidity Correction	0.8
Corrected Total Settlement (mm)	7.0

Footing Depth (m)	4.50
SBC (t/m2)	14.00
Average N value	26.00
Settlement for 10 t/m2 (mm)	7.80
Total Settlement (mm)	10.92
Depth Correction	0.675
Rigidity Correction	0.8
Corrected Total Settlement (mm)	5.9

Footing Depth (m)	6.00
SBC (t/m2)	16.00
Average N value	26.00
Settlement for 10 t/m2 (mm)	7.80
Total Settlement (mm)	12.48
Depth Correction	0.63
Rigidity Correction	0.8
Corrected Total Settlement (mm)	6.3

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CHAPTER – 18

"Minor Bridge No. 366A",

Location – Existing Km. - 328/01-03

18.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge No. 366 A at Chainage 328/1-3

18.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL of existing GL shown in **FIGURE-1**.

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ≥20.00m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 1.50	Sandy Silt with Clay	Loose
	1.50 to 3.00	Silty Sand	Loose
	3.00 to 4.50	Silty Sand with gravels	Medium Dense
	4.50 to 6.00	Silty Sand	Medium Dense
	6.00 to 7.50	Sandy Silt	Medium Dense
	7.50 to 10.50	Silty Sand	Medium Dense
	10.50 to 12.00	Silty Sand	Dense

18.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.60	0.005	0.0021	NIL	0.0012	0.037

18.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

18.5 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	11.00
	3.00	16.00
	4.50	18.00
	6.00	21.00

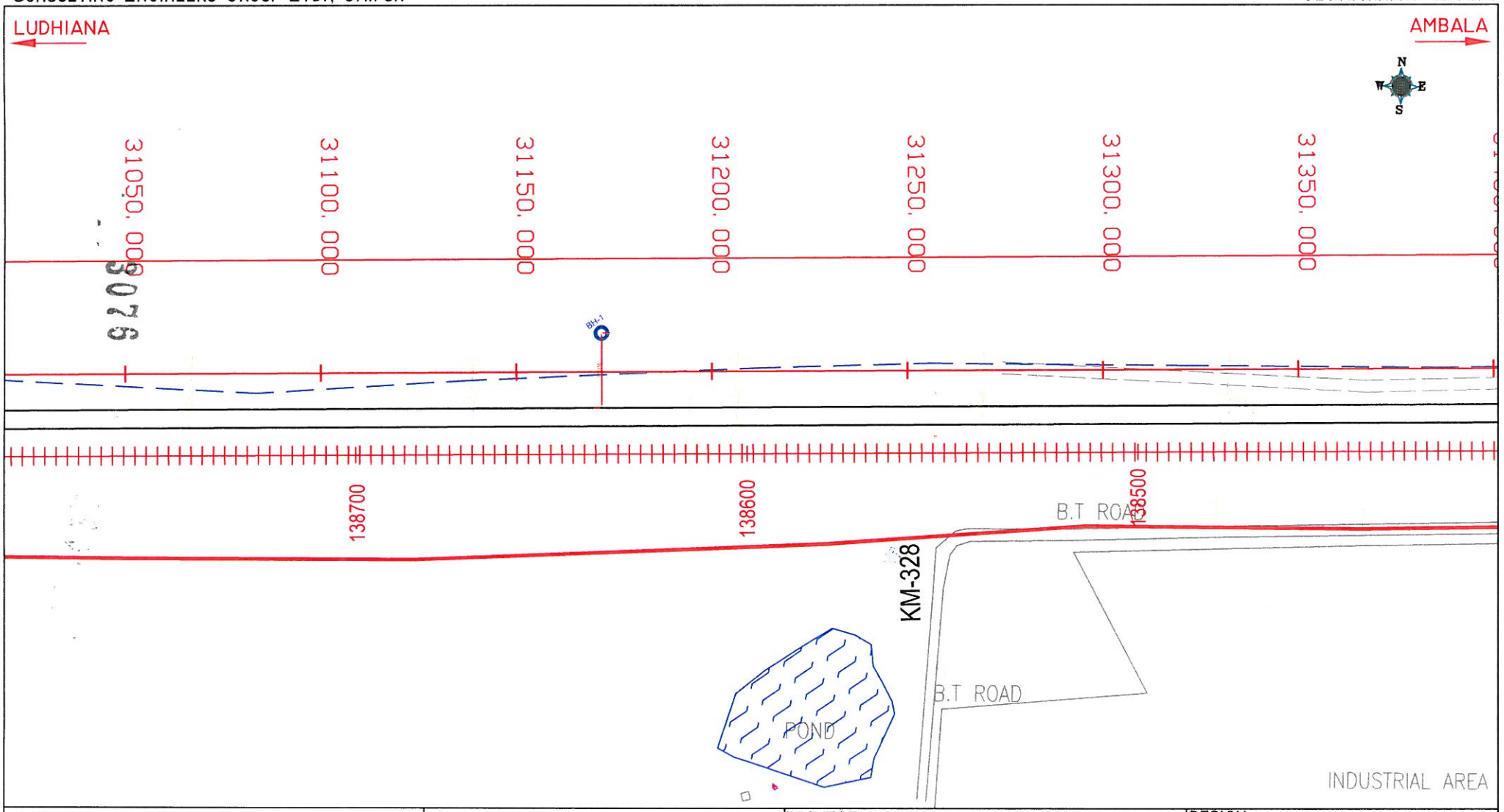
18.6 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.

18.7 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 3.00m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER

FIG.:-I
LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 328/1-3

RL OF BH-I = 263.454

PROJECT :-
LUDHIANA-AMBALA (DFCCIL)

DESIGN :-
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E-12,Moji Colony,Malviya Nagar Jaipur-17
Tel: +91-141- 2520899, 2521899, 2520556
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ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1(LHS) FOR MINOR BRIDGE No. 366-A AT CHAINAGE 328/2-3

Project :	Chainage 328/2-3 Bridge No. 366-A			Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
				04.06.2009 to 04.06.2009	1	1(LHS)	below 20.00 m.	12.00mtr	263.454

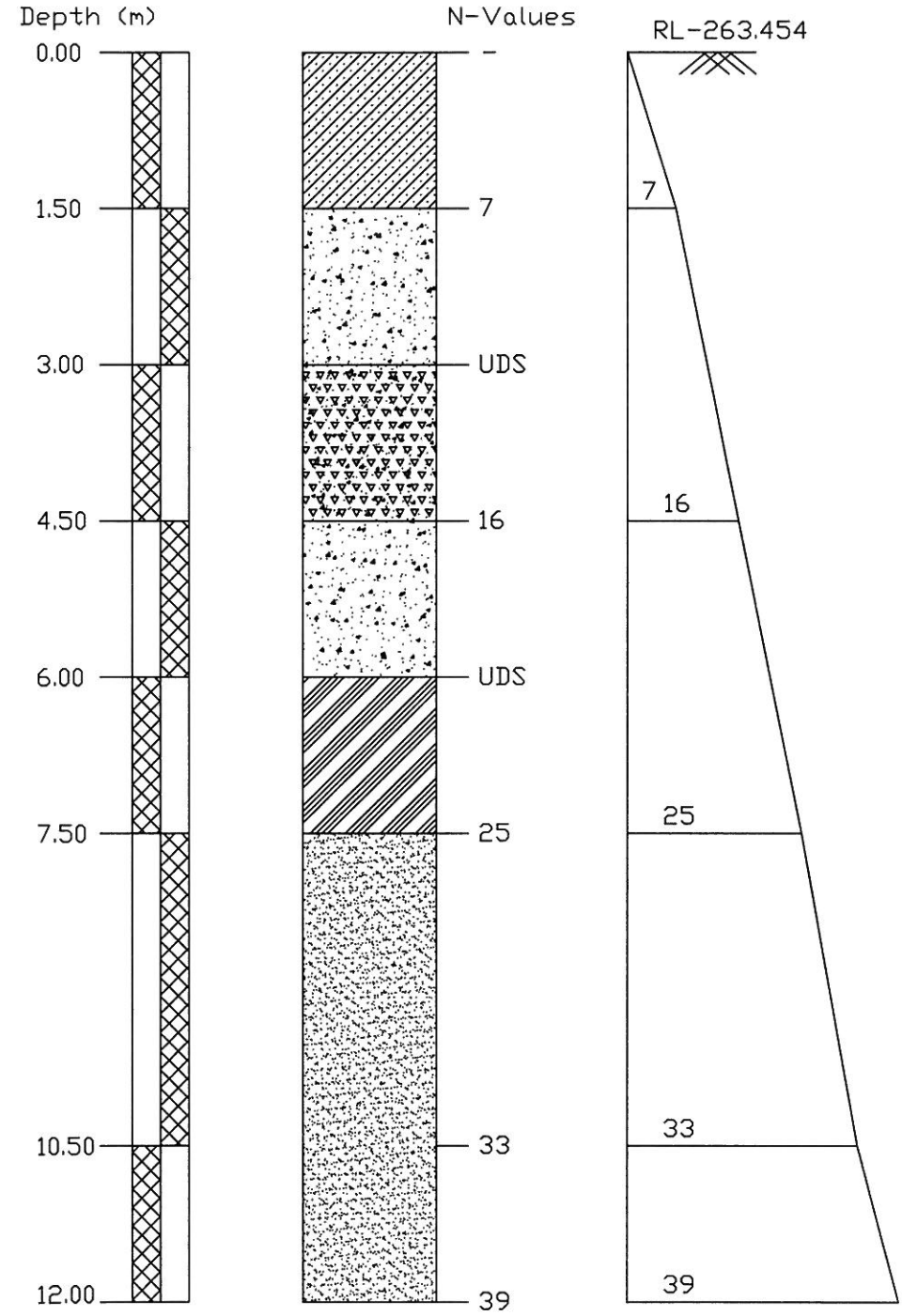
Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained							Atterberg Limits %			B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength	
					Clay	Silt	Sand			Gravel										c kg/cm^2	ϕ degree
							Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.						
0.00	-	-	-	Silty Sand with clay	13.16	21.38	60.32	3.93	1.21	0.00	0.00	32	22	10	-	-	-	-	-	-
1.50	7	1.44	10.08	Silty Sand	2.19	11.06	84.08	2.43	0.24	0.00	0.00	23	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand with Gravels	3.15	6.56	72.53	6.04	4.50	7.22	0.00	27	NIL	NP	1.82	6.10	1.72	2.66	0.00	27.50
4.50	16	1.07	17.12	Silty Sand	3.11	7.93	72.82	15.77	0.37	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Sandy Silt	4.11	81.81	11.54	0.60	1.94	0.00	0.00	27	NIL	NP	1.65	4.26	1.58	2.67	0.00	27.50
7.50	25	0.91	22.75	Sand	2.64	6.92	66.98	22.08	1.38	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
10.50	33	0.80	26.40	Sand	0.00	3.96	73.45	21.32	1.27	0.00	0.00	23	NIL	NP	-	-	-	-	-	-
12.00	28	0.80	22.32	Sand	0.00	4.21	73.13	21.29	1.37	0.00	0.00	24	NIL	NP	-	-	-	-	-	-

DOCCIL KESARI TO SANEHWAL

CONSULTING Engineers Group Ltd.

BORELOG OF BH–1(LHS) AT EXISTING KM–328/1–3 FOR MINOR BRIDGE NO.–366 A,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND WITH CLAY
	SILTY SAND
	SILTY SAND WITH GRAVELS
	SANDY SILT
	SAND

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 328/2-3 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Continuous Strip | 1

Angle of internal friction (ϕ °)	27.50
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.55
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.65
Density of foundation soil (t/m^3)	1.65
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)
1	1.50	1.20
2	3.00	1.20
3	4.50	1.20
4	6.00	1.20

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	27.50
N_c	25.43
N_q	14.53
N_γ	16.64

ϕ'	19.23
N'_c	14.24
N'_q	6.02
N'_γ	4.97

Shape factors :

S.no.	Width(m)	S_c	S_q	S_γ
1	1.20	1.00	1.00	1.00
2	1.20	1.00	1.00	1.00
3	1.20	1.00	1.00	1.00
4	1.20	1.00	1.00	1.00

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	1.20	1.41	1.21	1.21
2	3.00	1.20	1.82	1.41	1.41
3	4.50	1.20	2.24	1.62	1.62
4	6.00	1.20	2.65	1.82	1.82

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1-\alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	1.20	0.00	0.50
2	3.00	1.20	-1.25	0.50
3	4.50	1.20	-2.50	0.50
4	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	SBC in (t/m^2)		
			General shea	Local shear	Actual
1	1.50	1.20	14.08	4.98	14.08
2	3.00	1.20	16.49	5.84	16.49
3	4.50	1.20	18.89	6.69	18.89
4	6.00	1.20	21.30	7.54	21.30

ANNEXURE - IV

Settlement Calculation for Cohesionless Soil As per IS 8009 (Part 1)	
Location	Minor Bridge No. 366A
Chainage	328/2-3
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	11.00
Average N value	11.84
Settlement for 10 t/m2 (mm)	30.00
Total Settlement (mm)	33.00
Depth Correction	0.91
Rigidity Correction	0.8
Corrected Total Settlement (mm)	24.0

Footing Depth (m)	3.00
SBC (t/m2)	16.00
Average N value	16.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	28.80
Depth Correction	0.83
Rigidity Correction	0.8
Corrected Total Settlement (mm)	19.1

Footing Depth (m)	4.50
SBC (t/m2)	18.00
Average N value	18.00
Settlement for 10 t/m2 (mm)	15.00
Total Settlement (mm)	27.00
Depth Correction	0.74
Rigidity Correction	0.8
Corrected Total Settlement (mm)	16.0

Footing Depth (m)	6.00
SBC (t/m2)	21.00
Average N value	20.00
Settlement for 10 t/m2 (mm)	15.00
Total Settlement (mm)	31.50
Depth Correction	0.68
Rigidity Correction	0.8
Corrected Total Settlement (mm)	17.1

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CHAPTER – 19

"Minor Bridge No. 365A",

Location – Existing Km. - 326/01-03

19.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge No. 365A at Chainage 326/01-03

19.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL of existing GL shown in **FIGURE-1**.

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ≥18.00m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 1.50	Sandy Silt with Clay	Loose
	1.50 to 4.50	Silty Sand with Gravels	Medium Dense
	4.50 to 10.50	Silty Sand	Medium Dense
	10.50 to 12.00	Silty Sand	Dense

19.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.50	0.005	0.0014	NIL	0.0011	0.022
	6.00	9.00	0.010	0.0011	NIL	0.0010	0.020

19.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

19.5 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	9.00
	3.00	10.50
	4.50	12.00
	6.00	13.50

19.6 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.

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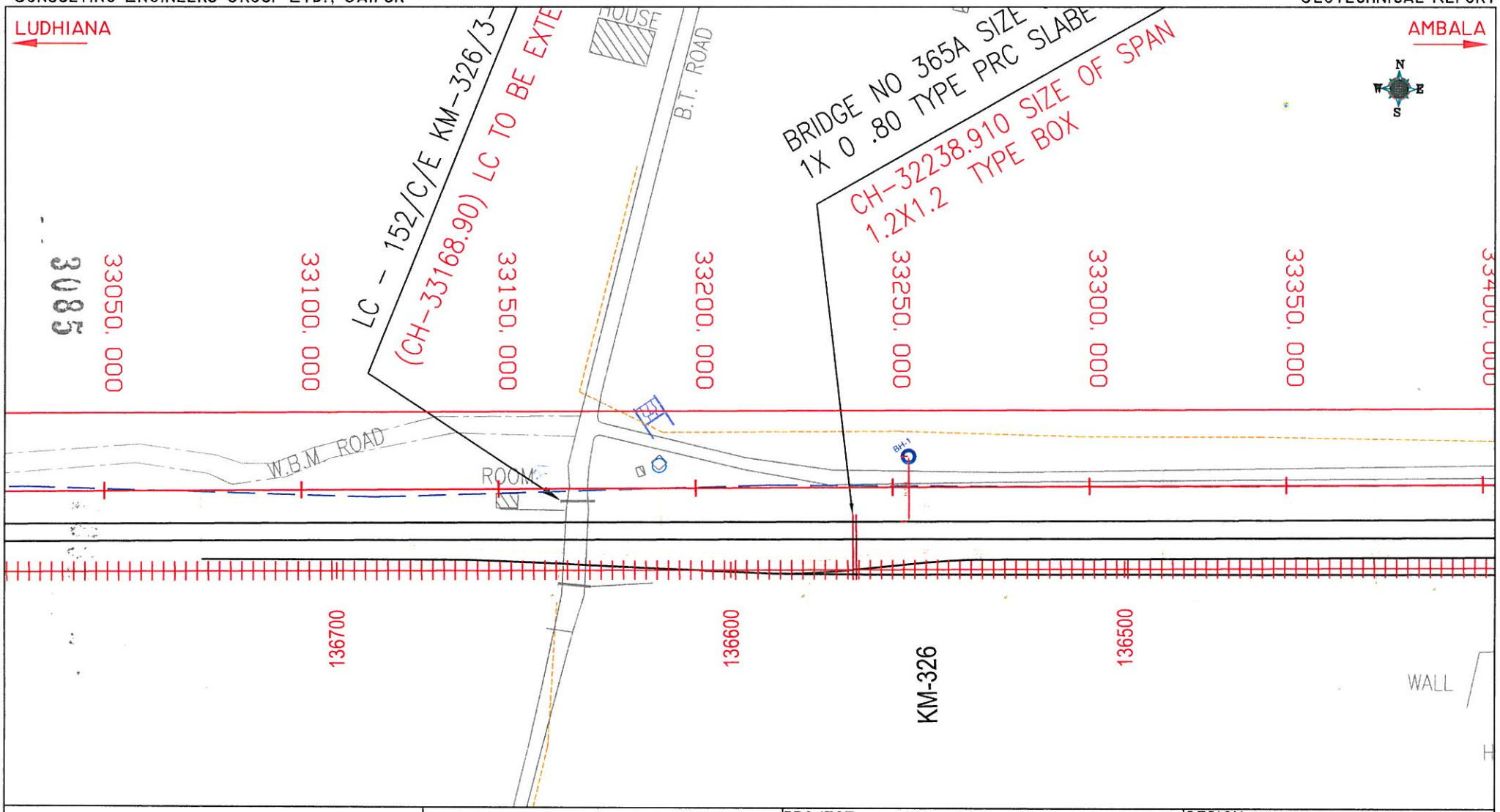
19.7 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 3.00m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 326/1-3	RL OF BH-I = 263.877	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax. 2521348, E-Mail: ceg@cegindia.com

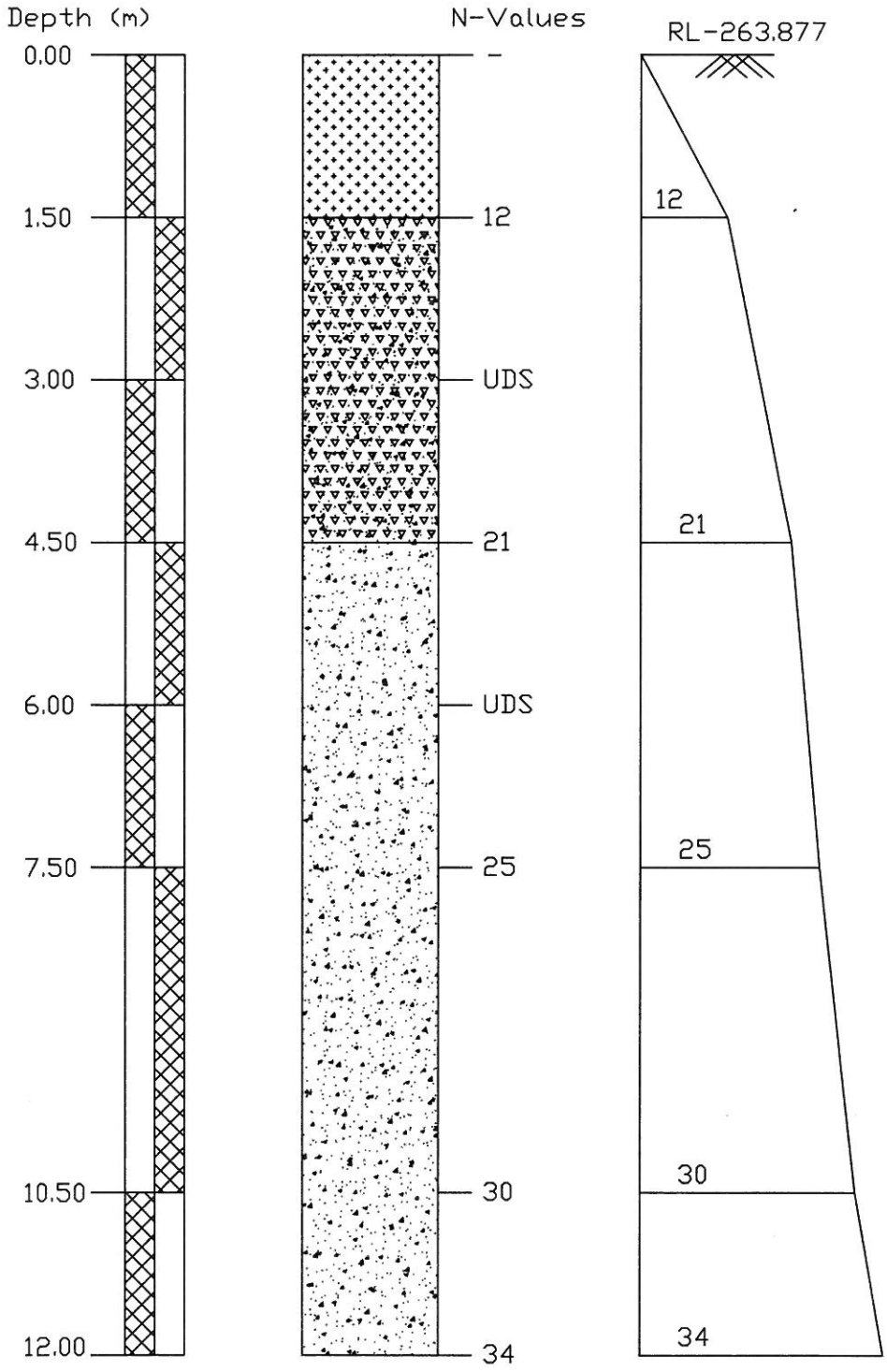
ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1(LHS) FOR MINOR BRIDGE No. 365-A AT CHAINAGE 326/1-3

Project :	Chainage 326/1-3 Bridge No. 365-A			Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
				05.06.2009 to 05.06.2009	1	1(LHS)	below 18.00 m.	12.00mtr	263.877

Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm^2	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Sandy Silt with clay	12.20	62.57	15.39	6.36	1.59	0.69	1.2	31	21	10	-	-	-	-	-	-
1.50	12	1.46	17.52	Silty Sand with Gravels	3.22	22.53	64.15	1.10	2.13	6.87	0.00	21	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand with Gravels	2.11	9.73	78.74	1.52	0.87	7.03	0.00	26	NIL	NP	1.70	8.97	1.56	2.61	0.00	27.00
4.50	21	1.09	22.89	Silty Sand	3.18	6.12	87.72	2.91	0.07	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	2.18	8.98	82.68	4.60	0.65	0.91	0.00	25	NIL	NP	1.89	15.01	1.64	2.65	0.00	27.00
7.50	25	0.91	22.75	Silty Sand	3.18	5.45	85.65	5.28	0.31	0.13	0.00	27	NIL	NP	-	-	-	-	-	-
10.50	30	0.79	23.70	Silty Sand	1.66	7.08	87.46	3.20	0.27	0.33	0.00	27	NIL	NP	-	-	-	-	-	-
12.00	34	0.74	20.08	Silty Sand	2.37	6.37	82.97	6.60	1.69	0.00	0.00	27	NIL	NP	-	-	-	-	-	-

BORELOG OF BH–1(LHS) AT EXISTING KM–326/1–3 FOR MINOR BRIDGE NO.–365 A, ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SANDY SILT WITH CLAY
	SILTY SAND WITH GRAVELS
	SILTY SAND

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 326/1-9 BH-1

Type of footing

1	Continuous Strip		
2	Rectangular	***Continuous Strip***	1
3	Square		
4	Circular		

Angle of internal friction (ϕ°)	27.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.66
Direction of load with vertical ($^\circ$)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.89
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)
1	1.50	1.20
2	3.00	1.20
3	4.50	1.20
4	6.00	1.20

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	27.00
N_c	24.49
N_q	13.76
N_γ	15.49

ϕ'	18.85
N'_c	13.94
N'_q	5.83
N'_γ	4.76

Shape factors :

S.no.	Width(m)	S_c	S_q	S_γ
1	1.20	1.00	1.00	1.00
2	1.20	1.00	1.00	1.00
3	1.20	1.00	1.00	1.00
4	1.20	1.00	1.00	1.00

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	1.20	1.41	1.20	1.20
2	3.00	1.20	1.82	1.41	1.41
3	4.50	1.20	2.22	1.61	1.61
4	6.00	1.20	2.63	1.82	1.82

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1-\alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	1.20	0.00	0.50
2	3.00	1.20	-1.25	0.50
3	4.50	1.20	-2.50	0.50
4	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	SBC in (t/m^2)		
			General shea	Local shear	Actual
1	1.50	1.20	13.97	5.04	9.06
2	3.00	1.20	16.33	5.89	10.59
3	4.50	1.20	18.70	6.75	12.13
4	6.00	1.20	21.07	7.60	13.66

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ANNEXURE - IV

Settlement Calculation for Cohesionless Soil As per IS 8009 (Part 1)	
Location	Minor Bridge No. 365A
Chainage	326/1-3
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	9.00
Average N value	19.51
Settlement for 10 t/m2 (mm)	15.00
Total Settlement (mm)	13.50
Depth Correction	0.91
Rigidity Correction	0.8
Corrected Total Settlement (mm)	9.8

Footing Depth (m)	3.00
SBC (t/m2)	10.50
Average N value	22.05
Settlement for 10 t/m2 (mm)	13.80
Total Settlement (mm)	14.49
Depth Correction	0.83
Rigidity Correction	0.8
Corrected Total Settlement (mm)	9.6

Footing Depth (m)	4.50
SBC (t/m2)	12.00
Average N value	23.28
Settlement for 10 t/m2 (mm)	13.10
Total Settlement (mm)	15.72
Depth Correction	0.74
Rigidity Correction	0.8
Corrected Total Settlement (mm)	9.3

Footing Depth (m)	6.00
SBC (t/m2)	13.50
Average N value	23.71
Settlement for 10 t/m2 (mm)	12.70
Total Settlement (mm)	17.15
Depth Correction	0.68
Rigidity Correction	0.8
Corrected Total Settlement (mm)	9.3

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CHAPTER – 20

"Minor Bridge No. 365",

Location – Existing Km. - 325/25-27

20.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge No. 365 at Chainage 325/25-27

20.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL of existing GL shown in **FIGURE-1**.

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ≥18.00m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 3.00	Sandy Silt with Clay	Loose
	3.00 to 7.50	Sixty Sand	Medium Dense
	7.50 to 12.00	Silty Sand	Dense
	Below 12.00	Sand	Dense

20.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.70	0.010	0.0018	NIL	0.0011	0.027
	6.00	8.70	0.015	0.0021	NIL	0.0012	0.039

20.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

20.5 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m^2)
BH-1	1.50	10.00
	3.00	11.00
	4.50	13.00
	6.00	15.00

20.6 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.

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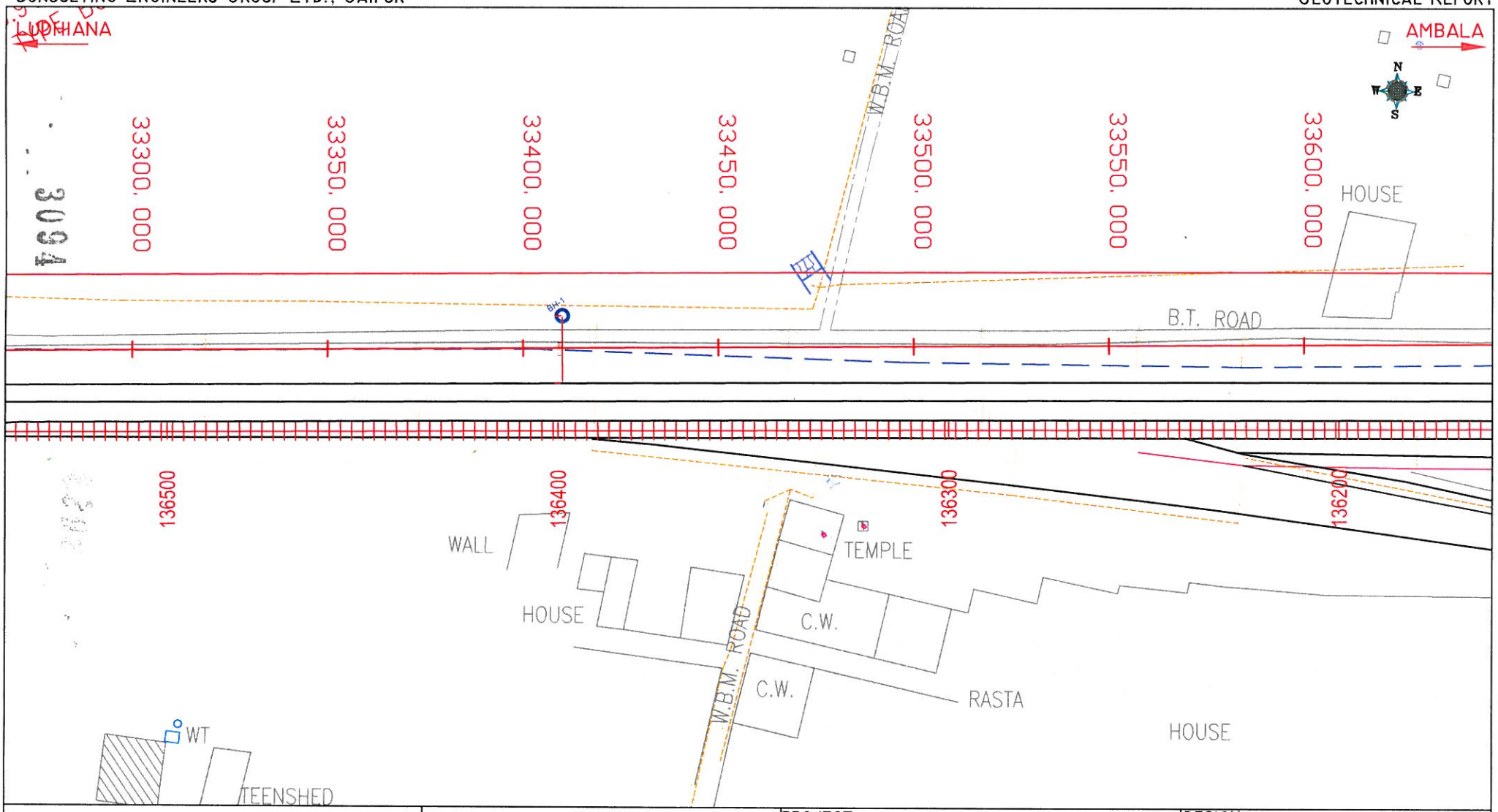
20.7 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 3.00m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER

FIG.:-I

LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 325/25-27

RL OF BH-I = 263.826

PROJECT :-

LUDHIANA-AMBALA (DFCCIL)

DESIGN :-

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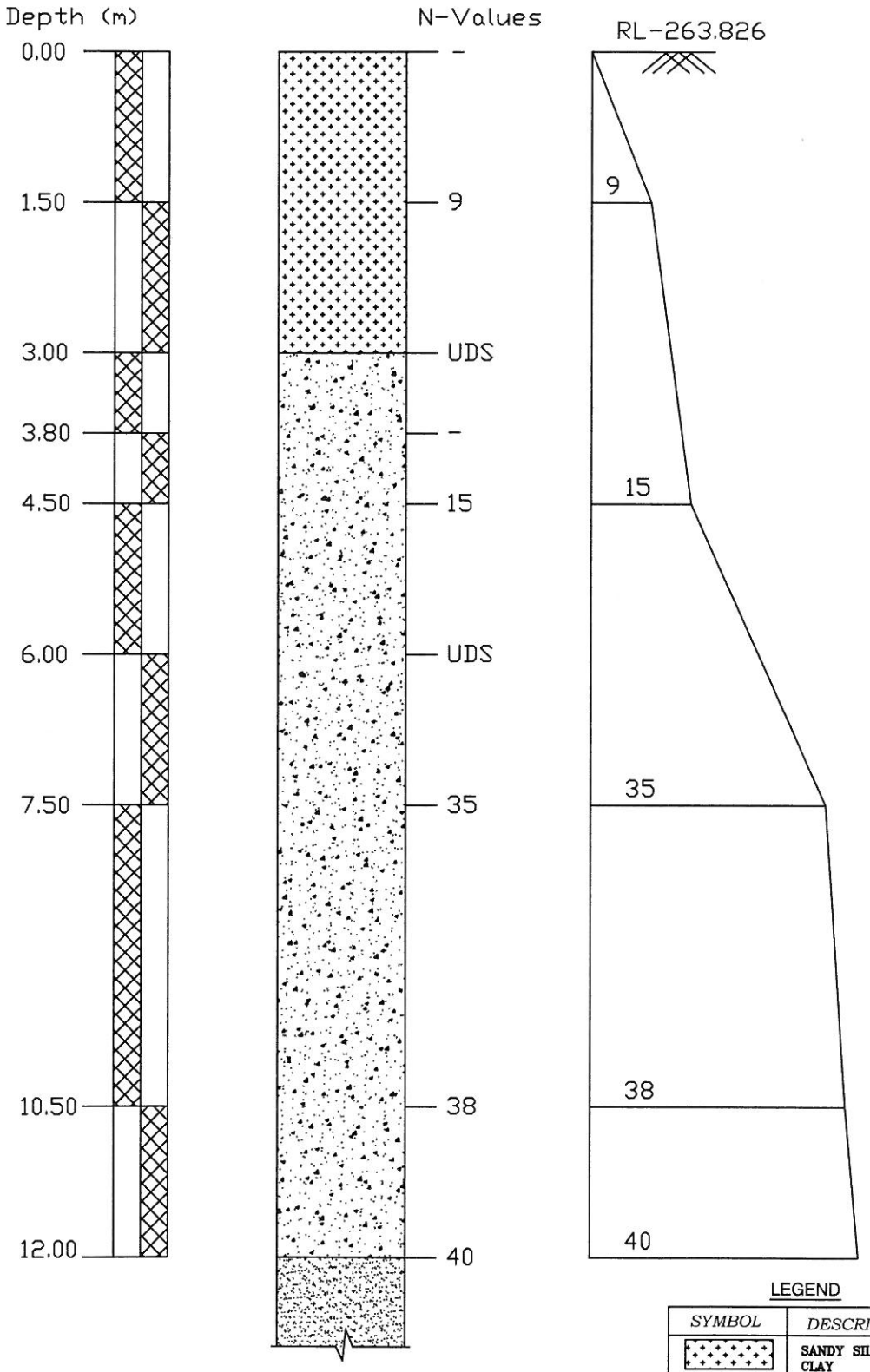
ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1(LHS) FOR MINOR BRIDGE No. 365 AT CHAINAGE 325/25-27

Project :	Chainage 325/25-27 Bridge No. 365			Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
				05.06.2009 to 05.06.2009	1	1(LHS)	below 18.00 m.	12.00mtr	263.826

Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm^2	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Sandy Silt with Clay	10.69	51.13	20.39	14.26	2.33	1.20	0.00	22	14	8	-	-	-	-	-	-
1.50	9	1.43	12.87	Sandy Silt with Clay	11.22	42.74	40.51	0.72	0.30	4.30	0.21	22	13	9	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	4.52	7.19	86.30	1.12	0.24	0.63	0.00	29	NIL	NP	1.88	10.86	1.70	2.65	0.00	26.00
3.80				Silty Sand	3.11	18.01	74.56	3.74	0.58	0.00	0.00	25	NIL	NP						
4.50	15	1.06	15.90	Silty Sand	2.52	6.65	85.11	5.40	0.32	0.00	0.00	24	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	3.19	12.57	78.10	5.54	0.60	0.00	0.00	23	NIL	NP	1.88	13.35	1.66	2.67	0.00	27.50
7.50	35	0.89	31.15	Silty Sand	3.97	6.29	76.85	4.74	4.38	3.77	0.00	27	NIL	NP	-	-	-	-	-	-
10.50	38	0.77	29.26	Silty Sand	2.97	19.15	68.82	8.66	0.40	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
12.00	40	0.73	29.20	Sand	2.84	4.75	86.22	5.91	0.28	0.00	0.00	25	NIL	NP	-	-	-	-	-	-

BORELOG OF BH–1(LHS) AT EXISTING KM–325/25–27 FOR MINOR BRIDGE NO.–365, ON KESARI TO SANEHWAL, LUDHIANA



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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 325/25-27 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Continuous Strip | **1**

Angle of internal friction (ϕ °)	21.00
Cohesion (c in t/m2)	0.80
Void ratio (e)	0.61
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.88
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)
1	1.50	1.20

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	21.00
N_c	16.01
N_q	7.25
N_γ	6.49

ϕ'	14.42
N'_c	10.68
N'_q	3.77
N'_γ	2.49

Shape factors :

S.no.	Width(m)	S_c	S_q	S_γ
1	1.20	1.00	1.00	1.00

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	1.20	1.36	1.18	1.18

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1- \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	1.20	0.00	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	SBC in (t/m^2)		
			General shea	Local shear	Actual
1	1.50	1.20	12.29	5.37	10.21

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 325/25-27 BH-1

Type of footing

1	Continuous Strip		
2	Rectangular	***Continuous Strip***	**1**
3	Square		
4	Circular		

Angle of internal friction (ϕ°)	26.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.61
Direction of load with vertical ($^\circ$)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.88
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)
1	3.00	1.20
2	4.50	1.20
3	6.00	1.20

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	26.00
N_c	22.60
N_q	12.21
N_γ	13.18

ϕ'	18.10
N'_c	13.36
N'_q	5.46
N'_γ	4.35

Shape factors :

S.no.	Width(m)	S_c	S_q	S_γ
1	1.20	1.00	1.00	1.00
2	1.20	1.00	1.00	1.00
3	1.20	1.00	1.00	1.00

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	3.00	1.20	1.80	1.40	1.40
2	4.50	1.20	2.20	1.60	1.60
3	6.00	1.20	2.60	1.80	1.80

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1-\alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	3.00	1.20	-1.25	0.50
2	4.50	1.20	-2.50	0.50
3	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	SBC in (t/m^2)		
			General shea	Local shear	Actual
1	3.00	1.20	14.14	5.39	11.52
2	4.50	1.20	16.16	6.16	13.16
3	6.00	1.20	18.18	6.93	14.81

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ANNEXURE - IV

Settlement Calculation for Cohesionless Soil As per IS 8009 (Part 1)	
Location	Minor Bridge No. 365
Chainage	325/25-27
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	10.00
Average N value	13.63
Settlement for 10 t/m2 (mm)	24.00
Total Settlement (mm)	24.00
Depth Correction	0.91
Rigidity Correction	0.8
Corrected Total Settlement (mm)	17.5

Footing Depth (m)	3.00
SBC (t/m2)	11.00
Average N value	17.94
Settlement for 10 t/m2 (mm)	17.00
Total Settlement (mm)	18.70
Depth Correction	0.83
Rigidity Correction	0.8
Corrected Total Settlement (mm)	12.4

Footing Depth (m)	4.50
SBC (t/m2)	13.00
Average N value	23.11
Settlement for 10 t/m2 (mm)	13.20
Total Settlement (mm)	17.16
Depth Correction	0.74
Rigidity Correction	0.8
Corrected Total Settlement (mm)	10.2

Footing Depth (m)	6.00
SBC (t/m2)	15.00
Average N value	27.66
Settlement for 10 t/m2 (mm)	9.80
Total Settlement (mm)	14.70
Depth Correction	0.68
Rigidity Correction	0.8
Corrected Total Settlement (mm)	8.0

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CHAPTER – 21

"Minor Bridge No. 364",

Location – Existing Km. - 323/23-25

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21.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x3.66

21.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL of existing GL shown in **FIGURE-1**.

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ≥21.00m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 1.50	Clayey Silt	Loose
	1.50 to 3.00	Clayey Silt	Medium Dense
	3.00 to 4.50	Clayey Silt with Gravels	Medium Dense
	4.50 to 7.50	Clayey Silt	Medium Dense
	7.50 to 10.50	Clayey Silt	Dense
	10.50 to 12.00	Sand	Dense

21.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	9.00	0.010	0.0021	NIL	0.0012	0.038
	6.00	9.00	0.012	0.0014	NIL	0.010	0.024

21.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	13
	6.00	13

21.5 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	8.00
	3.00	12.50
	4.50	17.50
	6.00	19.00

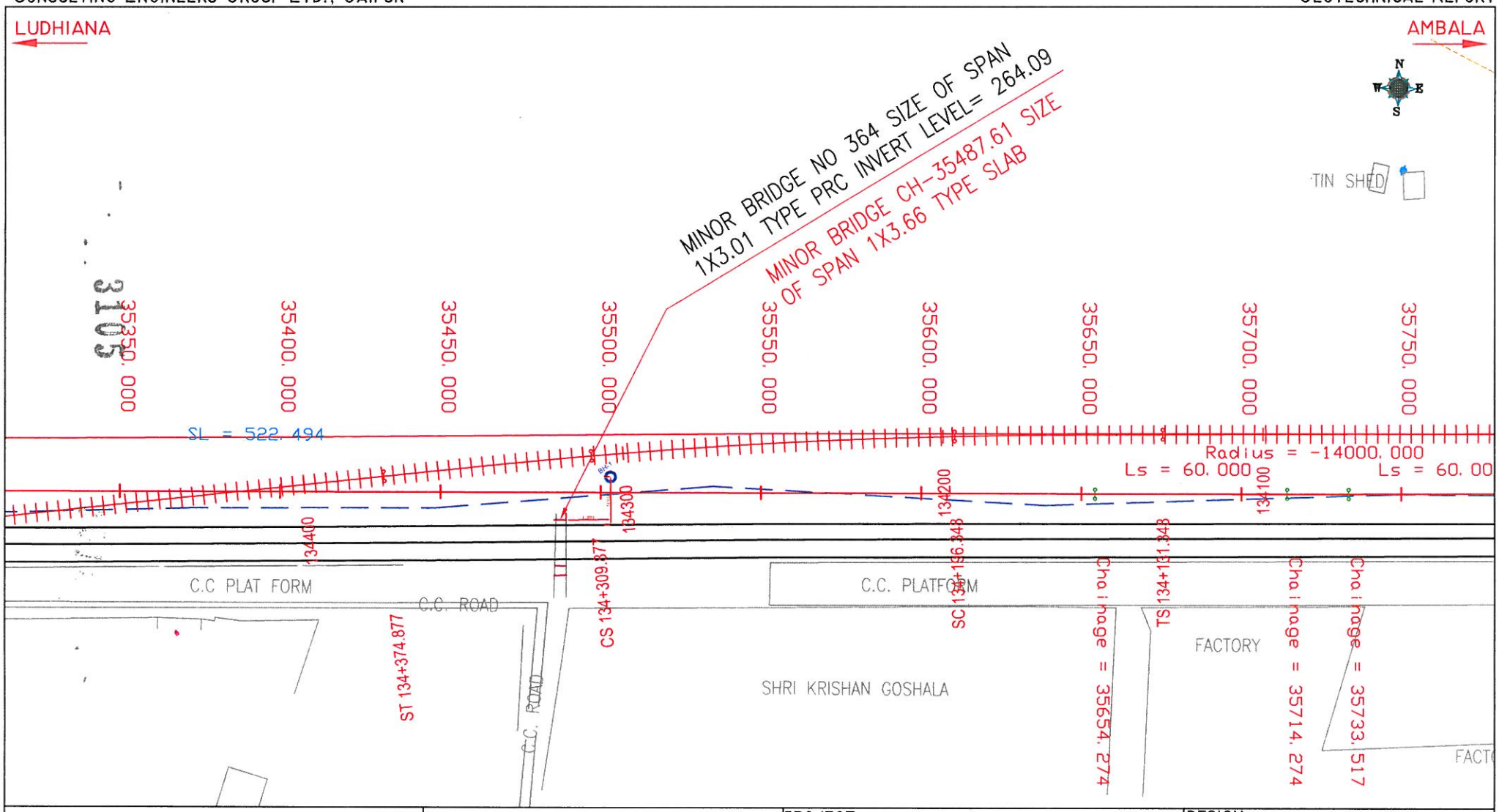
21.6 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.

21.7 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



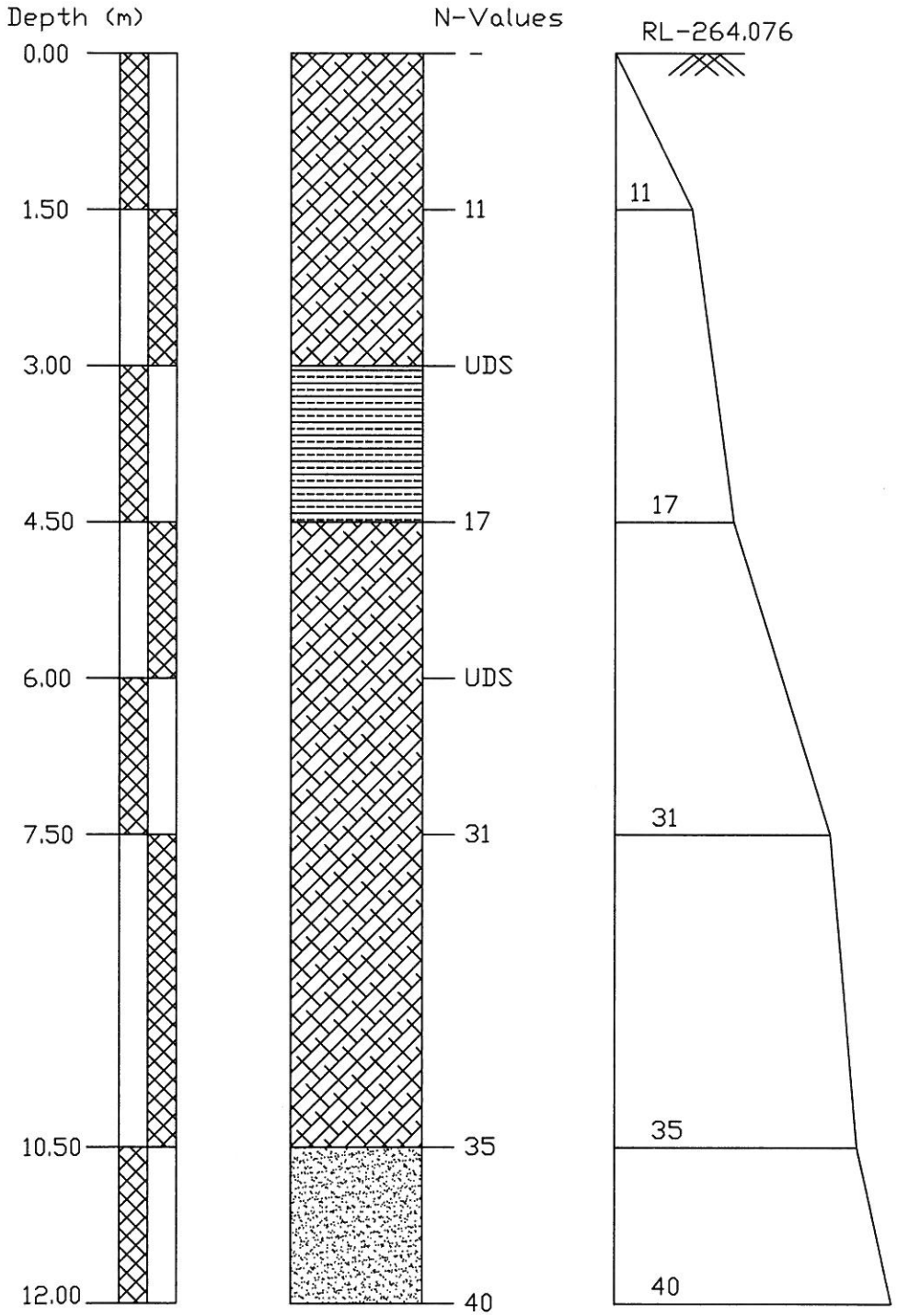
ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 323/23-25	RL OF BH-I = 264.076	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel. +91-141- 2520899, 2521899, 2520556 Fax. 2521348, E-Mail: ceg@cegindia.com

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1(LHS) FOR MINOR BRIDGE No. 364 AT CHAINAGE 323/23-25

Project :	Chainage 323/23-25 Bridge No. 364			Date of Testing	Location at		B.H. No.		Depth of Water Table		Termination Depth			Surface Elevation					
				05.06.2009 to 05.06.2009	1		1(LHS)		below 21.00 m.		12.00mtr			264.076					
Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm^2	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Clayey silt	10.69	86.43	2.29	0.59	0	0	0.00	30	21	9	-	-	-	-	-	-
1.50	11	1.45	15.95	Clayey silt	12.66	83.32	2.15	0.14	0.18	1.55	0.00	32	21	11	-	-	-	-	-	-
3.00	UDS	-	-	Clayey Silt with Gravels	11.28	74.29	2.36	1.64	0.95	9.48	0.00	34	24	10	1.75	11.36	1.57	2.62	0.12	21.00
4.50	17	1.08	18.36	Clayey Silt	11.69	85.32	2.06	0.25	0.13	0.55	0.00	32	22	10	-	-	-	-	-	-
6.00	UDS	-	-	Clayey Silt	10.97	81.64	5.32	0.34	0.00	1.73	0.00	32	23	9	1.82	12.45	1.62	2.60	0.11	22.00
7.50	31	0.91	28.21	Clayey Silt	12.67	84.02	2.13	0.31	0.11	0.76	0.00	30	20	10	-	-	-	-	-	-
10.50	35	0.79	27.65	Sand	0.00	3.58	87.22	9.15	0.05	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
12.00	40	0.75	30.00	Sand	0.00	3.17	87.35	9.39	0.09	0.00	0.00	25	NIL	NP	-	-	-	-	-	-

BORELOG OF BH–1(LHS) AT EXISTING KM–323/23–25 FOR MINOR BRIDGE NO.–364,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	CLAYEY SILT
	CLAYEY SILT WITH GRAVELS
	SAND

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 323/23-25 BH-1

Type of footing

1	Continuous Strip		
2	Rectangular	***Rectangular***	**2**
3	Square		
4	Circular		

Angle of internal friction (ϕ°)	21.00
Cohesion (c in t/m2)	1.20
Void ratio (e)	0.67
Direction of load with vertical ($^\rho$)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.75
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	21.00
N_c	16.01
N_q	7.25
N_γ	6.49

ϕ'	14.42
N'_c	10.68
N'_q	3.77
N'_γ	2.49

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.15	1.07	1.07
2	3.00	3.00	1.29	1.15	1.15
3	4.50	3.00	1.44	1.22	1.22
4	6.00	3.00	1.58	1.29	1.29

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1-\alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	16.60	7.21	10.97
2	3.00	3.00	8.00	24.74	10.81	16.38
3	4.50	3.00	8.00	26.75	11.69	17.71
4	6.00	3.00	8.00	28.75	12.57	19.04

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)

BH No. (A1)			**Minor Bridge at Ch. 323/23-25**	
Depth of foundation		=	1.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	6.5625	t/m^2
Concentrated load *P*		=	8.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.22	
	ΔP	=	1.8	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.67	
	$\frac{Po + \Delta p}{Po}$	=	1.26819	

Settlement of clay layer $S_f = \frac{Cc}{1+ eo} H \log_{10} \frac{Po + \Delta P}{Po}$

S_f = 0.03337 m

= 33.365 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.61

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.91

Rigidity Factor = $\frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$

= 0.8

Pore Pressure correction = N.A.

Total Settlement = Sf x D.F.x R.F.x Pore Pr. Correction

S_{f2} = **24.3 mm**

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Settlement Calculation As per IS 8009 (Part 1)

BH No. (A1)			**Minor Bridge at Ch. 323/23-25**	
Depth of foundation		=	3.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	9.1875	t/m^2
Concentrated load *P*		=	12.50	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.22	
	ΔP	=	2.8	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.67	
	$\frac{Po + \Delta p}{Po}$	=	1.29932	

Settlement of clay layer $S_f = \frac{Cc}{1+ eo} H \log_{10} \frac{Po + \Delta P}{Po}$

S_f = 0.03677 m

= 36.7705 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.61

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.83

Rigidity Factor = $\frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$

= 0.8

Pore Pressure correction = N.A.

Total Settlement = Sf x D.F.x R.F.x Pore Pr. Correction

S_{f2} = **24.4 mm**

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Settlement Calculation As per IS 8009 (Part 1)

BH No. (A1)			**Minor Bridge at Ch. 323/23-25**	
Depth of foundation		=	4.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	12.15	t/m^2
Concentrated load *P*		=	17.50	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.22	
	ΔP	=	3.9	t/m^2
Compression Index	Cc	=	0.11	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.6	
	$\frac{Po + \Delta p}{Po}$	=	1.31687	

Settlement of clay layer

$$S_f = \frac{Cc}{1+ eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.03698 m

= 36.9838 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.61

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.78

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pressure correction = N.A.

Total Settlement = Sf x D.F.x R.F.x Pore Pr. Correction

S_{f2} = **23.1 mm**

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Settlement Calculation As per IS 8009 (Part 1)

BH No. (A1)			**Minor Bridge at Ch. 323/23-25**	
Depth of foundation		=	6.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	14.85	t/m^2
Concentrated load *P*		=	19.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.22	
	ΔP	=	4.2	t/m^2
Compression Index	Cc	=	0.11	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.6	
	$\frac{Po + \Delta p}{Po}$	=	1.28148	

Settlement of clay layer $S_f = \frac{Cc}{1+eo} H \log_{10} \frac{Po + \Delta P}{Po}$

S_f = 0.03332 m

= 33.3235 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.82

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.68

Rigidity Factor = $\frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$

= 0.8

Pore Pressure correction = N.A.

Total Settlement = Sf x D.F.x R.F.x Pore Pr. Correction

S_{f2} = **18.1 mm**

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CHAPTER – 22

"Minor Bridge No. 363",

Location – Existing Km. - 321/27-29

22.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x1.2x1.2

22.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL of existing GL shown in **FIGURE-1**.

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ≥22.00m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 1.50	Silty Sand with Clay	Loose
	1.50 to 3.00	Silty Sand	Loose
	3.00 to 6.00	Silty Sand	Medium Dense
	6.00 to 7.50	Silty Sand with Gravels	Medium Dense
	7.50 to 10.50	Silty Sand	Medium Dense
	10.50 to 12.00	Sand	Dense

22.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.70	0.005	0.0021	NIL	0.0013	0.062

22.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

22.5 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	12.00
	3.00	15.50
	4.50	18.00
	6.00	20.00

22.6 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.

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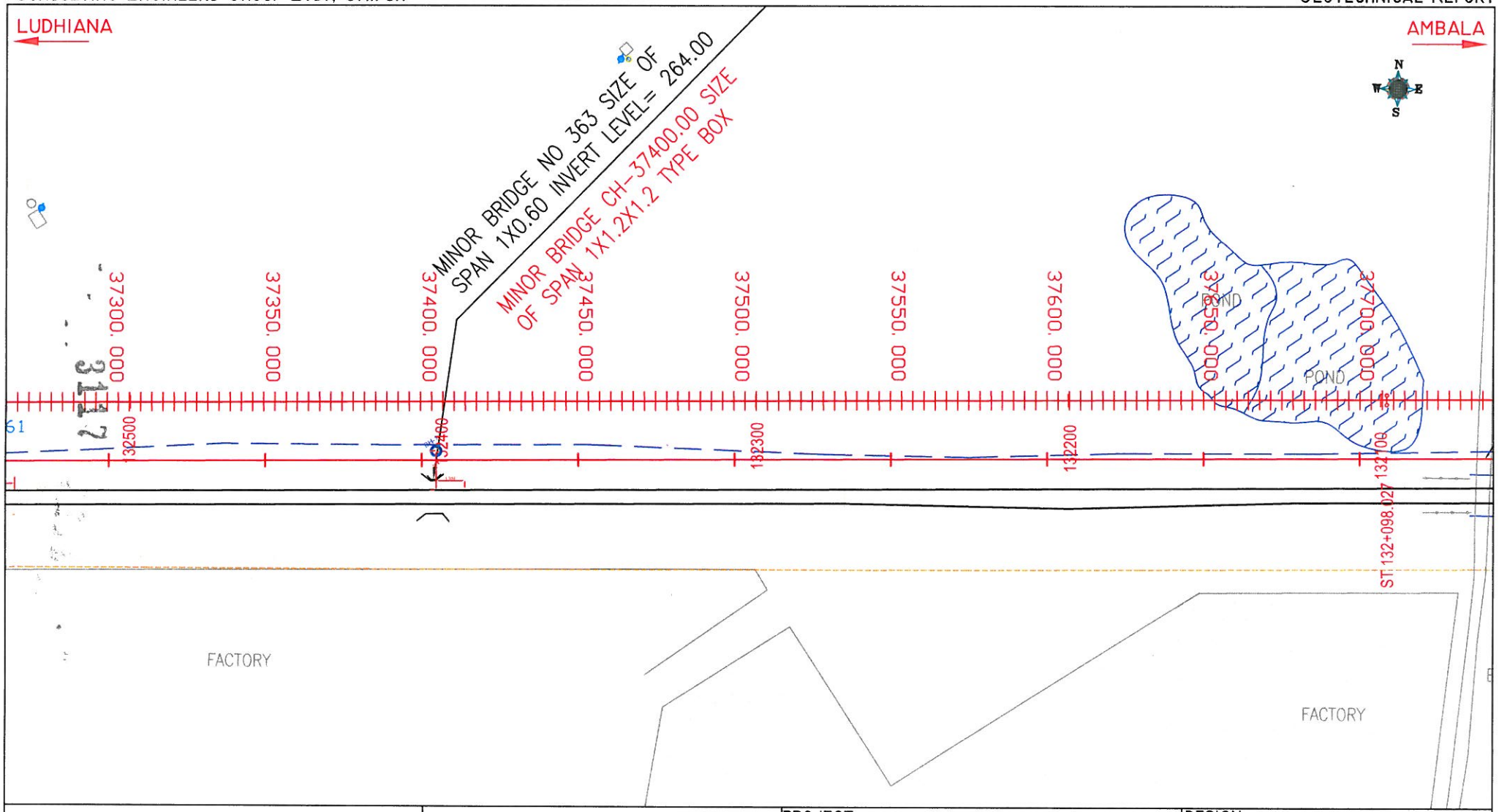
22.7 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 3.00m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER

FIG.:-I

LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 321/27-29

RL OF BH-I = 264.156

PROJECT :-

LUDHIANA-AMBALA (DFCCIL)

DESIGN :-

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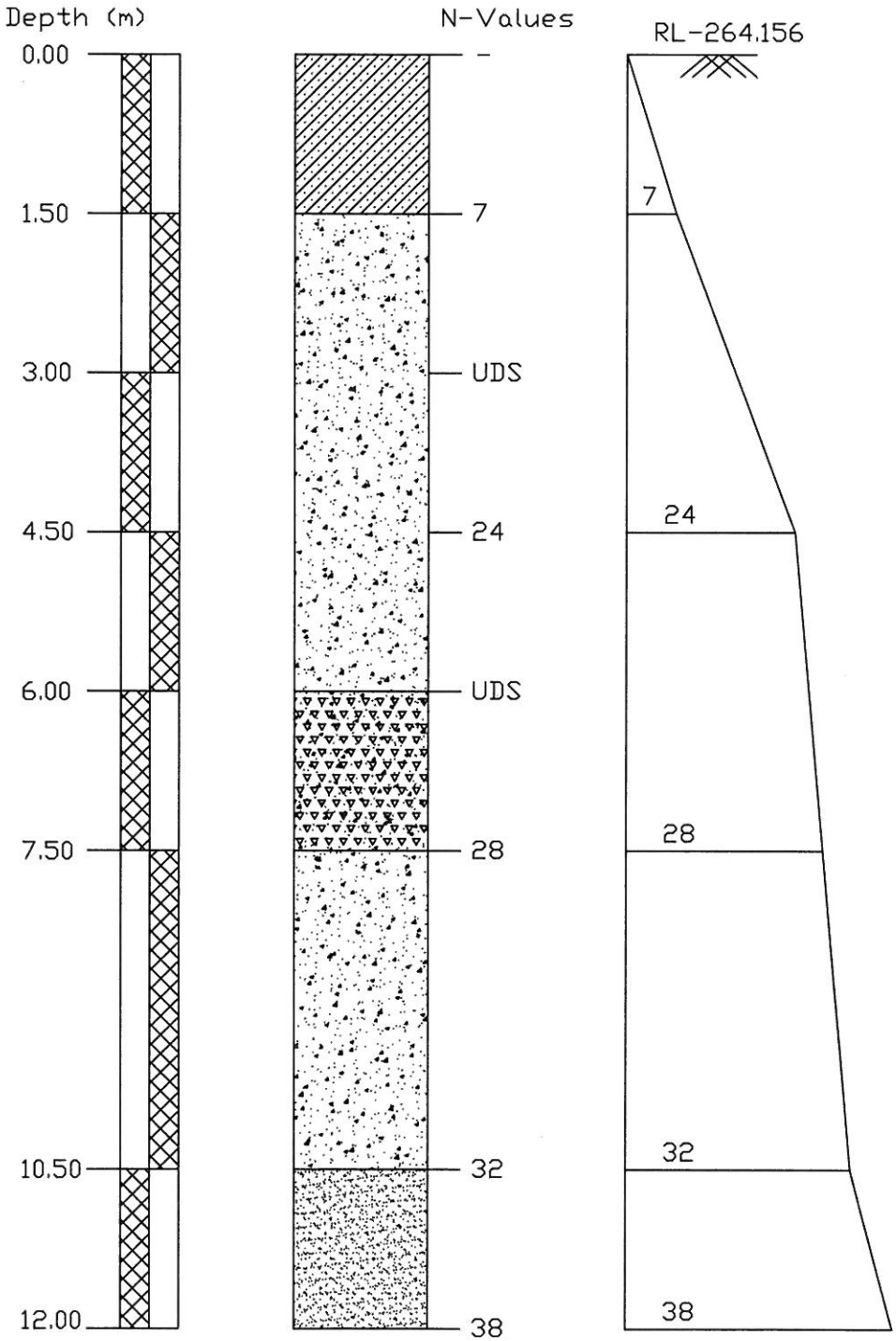
ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1(LHS) FOR MINOR BRIDGE No. 363 AT CHAINAGE 321/28-29

Project :	Chainage 321/28-29 Bridge No. 363			Date of Testing	Location at		B.H. No.		Depth of Water Table			Termination Depth			Surface Elevation					
				06.06.2009 to 06.06.2009	1		1(LHS)		below 22.00 m.			12.00mtr			264.156					
Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm^2	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Silty Sand with clay	10.89	60.47	21.26	5.36	0.89	1.13	0.00	30	21	9	-	-	-	-	-	-
1.50	7	1.46	10.22	Silty Sand	2.68	29.86	66.27	1.08	0.11	0.00	0.00	22	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	3.11	10.08	82.83	2.49	0.35	1.14	0.00	26	NIL	NP	1.70	1.79	1.67	2.66	0.00	28.00
4.50	24	1.09	26.16	Silty Sand	2.19	10.74	83.25	2.90	0.52	0.40	0.00	24	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand with Gravels	2.18	13.09	69.01	3.68	1.76	10.28	0.00	26	NIL	NP	1.78	5.42	1.69	2.68	0.00	28.00
7.50	28	0.91	25.48	Silty Sand	4.23	7.10	80.54	8.13	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
10.50	32	0.80	25.60	Sand	2.16	4.55	85.40	7.89	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
12.00	38	0.75	28.50	Sand	1.86	4.64	86.19	7.31	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-

BORELOG OF BH–1(LHS) AT EXISTING KM–321/27–29 FOR MINOR BRIDGE NO.–363,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND WITH CLAY
	SILTY SAND
	SILTY SAND WITH GRAVELS
	SAND

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 321/28-29 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Continuous Strip | 1

Angle of internal friction (ϕ °)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.59
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.70
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)
1	1.50	1.20
2	3.00	1.20

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	28.00
N_c	26.37
N_q	15.30
N_γ	17.79

ϕ'	19.61
N'_c	14.53
N'_q	6.21
N'_γ	5.18

Shape factors :

S.no.	Width(m)	S_c	S_q	S_γ
1	1.20	1.00	1.00	1.00
2	1.20	1.00	1.00	1.00

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	1.20	1.42	1.21	1.21
2	3.00	1.20	1.83	1.42	1.42

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1- \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	1.20	0.00	0.50
2	3.00	1.20	-1.25	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	SBC in (t/m^2)		
			General shea	Local shear	Actual
1	1.50	1.20	15.40	5.34	13.39
2	3.00	1.20	18.06	6.26	15.70

3121

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 321/28-29 BH-1

Type of footing

1	Continuous Strip		
2	Rectangular	***Continuous Strip***	**1**
3	Square		
4	Circular		

Angle of internal friction (ϕ°)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.59
Direction of load with vertical ($^\circ$)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.78
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)
1	4.50	1.20
2	6.00	1.20

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

3122

CONSULTING Engineers Group Ltd.

ANNEXURE - III

Bearing capacity factors :

ϕ	28.00
N_c	26.37
N_q	15.30
N_γ	17.79

ϕ'	19.61
N'_c	14.53
N'_q	6.21
N'_γ	5.18

Shape factors :

S.no.	Width(m)	S_c	S_q	S_γ
1	1.20	1.00	1.00	1.00
2	1.20	1.00	1.00	1.00

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	4.50	1.20	2.25	1.62	1.62
2	6.00	1.20	2.66	1.83	1.83

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1- \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	4.50	1.20	-2.50	0.50
2	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	SBC in (t/m^2)		
			General shea	Local shear	Actual
1	4.50	1.20	20.94	7.25	18.20
2	6.00	1.20	23.62	8.18	20.53

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ANNEXURE - IV

Settlement Calculation for Cohesionless Soil As per IS 8009 (Part 1)	
Location	Minor Bridge No. 363
Chainage	321/28-29
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	12.00
Average N value	14
Settlement for 10 t/m2 (mm)	19.00
Total Settlement (mm)	22.80
Depth Correction	0.83
Rigidity Correction	0.8
Corrected Total Settlement (mm)	**15.1**

Footing Depth (m)	3.00
SBC (t/m2)	15.50
Average N value	21
Settlement for 10 t/m2 (mm)	10.00
Total Settlement (mm)	15.50
Depth Correction	0.73
Rigidity Correction	0.8
Corrected Total Settlement (mm)	**9.1**

Footing Depth (m)	4.50
SBC (t/m2)	18.00
Average N value	25
Settlement for 10 t/m2 (mm)	8.40
Total Settlement (mm)	15.12
Depth Correction	0.675
Rigidity Correction	0.8
Corrected Total Settlement (mm)	**8.2**

Footing Depth (m)	6.00
SBC (t/m2)	20.00
Average N value	25
Settlement for 10 t/m2 (mm)	8.40
Total Settlement (mm)	16.80
Depth Correction	0.63
Rigidity Correction	0.8
Corrected Total Settlement (mm)	**8.5**

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CHAPTER – 23

"Minor Bridge No. 362",

Location – Existing Km. - 320/25-27

23.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 2x3.05

23.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL of existing GL shown in **FIGURE-1**.

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ≥22.00m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 0.50	Sandy Silt with Clay	Loose
	0.50 to 1.50	Sandy Silt with Clay & Gravels	Loose
	1.50 to 3.00	Sandy Silt with Clay & Gravels	Medium Dense
	3.00 to 4.50	Silty Sand	Medium Dense
	4.50 to 7.50	Clayey Silt	Medium Dense
	7.50 to 12.00	Silty sand	Dense

23.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.70	0.007	0.0014	NIL	0.0009	0.017
	6.00	8.70	0.007	0.0014	NIL	0.0010	0.0258

23.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	22

23.5 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	8.00
	3.00	14.50
	4.50	18.00
	6.00	19.00

23.6 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.

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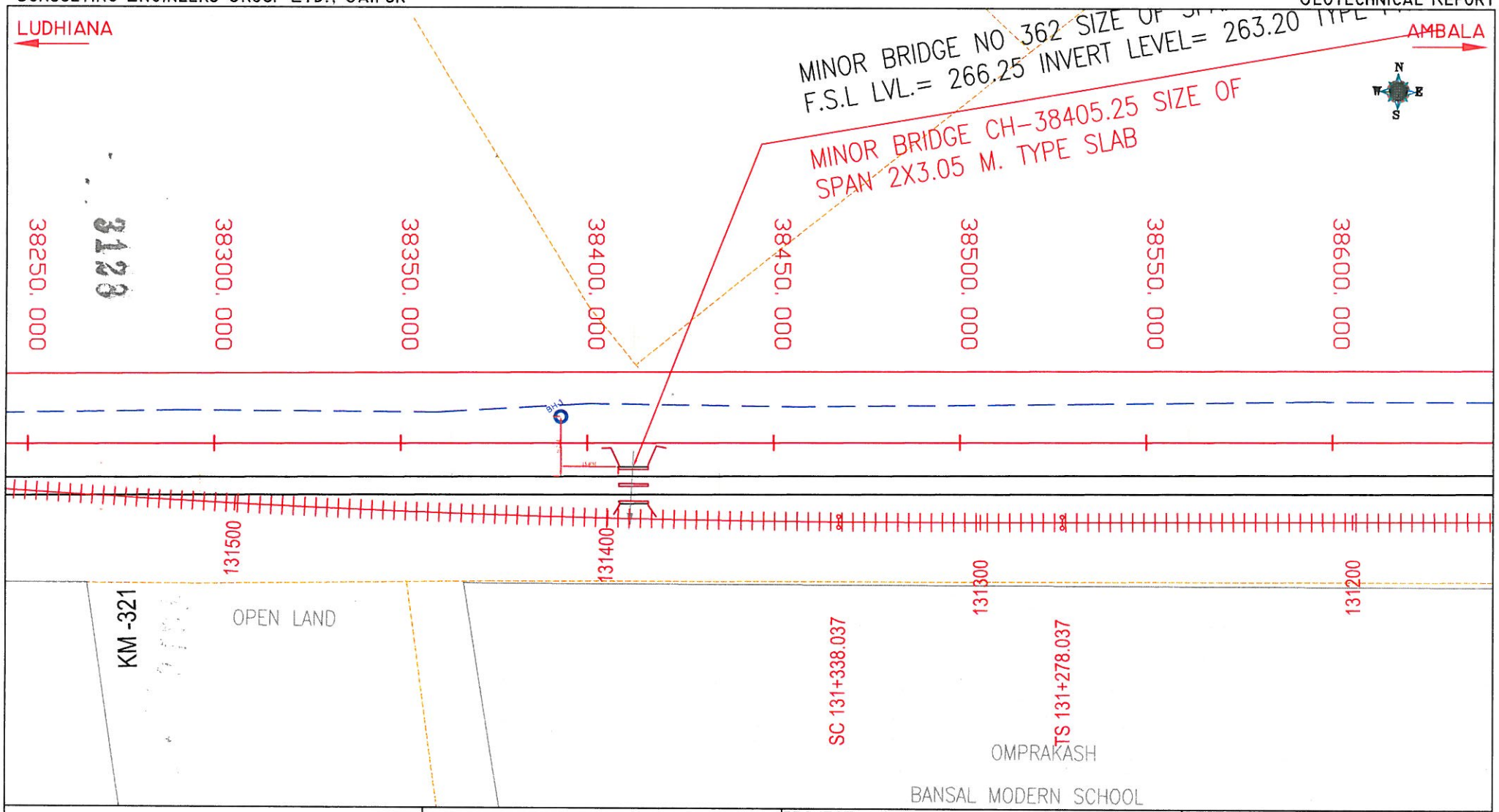
23.7 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 3.00m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.

3127



ALL DIMENSIONS IN METER

FIG.:-I
LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 320/25-27

RL OF BH-I = 263.438

PROJECT :-
LUDHIANA-AMBALA (DFCCIL)

DESIGN :-
CONSULTING ENGINEERS GROUP LTD.
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ANNEXURE - I

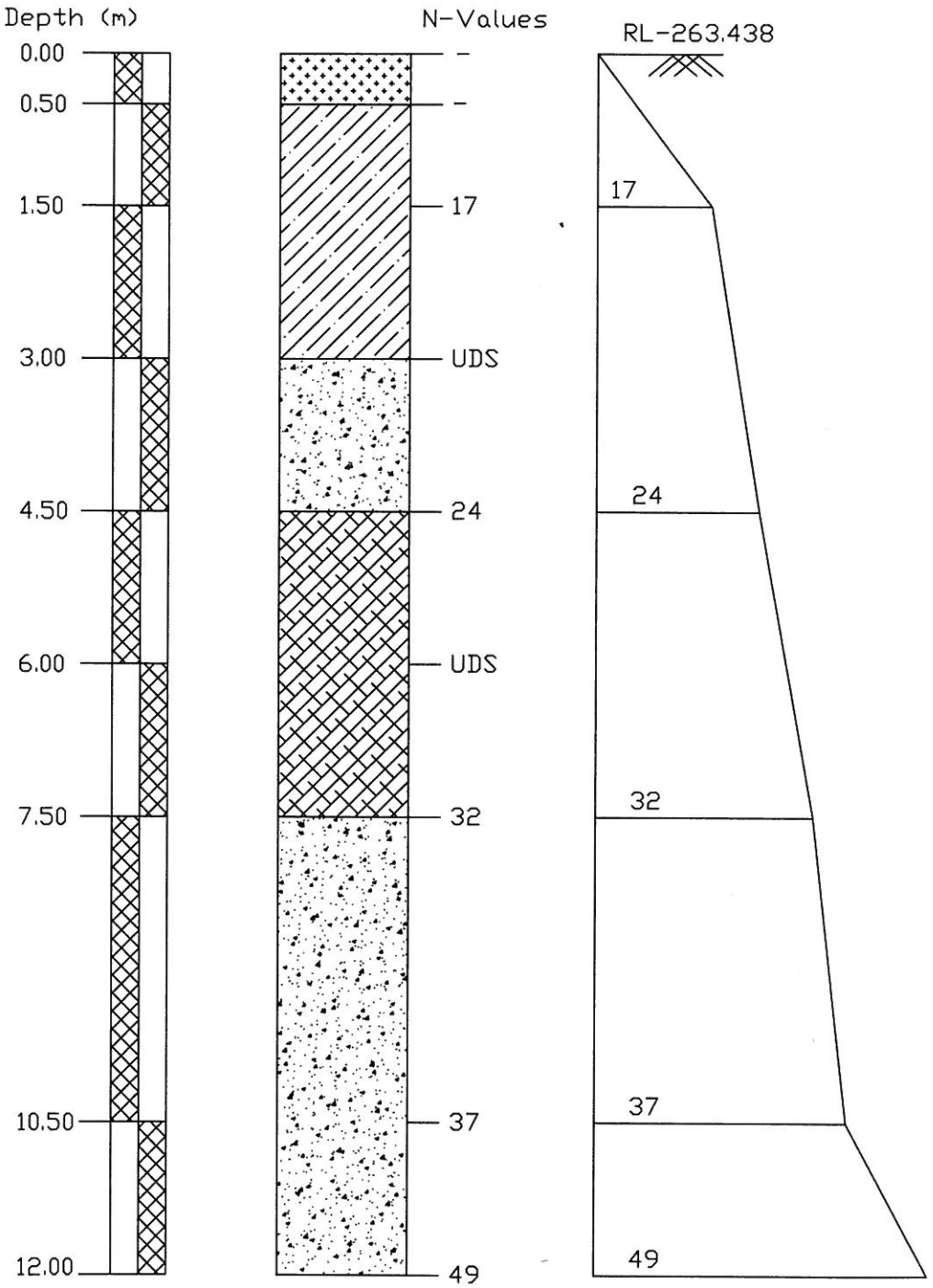
SOIL CHARACTERISTICS OF BORE HOLE AT BH-1(LHS) FOR MINOR BRIDGE No. 362 AT CHAINAGE 320/25-27

Project :	Chainage 320/25-27 Bridge No. 362			Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
				06.06.2009 to 06.06.2009	1	1(LHS)	below 22.00 m.	12.00mtr	263.438

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained							Atterberg Limits %			B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength	
					Clay	Silt	Sand			Gravel										c kg/cm^2	ϕ degree
							Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.						
0.00	-	-	-	Sandy Silt with Clay	10.68	68.49	10.36	4.59	2.18	3.29	0.41	27	18	9	-	-	-	-	-	-
0.50				Sandy Silt with Clay & Gravels	11.69	67.14	8.69	5.26	1.29	5.39	0.54	28	18	10						
1.50	17	1.51	25.67	Sandy Silt with Clay & Gravels	14.21	59.32	7.27	2.00	2.20	14.72	0.28	27	17	10	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	4.68	19.73	66.87	7.12	0.43	1.17	0.00	28	NIL	NP	1.64	5.80	1.55	2.63	0.00	26.00
4.50	24	1.10	26.40	Clayey Silt	15.36	61.46	7.44	2.98	8.86	3.90	0.00	30	18	12	-	-	-	-	-	-
6.00	UDS	-	-	Clayey Silt	21.54	72.08	3.04	1.07	0.67	1.60	0.00	43	26	17	1.99	19.71	1.66	2.61	0.25	13.50
7.50	32	0.91	29.12	Silty Sand	3.16	14.34	79.08	2.77	0.41	0.24	0.00	26	NIL	NP	-	-	-	-	-	-
10.50	37	0.78	28.86	Silty Sand	2.94	22.82	69.41	2.19	0.96	1.68	0.00	24	NIL	NP	-	-	-	-	-	-
12.00	49	0.73	35.77	Silty Sand	1.94	42.03	50.86	2.53	1.74	0.90	0.00	19	NIL	NP	-	-	-	-	-	-

BORELOG OF BH–1(LHS) AT EXISTING KM–320/25–27 FOR MINOR BRIDGE NO.–362,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SANDY SILT WITH CLAY
	SANDY SILT WITH CLAY & GRAVELS
	SILTY SAND
	CLAYEY SILT

3130

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 320/25-27 BH-1

Type of footing

1	Continuous Strip		
2	Rectangular	***Rectangular***	**2**
3	Square		
4	Circular		

Angle of internal friction (ϕ °)	26.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.70
Direction of load with vertical (^{0})	0.00
Density of surcharge (t/m^3)	1.64
Density of foundation soil (t/m^3)	1.64
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	26.00
N_c	22.60
N_q	12.21
N_γ	13.18

ϕ'	18.10
N'_c	13.36
N'_q	5.46
N'_γ	4.35

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.32	1.16	1.16

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1-\alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	15.63	5.89	8.32
2	3.00	3.00	8.00	28.25	10.89	15.23

CONSULTING Engineers Group Ltd.

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 320/25-27 BH-1

Type of footing

1	Continuous Strip		
2	Rectangular	***Rectangular***	**2**
3	Square		
4	Circular		

Angle of internal friction (ϕ°)	13.50
Cohesion (c in t/m2)	2.50
Void ratio (e)	0.57
Direction of load with vertical ($^\circ$)	0.00
Density of surcharge (t/m^3)	1.64
Density of foundation soil (t/m^3)	1.90
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	4.50	3.00	8.00
2	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	13.50
N_c	10.19
N_q	3.50
N_γ	2.22

ϕ'	9.14
N'_c	8.03
N'_q	2.31
N'_γ	1.09

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	4.50	3.00	1.38	1.19	1.19
2	6.00	3.00	1.51	1.25	1.25

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1-\alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	4.50	3.00	-1.00	0.50
2	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	4.50	3.00	8.00	18.92	9.90	18.01
2	6.00	3.00	8.00	20.41	10.68	19.44

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ANNEXURE - IV

Settlement Calculation for As per IS 8009 (Part 1)

Location	Minor Bridge No. 362
Chainage	320/25-27
Bore Hole No.	1

Depth of foundation		=	1.5	m	
Length of footing (L)		=	8.0	m	
Width of footing (B)		=	3.0	m	
Initial effective stress at mid of layer	Po	=	3.69	t/m^2	
Concentrated load *P*		=	8.00	t/m^2	
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$		
	I_B	=	0.238		
	ΔP	=	1.9	t/m^2	
Compression Index	Cc	=	0.13		
Thickness of clay layer	H	=	1.5	m	
Initial Void ratio	e_o	=	0.7		
	$\frac{Po + \Delta p}{Po}$	=	1.5159892		
Settlement of clay layer	S_f	=	$\frac{Cc}{1+ eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$		
	S_f	=	0.0207269	m	
		=	20.726905	mm	

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

D = Depth of Foundation

	$D/(LB)^{\wedge 0.5}$	=	0.31
	L/B	=	2.67
Depth Factor		=	0.91

Rigidity Factor = $\frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$ = 0.8

Pore Pressure correction = 0.85

Total Settlement = Sf x D.F.x R.F.x Pore Pr. Correction

S_{f2} = **12.8** **mm**

Footing Depth (m)	**1.50**
effective pr.(t/m2)	1.84
Average N value	26
Settlement for 10 t/m2 (mm)	10.00
Total Settlement (mm)	1.84
Depth Correction	0.91
Rigidity Correction	0.8
Corrected Total Settlement (mm)	**1.34**

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Depth of foundation		=	1.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	8.61	t/m^2
Concentrated load *P*		=	1.84	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.238	
	ΔP	=	0.4	t/m^2
Compression Index	Cc	=	0.13	
Thickness of clay layer	H	=	1.5	m
Initial Void ratio	e_o	=	0.7	
	$\frac{Po + \Delta p}{Po}$	=	1.0508618	

Settlement of clay layer

$$S_f = \frac{Cc}{1+ eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.0024714 m

= 2.4714071 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.31

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.91

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pressure correction = N.A.

Total Settlement = Sf x D.F.x R.F.x Pore Pr. Correction

S_{f2} = **1.8 mm**

Total Settlement (mm) 15.96

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ANNEXURE - IV

Settlement Calculation for Cohesionless Soil As per IS 8009 (Part 1)

Location	Minor Bridge No. 362
Chainage	320/25-27
Bore Hole No.	1

Footing Depth (m)	**3.00**
SBC (t/m2)	14.50
Average N value	27
Settlement for 10 t/m2 (mm)	10.00
Total Settlement (mm)	14.50
Depth Correction	0.83
Rigidity Correction	0.8
Corrected Total Settlement (mm)	**9.63**

Settlement Calculation for Cohesive Soil As per IS 8009 (Part 1)

BH No. (A1) — **Minor Bridge at Ch. 320/25-27**

Depth of foundation		=	3.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	9.84	t/m^2
Concentrated load *P*		=	14.50	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
		I_B =	0.238	
	ΔP	=	3.5	t/m^2
Compression Index	Cc	=	0.13	
Thickness of clay layer	H	=	3	m
Initial Void ratio	e_o	=	0.7	
	$\frac{Po + \Delta p}{Po}$	=	1.350711382	

Settlement of clay layer

$$S_f = \frac{Cc}{1+ eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.029952587 m

= 29.9525872 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

D = Depth of Foundation

$D/(LB)^{\wedge 0.5}$ = 0.61

L/B = 2.67

Depth Factor = 0.74

Rigidity Factor = $\frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$ = 0.8

Pore Pressure correction = 0.85

Total Settlement = Sf x D.F.x R.F.x Pore Pr. Correction

S_{f2} = **15.1** **mm**

Total Settlement (mm) **24.70**

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Settlement Calculation for Cohesive Soil As per IS 8009 (Part 1)

BH No. (A1) — **Minor Bridge at Ch. 320/25-27**

Depth of foundation		=	4.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	11.475	t/m^2
Concentrated load *P*		=	18.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
		I_B =	0.238	
	ΔP	=	4.3	t/m^2
Compression Index	Cc	=	0.1	
Thickness of clay layer	H	=	3	m
Initial Void ratio	e_o	=	0.61	
	$\frac{Po + \Delta p}{Po}$	=	1.373333333	

Settlement of clay layer

$$S_f = \frac{Cc}{1+eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.025672539 m

= 25.67253938 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.92 $(LB)^{\wedge 0.5}/D$ = 1.09

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.74

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.80

Pore Pressure correction = 0.85

Total Settlement = S_f x D.F.x R.F.x Pore Pr. Correction

S_{f2} = **12.9** **mm**

Settlement Calculation for Cohesionless Soil As per IS 8009 (Part 1)

Location	Minor Bridge No. 362
Chainage	320/25-27
Bore Hole No.	1
Footing Depth (m)	**4.50**
SBC (t/m2)	3.60
Average N value	28
Settlement for 10 t/m2 (mm)	9.70
Total Settlement (mm)	3.49
Depth Correction	0.74
Rigidity Correction	0.8
Corrected Total Settlement (mm)	**2.58**

Total Settlement (mm) **15.50**

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Settlement Calculation for Cohesive Soil As per IS 8009 (Part 1)

BH No. (A1) — **Minor Bridge at Ch. 320/25-27**

Depth of foundation		=	6.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	12.15	t/m^2
Concentrated load *P*		=	19.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B =		0.238	
	ΔP	=	4.5	t/m^2
Compression Index	Cc	=	0.1	
Thickness of clay layer	H	=	1.5	m
Initial Void ratio	e_o	=	0.61	
	$\frac{Po + \Delta p}{Po}$	=	1.37218107	

Settlement of clay layer

$$S_f = \frac{Cc}{1+eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.012802307 m

= 12.80230655 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 1.22 $(LB)^{\wedge 0.5}/D$ = 0.82

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.74

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.80

Pore Pressure correction = 0.85

Total Settlement = S_f x D.F.x R.F.x Pore Pr. Correction

S_{f2} = 6.4 mm

Settlement Calculation for Cohesionless Soil As per IS 8009 (Part 1)

Location	Minor Bridge No. 362
Chainage	320/25-27
Bore Hole No.	1
Footing Depth (m)	**6.00**
SBC (t/m2)	3.52
Average N value	29
Settlement for 10 t/m2 (mm)	9.30
Total Settlement (mm)	3.27
Depth Correction	0.68
Rigidity Correction	0.8
Corrected Total Settlement (mm)	**2.2**

Total Settlement (mm) **8.7**

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CHAPTER – 24

"Minor Bridge No. 361",

Location – Existing Km. - 317/28-30

24.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge No. 361

24.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL of existing GL shown in **FIGURE-1**.

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ≥21.00m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 1.50	Sandy Silt with Clay	Loose
	1.50 to 3.00	Clayey Silt with Gravels	Medium Dense
	3.00 to 4.50	Clayey Silt	Medium Dense
	4.50 to 7.50	Silty Sand	Dense
	7.50 to 10.50	Silty Sand with Gravels	Dense
	10.50 to 12.00	Silty Sand	Dense

24.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.40	0.010	0.0043	NIL	0.013	0.073

24.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	25
	6.00	NIL

24.5 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	12.00
	3.00	15.00
	4.50	36.00
	6.00	36.00

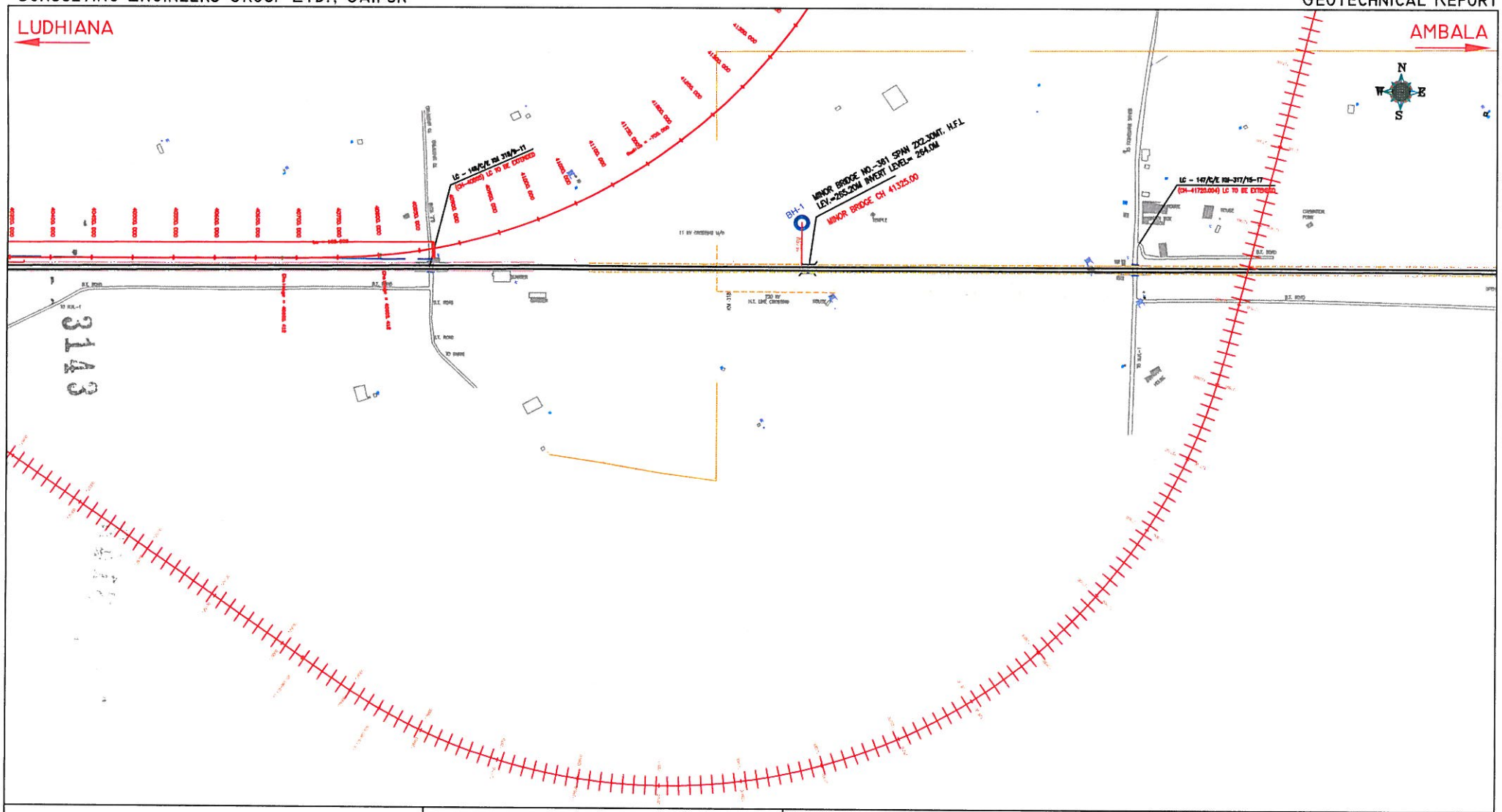
24.6 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.

24.7 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 3.00m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER

FIG.:-I

LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 317/28-30

RL OF BH-I = 264.243

PROJECT :-

LUDHIANA-AMBALA (DFCCIL)

DESIGN :-

CONSULTING ENGINEERS GROUP LTD.
E-12,Moji Colony,Malviya Nagar Jaipur-17
Tel: +91-141- 2520899, 2521899, 2520556
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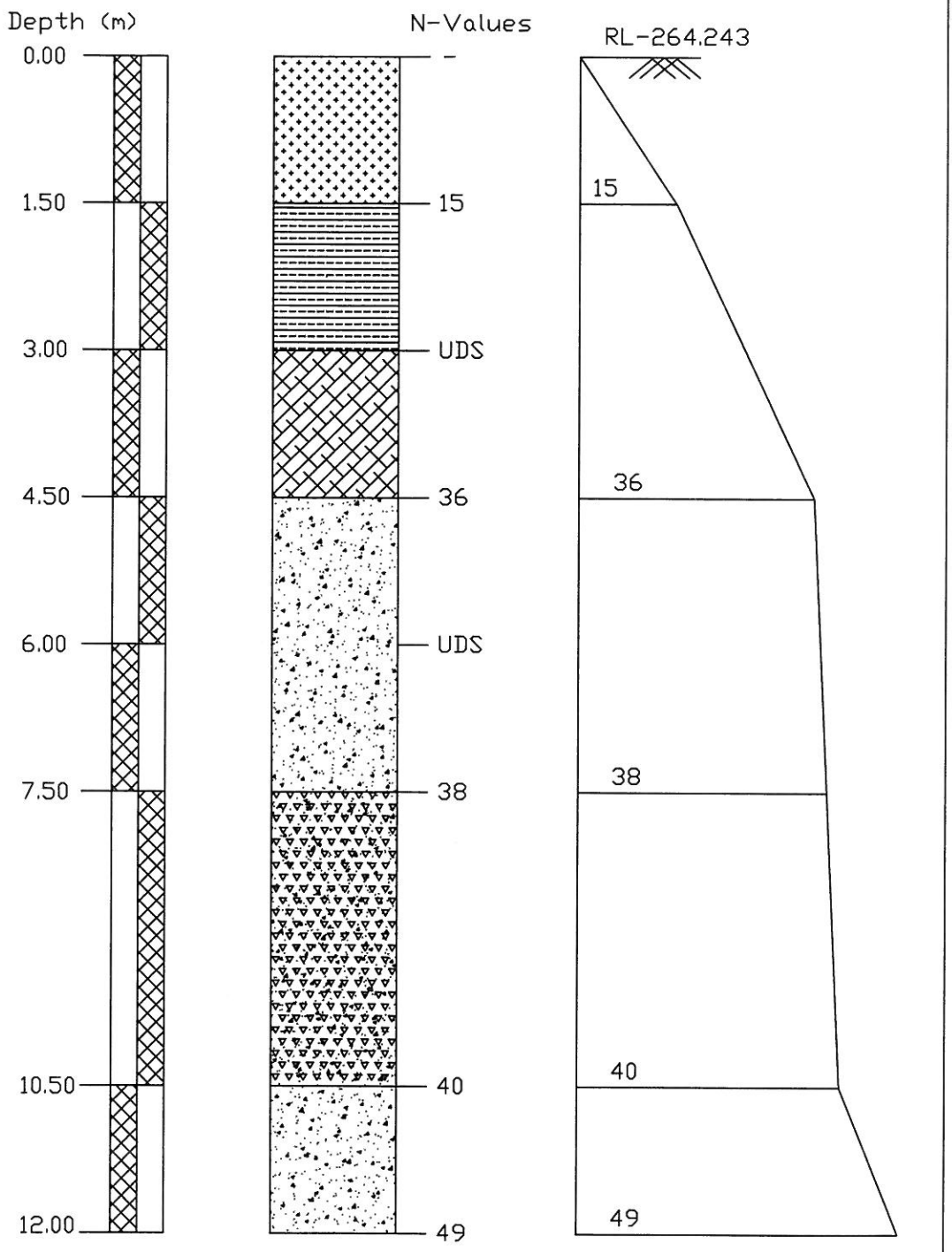
ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1(LHS) FOR MINOR BRIDGE No. 361 AT CHAINAGE 317/28-30

Project :	Chainage 317/28-30 Bridge No. 361			Date of Testing	Location at		B.H. No.		Depth of Water Table			Termination Depth			Surface Elevation					
				08.06.2009 to 08.06.2009	1		1(LHS)		below 21.00 m.			12.00mtr			264.243					
Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm^2	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Sandy Silt with Clay	12.86	61.70	10.36	8.59	2.1	3.25	1.14	31	20	11	-	-	-	-	-	-
1.50	15	1.43	21.45	Clayey Silt with Gravels	20.98	35.58	5.55	2.49	1.99	33.41	0.00	35	18	17	-	-	-	-	-	-
3.00	UDS	-	-	Clayey Silt	23.67	69.64	3.04	1.06	0.31	2.28	0.00	44	25	19	1.86	16.09	1.60	2.63	0.28	14.00
4.50	36	1.06	38.16	Silty Sand	3.56	9.53	85.25	1.57	0.09	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	2.68	5.59	80.84	10.42	0.25	0.22	0.00	26	NIL	NP	1.90	11.29	1.71	2.64	0.00	27.50
7.50	38	0.89	33.82	Silty Sand with Gravels	3.18	8.30	78.72	2.00	0.19	7.61	0.00	26	NIL	NP	-	-	-	-	-	-
10.50	40	0.77	30.80	Silty Sand	4.33	5.99	85.51	4.01	0.16	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
12.00	49	0.73	35.77	Silty Sand	2.10	7.63	83.13	7.14	0.00	0.00	0.00	26	NIL	NP	-	-	-	-	-	-

BORELOG OF BH–1(LHS) AT EXISTING KM–317/28–30 FOR MINOR BRIDGE NO.–361, ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SANDY SILT WITH CLAY
	CLAYEY SILT WITH GRAVELS
	CLAYEY SILT
	SILTY SAND
	SILTY SAND WITH GRAVELS

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 320/25-27 BH-1

Type of footing

1	Continuous Strip		
2	Rectangular	***Rectangular***	**2**
3	Square		
4	Circular		

Angle of internal friction (ϕ°)	14.00
Cohesion (c in t/m2)	2.80
Void ratio (e)	0.64
Direction of load with vertical ($^\rho$)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.86
Depth of water table(m)	3.00
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	14.00
N_c	10.45
N_q	3.65
N_γ	2.36

ϕ'	9.48
N'_c	8.16
N'_q	2.38
N'_γ	1.14

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.13	1.06	1.06
2	3.00	3.00	1.26	1.13	1.13

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1-\alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.50	0.75
2	3.00	3.00	0.00	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	15.90	8.21	12.44
2	3.00	3.00	8.00	19.68	10.20	15.42

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Minor Bridge No 320/25-27 BH-1

Type of footing

1	Continuous Strip		
2	Rectangular	***Rectangular***	**2**
3	Square		
4	Circular		

Angle of internal friction (ϕ°)	27.50
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.54
Direction of load with vertical ($^\circ$)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.90
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	4.50	3.00	8.00
2	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67\tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	27.50
N_c	25.43
N_q	14.53
N_γ	16.64

ϕ'	19.23
N'_c	14.24
N'_q	6.02
N'_γ	4.97

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	4.50	3.00	1.49	1.25	1.25
2	6.00	3.00	1.66	1.33	1.33

Inclination factors :

$i_c = (1-\alpha / 90)^2$	$i_q = (1-\alpha / 90)^2$	$i_\gamma = (1-\alpha / \phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	4.50	3.00	-1.00	0.50
2	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	4.50	3.00	8.00	39.22	13.94	39.22
2	6.00	3.00	8.00	41.81	14.86	41.81

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ANNEXURE - IV

Settlement Calculation for Cohesive soil As per IS 8009 (Part 1)

BH No. (A1)			**Minor Bridge at Ch. 317/28-30**	
Depth of foundation		=	1.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	5.4	t/m^2
Concentrated load *P*		=	12.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.22	
	ΔP	=	2.6	t/m^2
Compression Index	Cc	=	0.11	
Thickness of clay layer	H	=	3	m
Initial Void ratio	e_o	=	0.64	
	$\frac{Po + \Delta p}{Po}$	=	1.48889	

Settlement of clay layer $S_f = \frac{Cc}{1+ eo} H \log_{10} \frac{Po + \Delta P}{Po}$

S_f = 0.03478 m

= 34.7833 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.61

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.91

Rigidity Factor = $\frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$

= 0.8

Pore Pressure correction = 0.85

Total Settlement = Sf x D.F.x R.F.x Pore Pr. Correction

S_{f2} = **21.5 mm**

Settlement Calculation for Cohesionless soil As per IS 8009 (Part 1)

Footing Depth (m)	**1.50**
SBC (t/m2)	2.40
Average N value	37
Settlement for 10 t/m2 (mm)	7.00
Total Settlement (mm)	1.68
Depth Correction	0.91
Rigidity Correction	0.8
Corrected Total Settlement (mm)	**1.22**

Total Settlement (mm) **22.7**

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