

**Soil Investigation works for proposed 400/220KV
substation at Maheshwaram, Meerkhanpet (V),
Kandukur mandal R.R District, T.S .**

Submitted to

M/S MEGHA Engineering Infrastructures Ltd.



28/3/2016

IMS EXPLORATIONS

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Introduction

1.1 Project Description

M/S MEGHA Engineering and Infrastructures Ltd. proposed to carry out soil investigations and field testing for the Planned 400/220KV substation at Meerkhanpet (V), Kandukur mandal R.R District, T.S. M/s IMS Explorations was entrusted with the task of carrying out soil exploration, field testing and reporting of key findings of Ground Investigation and testing.

1.2 Purpose of Study

The overall purpose of this study is to conduct a geotechnical investigation to assess the stratigraphy and to develop geotechnical recommendations for foundation design for the various structures planned in the project area. To accomplish these purposes the study was conducted in the following phases:

- Drilling boreholes at 6 locations.
- Conducting SPT in Bore Holes.
- Testing samples in laboratory to determine the engineering properties of the strata.
- Analyzing all field and laboratory data to develop preliminary geotechnical recommendations for foundations.

1.3 Report Format

The initial sections of this report presents brief descriptions of the field work methodology together with list of various laboratory tests conducted. This is followed by presentation of site, stratigraphy and engineering recommendations.

This is followed by the foundation construction considerations. The report closes with a summary of the principal findings and recommendations.

All field and laboratory data is presented in the appendix Bore Hole Wise.

2.0 FIELD INVESTIGATION

2.1 Soil Borings

The borings were progressed using a shell and auger to the specified depth or refusal whichever occurs earlier. Casing were used for advanced borings. The casing with a diamond shoe bit was used to assist the casings to advance. The work was in general accordance with IS 1892 - 1979.

Standard Penetration Test (SPT) were conducted in the boreholes at 1.5 m depth intervals by connecting the split spoon sampler to SPT rod and driving it by 45 cm using

a 63.5 kg hammer falling freely from a height of 75 cm . The test was conducted in accordance with IS 2131 – 1981.

The number of blows for each 15 cm of penetration of the split spoon sampler was recorded. The number of blows required to penetrate the initial 15 cm of the split spoon is ignored for seating the sampler due to possible presence of loose materials or cutting from the drilling operation. The cumulative number of blows required to penetrate the balance 30 cm out of 45 cm is termed as the SPT or N values.

The N values are presented on the soil profile for each borehole. Refusal to further boring penetration was considered when the N value exceeds 75 blows for 30 cm penetration or when practical refusal to further penetration by shell and auger was encountered.

Disturbed samples were collected from split spoon after conducting the SPT. The samples were preserved in transparent polythene bags. Undisturbed samples were collected by attaching 75 mm diameter thin walled 'Shelby' tubes and driving the sampler using the 63.5 kg hammer in accordance with IS 2132 – 1986. The tubes are sealed with wax at both ends .All samples are transported to our laboratory at Uppal for further examination and testing.

2.2 Rock Drilling

Rotary drilling through the rock was performed using heavy-duty skid mounted Joy Voltas 12B diamond coring rotary drill machine. The drill machine has a hydraulic feed and is driven by a bevel gear system run by a 28 HP Perkin engine. The drill chuck has four jaws to accommodate NW size drill rods.

Drilling and sampling of the rock was performed using a NX size double tube core barrel. Tungsten Carbide bit and 32 carat impregnated diamond bit was used to drill through hard rock. It was attached to the end of a core barrel, which is connected to the machine by a string of NW drill rods and rotated by the drilling machine.

Water was circulated through the drill rods to the bottom of the hole. The water serves the purpose of lubrication, cooling and protection of the diamond drill bit in addition to flushing the cuttings out of the hole. A reciprocating pump was used to circulate the water. While drilling through soft rock that is likely to collapse, casing was installed. A NX casing (80 mm OD) was used. The casing with a diamond shoe bit was used to assist the casing to advance.



2.3 Groundwater

Groundwater level was measured in the boreholes in 24 hours after drilling and sampling was completed. The measured water levels are recorded on the individual soil profiles.

3.0 LABORATORY TESTS

The laboratory testing has been carried out in our laboratory. The testing program was aimed at verifying the field classifications and developing parameters for engineering analysis. All testing was performed in accordance with the current applicable IS specifications. The following tests were conducted on selected soil / rock samples recovered from the boreholes.

The percent recovery and Rock Quality Designation (RQD) was measured for each core run. The percent recovery is defined as the percent ratio of the cumulative length of core sample recovered to the total length of the core run. The Rock Quality Designation (RQD) is defined as the ratio of the cumulative length of core pieces 10 cm or longer to the total length of the core run, expressed as percentage. Details of samples collected are presented on the rock profiles and RQD at various depths. The net effective drilling time, a qualitative assessment of the nature of the strata, is also included on the borehole logs.

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

Name of Test		IS Code No.
Bulk Density		By Calculation
Natural moisture content		IS:2720 (Part-2)-1973
Grain size analysis		IS:2720 (Part-4)-1985
Specific gravity		IS:2720 (Part-3)-1980
Free Swell Index		IS:2720 (Part-40)-1977
Liquid and plastic limits		IS:2720 (Part-5)-1985
Unconfined compression test		IS:2720 (Part-10)-1991
Unconsolidated undrained Direct Shear Test		IS:2720 (Part-13)-1986
Consolidation Test		IS:2720 (Part-15)-1986
Chemical analysis of	Determination of pH value	IS:2720 (Part-26) -1987
	Determination of sulphate content	IS:2720 (Part-27) -1977

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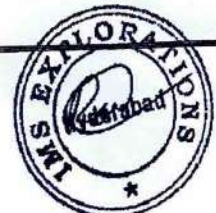
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Liquid and plastic limits		IS:2720 (Part-5)-1985
Unconfined compression test		IS:2720 (Part-10)-1991
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Consolidation Test		IS:2720 (Part-15)-1986
Chemical analysis of	Determination of pH value	IS:2720 (Part-26) -1987
	Determination of sulphate content	IS:2720 (Part-27) -1977





soil*	Determination of chloride content	IS:3025 (Part-32)-1993
Chemical analysis of water*	Determination of pH value	IS:3025 (Part-11) -1996
	Determination of sulphate content	IS:3025 (Part-24) -1998
	Determination of chloride content	IS:3025 (Part-32)-1993

Name of Test (Rock Cores)	IS Code No.
Bulk density	IS: 13030-1991
Specific Gravity	IS:2720 (Part-3)-1980
Porosity and Void Ratio	By Calculations
Water absorption	IS: 2386 (Part 3)-1963
Crushing strength	IS: 9143-1979
Point load strength index	IS: 8764-1998

4 GENERAL SITE CONDITIONS

4.1 General Geology of Project Site

Hyderabad area forms part of an upland plateau region called the Deccan Plateau. It is generally surrounded by rocky hills. Prominent among them are : Banjara Hills, 533-640m above MSL, Golconda Range 518-596 m above MSL in the south, Moula-Ali Hills 518-628 m above MSL in the North east par with the Trimulgherry Heights forming the Northern part.

A few isolated hillocks (inselbergs) are also found within the city like Red Hills and Naubat Pahad. The rest of the area is marked by generally undulating terrain between 487 m and 533 m above MSL with city clusters.

The city is underlain by Archean Crystalline Complex consisting of pink and grey granites, gneisses, magmatites, quartz reefs and dolorite dykes. The granites are medium to coarse grained, poryphritic and equiangular in texture and foliated at places. Dolerite dykes traverse mostly in East-west and North-south directions

4.2 Site Stratigraphy

As per the boreholes drilled at the site, the top soil is generally by murrum underlain by soft disintegrated rock followed by fractured rock and hard rock.



BH.No.	Depth (m)		Strata Description*	CR%	RQD%
1	0.00	3.00	Mourrum		
	3.00	4.50	S.D.R		
	4.50	5.50	Fractured rock		
	5.50	8.00	Hard rock	90-100%	76-100%
2	0.00	3.00	Mourrum		
	3.00	10.00	SDR		
3	0.00	1.50	Mourrum		
	1.50	3.50	S.D.R		
	3.50	7.50	Fractured rock	65-85%	
4	0.00	1.00	Mourrum with boulders		
	1.00	2.00	Mourrum		
	2.00	3.00	S.D.R		
	3.00	7.20	Fractured rock	47-93%	
5	0.00	2.00	Mourrum with boulders		
	2.00	4.00	Boulders		
	4.00	8.00	Fractured Rock	30-77%	
6	0.00	3.00	Mourrum with boulders		
	3.00	6.00	S.D.R		
	6.00	10.00	Fractured rock	56-88%	



4.3 Hydrogeology

Based on the measurements in the completed boreholes, groundwater is met at a depth of, 6.30m, 7.60m, 5.8m, 4.70m and 7.30m below existing ground level at different boreholes during the period of our field investigation.

5.0 LIQUEFACTION SUSCEPTIBILITY ANALYSIS

Liquefaction is defined as the transformation of a granular material from a solid to a liquefied state as a consequence of increased pore-water pressure and reduced effective stress (Marcuson, 1978(4)). Increased pore pressure may be induced by the tendency of granular materials to compact when subjected to cyclic shear deformation, such as in the event of an earthquake.

As per IS 1893 (Part-1): 2002, Table-1; liquefaction is likely in fine sands below water table.

Based on a review of all soil parameters like in-situ density, measured groundwater levels, fines content; we are of the opinion that liquefaction is not likely to take place at the site in the event of a major earthquake.

According to Fig.1 of IS:1893 (Part1)-2002 showing seismic zones, the proposed site falls under Zone-II. The design for seismic forces should be done considering the project in Zone-II.

6.0 CONCEPTS FOR FOUNDATION ANALYSIS

6.1 General

A suitable foundation for any structure should have an adequate factor of safety against exceeding the bearing capacity of the supporting soils. Also the vertical movements due to compression of the soils should be within tolerable limits for the structure. We consider that foundation designed in accordance with the recommendations given herein will satisfy these criteria. It is inferred that the recorded water levels in Bore Holes were from drilling fluids water and based on the local hydrogeology and depleting Ground Water levels, the ground water table is likely to be beyond the influence depth of foundations. However suitable corrections for shallow water table conditions were made in recommending foundation safe bearing pressures.

6.2 Shallow Foundation Summary

For recommending net safe bearing capacities a rectangular footing of L/B ratio 1 is considered and the summary of bearing capacities is presented as below:



Borehole No's	Footing Size	Depth bgl (m)	SBC (from Shear) T/sq.m	SBC(from settlement) T/sq.m	Recommended SBC In T/sq.m
1	2X2	3.50	32.80	32.80	32.80
	3X3	3.50	33.60	33.60	33.60
2	2X2	3.50	33.00	33.00	33.00
	3X3	3.50	33.80	33.80	33.80
3	2X2	3.50	32.50	32.50	32.50
	3X3	3.50	33.30	33.30	33.30
4	2X2	3.50	32.40	32.40	32.40
	3X3	3.50	33.20	33.20	33.20
5	2X2	3.50	32.60	32.60	32.60
	3X3	3.50	33.40	33.40	33.40
6	2X2	3.50	32.30	32.30	32.30
	3X3	3.50	33.20	33.20	33.20
7	2X2	3.50	32.60	32.60	32.60
	3X3	3.50	33.40	33.40	33.40
8	2X2	3.50	32.60	32.60	32.60
	3X3	3.50	33.40	33.40	33.40
9	2X2	3.50	32.60	32.60	32.60
	3X3	3.50	33.50	33.50	33.50
10	2X2	3.50	32.60	32.60	32.60
	3X3	3.50	33.50	33.50	33.50

6.3 Variability in Subsurface Conditions

Subsurface conditions encountered during construction may vary somewhat from the conditions encountered during the site investigation. In case significant variations are encountered during construction, we request to be notified so that our engineers may review the recommendations in this report in light of these variations.





7.0 CLOSURE

We appreciate the opportunity to perform this investigation for you and have pleasure in submitting this report. Please contact us when we can be of further service to you.

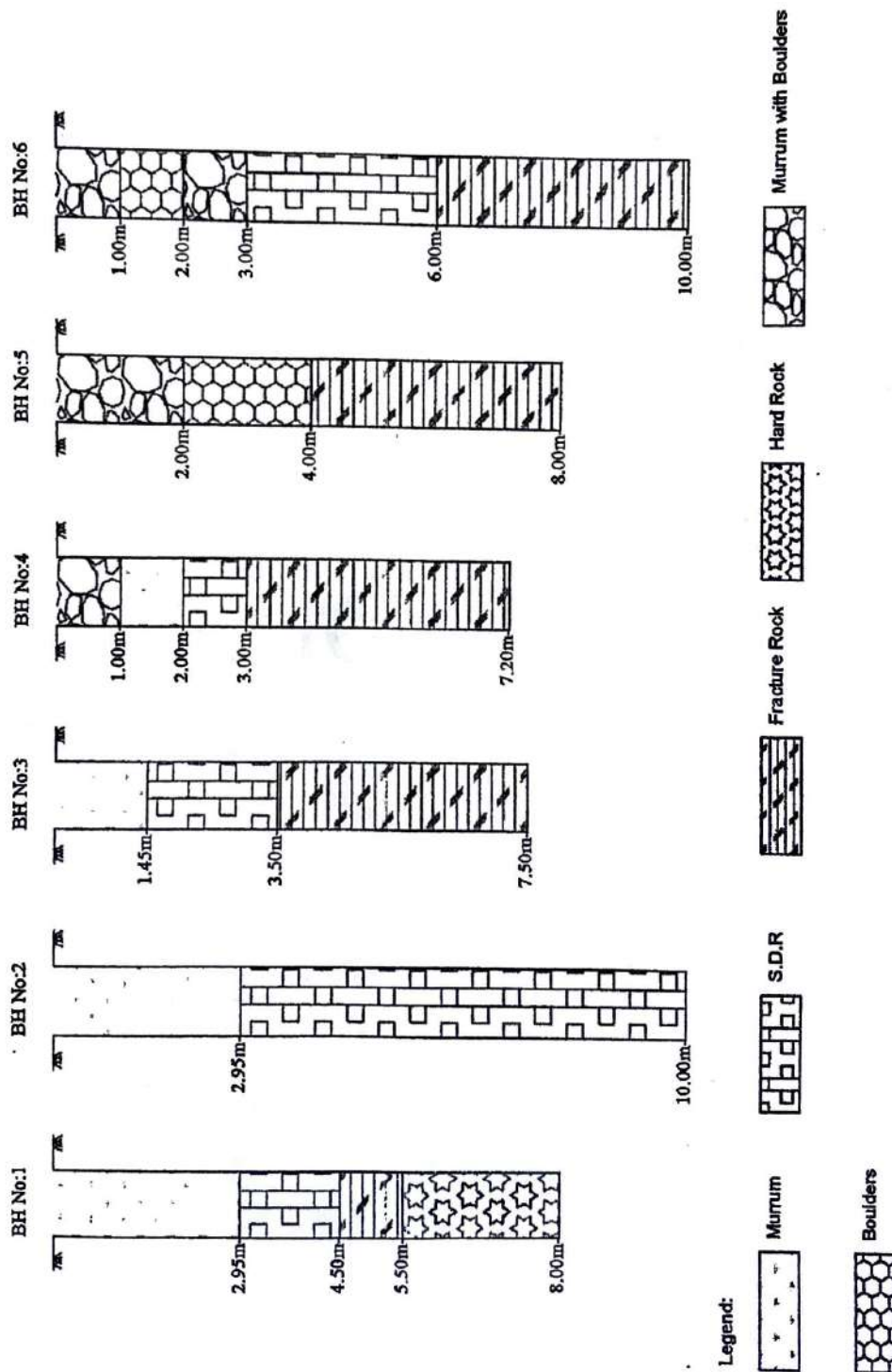
for IMS EXPLORATIONS



(Chief Consultant)

APPENDIX I

Fig-1: Log of Boreholes



SOIL PROFILE

Soil Investigation works for proposed 400/220KV substation at Maheshwaram, Meerkhanpet (V), Kandukur mandal R.R District, T.S.

Soil Investigation works for proposed 400/220KV substation at Maheshwaram, Meerkhanpet (V), Kandukur mandal R.R District, T.S.										Bore Hole No 1		Termination Depth: 8.00		Date 12-03-2016 14-03-2016					
Water Table:										Atterberg Limits		Direct Shear							
N-Value*	Reduced Level, m	Depth (m)	Sample No.	SOIL DESCRIPTION	Gravel %	Sand %	Silt %	Clay %	Liquid %	Plastic %	Plasticity Index %	Specific Gravity	Silt Factor	Natural Density gms/cm ³	Dry Density gms/cm ³	Moisture Content %	Confining Pressure kg/cm ²	Cohesion Intercept kg/cm ²	Angle of Internal Friction
20		0.00	DS1	MURROM															
		1.00		-do-				8				2.68							
		1.50	SPT1	-do-															
		2.50	DS2	-do-															
31		2.50		-do-															
		3.00	SPT2	-do-				5				2.69							
		3.00		S.D.R															
		4.50	DS3	S.D.R				7											

IMS EXPL
Hydro



SOIL PROFILE

Soil Investigation works for proposed 400/220KV substation at Maheshwaram, Meerthampet (V), Kandukur mandal R.R District, T.S.

Bore Hole No
2

Termination Depth:
10.00

Date
15-03-2016

Water Table:
15-03-2016

Atterberg Limits

Reduced Level, m	Depth (m)	Sample No.	SOIL DESCRIPTION	Gravel %	Sand %	Silt %	Clay %	Liquid %	Plastic %	Plasticity Index %	Specific Gravity	Silt Factor	Natural Density gms/cm ³	Dry Density gms/cm ³	Moisture Content %	Confining Pressure Kg/cm ²	Cohesion Intercept Kg/cm ²	Angle of Internal Friction
	0.00	DS1	MORRUM															
	1.00																	
18	1.50	SPT1	-do-	49	33	9	9				2.67							
	1.50																	
	2.50	DS2	-do-															
	2.50																	
27	2.50	SPT2	-do-	51	35	8	8				2.68							
	3.00																	
	4.00	DS3	S.D.R															
	4.00																	
>50	5.00	SPT3	-do-	26	58	12	4				2.71							
	5.00																	
	6.00	DS4	-do-															
	6.00																	
	7.00	DS5	-do-															
	7.00																	
>50	8.00	SPT4	-do-	20	62	13	5				2.72							
	8.00																	
	9.00	DS6	-do-															
	9.00																	
	10.00	DS7	-do-															



SOIL PROFILE				Soil Investigation works for proposed 400/220KV substation at Maheshwaram, Meerkhanpet (V), Kandukur mandal R.R District, T.S.		Bore Hole No 3	Termination Depth: 7.50	Date											
								16-03-2016	17-03-2016										
N-Value*	Reduced Level, m	Depth (m)	Sample No.	SOIL DESCRIPTION	Gravel %	Sand %	Silt %	Clay %	Atterberg Limits			Specific Gravity	Silt Factor	Natural Density gms/cm ³	Dry Density gms/cm ³	Moisture Content %	Confining Pressure Kg/cm ²	Cohesion Intercept Kg/cm ²	Angle of Internal Friction
									Liquid %	Plastic %	Plasticity Index %								
18		0.00	DS1	MORRUM															
		1.00																	
		1.00	SPT1	-do-	43	39	10	8				2.69							
		1.50																	
>50		1.50	DS2	S.D.R															
		2.50																	
		2.50	SPT2	-do-	23	52	18	7				2.71							
		3.50																	



BORE HOLE LOG			Soil Investigation works for proposed 400/220KV substation at Maheshwaram, Meerthampet (V), Kandukur mandal R.R District, T.S.				TERMINATION DEPTH 7.50		DATE 16-3-2016 17-3-2016						
Reduced Level, m	Depth (m)	Drill Run (m)	Sample No.	SPT Value	Serial No. of Cores	DESCRIPTION	Percent Recovery	Rock Quality Designation (RQD) (%)	Specific Gravity	Water Strength	UCC Strength, kg/cm ²	Colour	Loss	Bits Used	Remarks
	3.50		DS3	>80		FRACTURE ROCK	65%				382.0	White	Yellow		
	4.50	1.00	DS3												
	5.50	1.00	SPT3			-do-	67%		2.74						
	6.50	1.00	DS4			-do-	70%								
	7.50	1.00	DS5			-do-	85%								



SOIL PROFILE				Soil Investigation works for proposed 400/220KV substation at Maheshwaram, Meerkhanpet (V), Kandukur mandal R.R District, T.S.		Bore Hole No 4		Termination Depth: 7.20		Date 18-03-2016 19-03-2016								
				Water Table:														
N-Value	Reduced Level, m	Depth (m)	Sample No.	SOIL DESCRIPTION	Atterberg Limits							Direct Shear						
					Gravel %	Sand %	Silt %	Clay %	Liquid %	Plastic %	Plasticity Index %	Specific Gravity	Silt Factor	Natural Density gms/cm ³	Dry Density gms/cm ³	Moisture Content %	Confining Pressure kg/cm ²	Cohesion Intercept kg/cm ²
> 50		0.00	SPT1	MORRUM WITH BOULDERS	52	35	9	4										
		1.00																
		1.00	DS1	-do-														
		2.00																
> 50		2.00																
		3.00	SPT2	S.D.R	24	56	14	6										





SOIL PROFILE

Soil Investigation works for proposed 400/220KV
substation at Maruthwaram, Meerthampet (V),
Kandukur mandal R.R District, T.S.

Bore Hole No
5

Water Table:

Termination Depth:

8.00

Date

21-03-2016

22-03-2016

Direct Shear

N-Value*

Reduced
Level, m

Depth (m)

Sample No.

SOIL DESCRIPTION

Gravel %

Sand %

Silt %

Clay %

Liquid %

Plastic %

Atterberg Limits
Plasticity Index
%

Specific Gravity

Silt Factor

Natural Density
gms/cm³

Dry Density
gms/cm³

Moisture Content
%

Confining
Pressure
Kg/cm²

Cohesion
Intercept
Kg/cm²

Angle of
Internal
Friction

>100

0.00

1.00

DS1

MORRUM WITH BOULDERS

49

35

11

5

2.67

1.00

2.00

SPT1

-do-

72

21

5

2

2.73

2.00

3.00

DS2

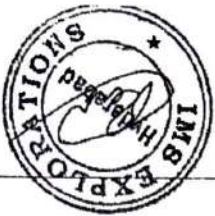
BOULDERS

3.00

4.00

DS3

-do-



SOIL PROFILE									
Soil Investigation works for proposed 400/220KV substation at Maheshwaram, Meerkhanpet (V), Kandukur mandal R.R District, T.S.									
					Bore Hole No		Termination Depth:		
					6		10.00		
					Water Table:		Date		
							22-03-2016		
							23-03-2016		
					Atterberg Limits		Direct Shear		

APPENDIX II

BEARING CAPACITY ANALYSIS FOR SHALLOW FOUNDATIONS

Analysis as per IS 6403-1981

Project : Soil Investigations works for the proposed 400/220KV substation at maheswaram, Meerkhanpet(V), Kandukur (M), RR Dist, T.S. BH-01

The bearing capacity equation is as follows :

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

where:

$q_{\text{net safe}}$ = safe net bearing capacity	c = cohesion intercept
q = overburden pressure	B = Foundation width
γ = Bulk density of soil below founding level	
R_w = Water table correction factor	FS = Factor of safety
N_c, N_q, N_γ = bearing capacity factors, which are a function of ϕ	
d_c, d_q, d_γ = Depth factors	
$\zeta_c, \zeta_q, \zeta_\gamma$ = Shape factors	

Soil parameters :

$c = 0.00 \text{ T/m}^2$	$\phi = 32.0 \text{ degrees}$	GENERAL SHEAR FAILURE		
$c' = 0.00 \text{ T/m}^2$	$\phi' = 22.6 \text{ degrees}$	LOCAL SHEAR FAILURE		
General Shear Failure :	$N_c = 35.49$	$N_q = 23.18$	$N_\gamma = 30.21$	
Local Shear Failure :	$N_c' = 17.59$	$N_q' = 8.33$	$N_\gamma' = 7.77$	

Bulk Density Profile		
Depth, m		γ
From	To	T/m^3
0.0	3.0	1.72
3.0	4.5	1.80
4.5	5.5	2.00
5.5	8.0	2.10

Factor of safety = 2.5 as per IS 1904-1986

Design Water Table depth = GL

R_w factor: Constant value(V) for worst condition or

calculate(C) based on WT Depth ? :

Depth factor to be considered ? Y

For computation of Depth Factor, depth below GL to be ignored to account for loose soils, poorly compacted backfill above foundation, scour etc. =

0.1 m

FAILURE CRITERIA : Average OF LOCAL & GENERAL SHEAR FAILURE

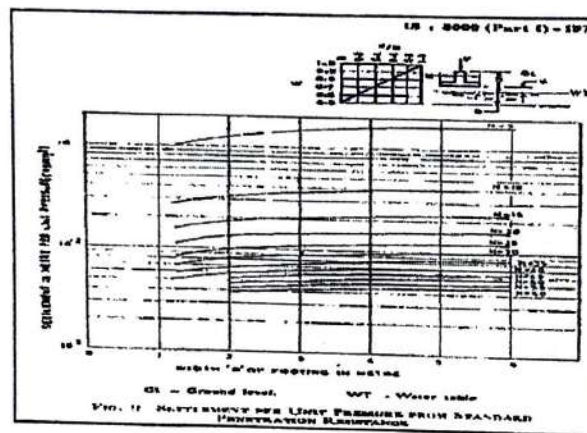
Foundation Dimensions		FOUN-DATION SHAPE	Depth, m	R_w	Shape Factors			Depth factors (GSF)			Depth factors (LSF)			$q_{\text{net safe}}, \text{ T/m}^2$		Safe Net Bearing Capacity T/m^2
B, m	L, m				ζ_c	ζ_q	ζ_γ	d_c	d_q	d_γ	d_c'	d_q'	d_γ'	GSF	LSF	
3.0	3.0	square	3.5	0.50	1.30	1.20	0.80	1.41	1.20	1.20	1.00	1.17	1.17	50.0	14.8	32.4
3.0	3.0	square	4.0	0.50	1.30	1.20	0.80	1.47	1.24	1.24	1.00	1.20	1.20	57.0	16.9	37.0
3.5	3.5	square	3.5	0.50	1.30	1.20	0.80	1.35	1.18	1.18	1.00	1.15	1.15	51.8	15.3	33.5
3.5	3.5	square	4.0	0.50	1.30	1.20	0.80	1.40	1.20	1.20	1.00	1.17	1.17	58.5	17.3	37.9



SETTLEMENT ANALYSIS FOR SHALLOW FOUNDATIONS BASED ON N - VALUES

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

Project : Soil Investigations works for the proposed 400/220KV substation
at maheswaram, Meerkhanpet(V), Kandukur (M), RR Dist, T.S.



Design Water Table Depth :

GL

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

or Fixed Value(V) for worst condition :

C

Fox's Depth Factor to be considered ?

Y

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

0.1 m

Foundation Width, m	Foundation Length, m	Foundation Depth, m	Shape	Design N-value	Net Allowable Bearing Pressure, T/m^2	Settlement @ $1 kg/cm^2$ (as read off from graph), mm	R_w	Fox's Depth Factor, d_f	Rigidity Factor, d_r	Computed Settlement, mm
3.0	3.0	3.5	square	20.0	25.3	14.0	0.50	0.70	1.0	49.7
3.0	3.0	4.0	square	20.0	26.1	14.0	0.50	0.68	1.0	49.8
3.5	3.5	3.5	square	20.0	23.6	14.4	0.50	0.73	1.0	49.7
3.5	3.5	4.0	square	20.0	24.7	14.4	0.50	0.70	1.0	49.8



BEARING CAPACITY ANALYSIS FOR SHALLOW FOUNDATIONS

Analysis as per IS 6403-1981

Project : Soil Investigations works for the proposed 400/220KV substation
at maheswaram, Meerkhanpet(V), Kandukur (M), RR Dist, T.S.
BH-02

The bearing capacity equation is as follows :

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

where:

$q_{\text{net safe}}$ = safe net bearing capacity	c = cohesion intercept
q = overburden pressure	B = Foundation width
γ = Bulk density of soil below founding level	
R_w = Water table correction factor	FS = Factor of safety
N_c, N_q, N_{γ} = bearing capacity factors, which are a function of ϕ	
d_c, d_q, d_{γ} = Depth factors	
$\zeta_c, \zeta_q, \zeta_{\gamma}$ = Shape factors	

Soil parameters :

$c = 0.00 \text{ T/m}^2$	$\phi = 32.0 \text{ degrees}$	GENERAL SHEAR FAILURE
$c' = 0.00 \text{ T/m}^2$	$\phi' = 22.6 \text{ degrees}$	LOCAL SHEAR FAILURE
General Shear Failure :	$N_c = 35.49$ $N_q = 23.18$ $N_{\gamma} = 30.21$	
Local Shear Failure :	$N'_c = 17.59$ $N'_q = 8.33$ $N'_{\gamma} = 7.77$	

Bulk Density Profile		
Depth, m		γ
From	To	T/m^3
0.0	3.0	1.72
3.0	10.0	1.91

Factor of safety = 2.5 as per IS 1904-1986

Design Water Table depth = GL

R_w factor: Constant value(V) for worst condition or

calculate(C) based on WT Depth ? : C

Depth factor to be considered ? Y

For computation of Depth Factor, depth below GL to be ignored to account for loose soils, poorly compacted backfill above foundation, scour etc. =

0.1 m

FAILURE CRITERIA : Average OF LOCAL & GENERAL SHEAR FAILURE

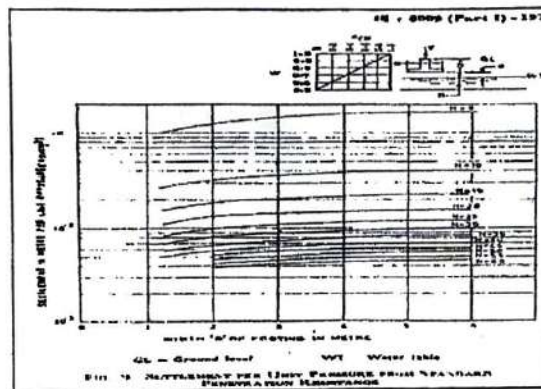
Foundation Dimensions		FOUN-DATION SHAPE	Depth, m	R_w	Shape Factors			Depth factors (GSF)			Depth factors (LSF)			$q_{\text{net safe}}, \text{ T/m}^2$		Safe Net Bearing Capacity T/m^2
B, m	L, m				ζ_c	ζ_q	ζ_{γ}	d_c	d_q	d_{γ}	d'_c	d'_q	d'_{γ}	GSF	LSF	
3.0	3.0	square	3.5	0.50	1.30	1.20	0.80	1.41	1.20	1.20	1.00	1.17	1.17	50.2	14.9	32.6
3.0	3.0	square	4.0	0.50	1.30	1.20	0.80	1.47	1.24	1.24	1.00	1.20	1.20	57.5	17.2	37.3
3.5	3.5	square	3.5	0.50	1.30	1.20	0.80	1.35	1.18	1.18	1.00	1.15	1.15	61.7	15.3	33.5
3.5	3.5	square	4.0	0.50	1.30	1.20	0.80	1.40	1.20	1.20	1.00	1.17	1.17	58.7	17.4	38.1



SETTLEMENT ANALYSIS FOR SHALLOW FOUNDATIONS BASED ON N - VALUES

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

Project : Soil Investigations works for the proposed 400/220KV substation
at maheswaram, Meerhanpet(V), Kandukur (M), RR Dist, T.S.



Design Water Table Depth :

GL

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

or Fixed Value(V) for worst condition :

C

Fox's Depth Factor to be considered ?

Y

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

0.1 m

Foundation Width, m	Foundation Length, m	Foundation Depth, m	Shape	Design N-value	Net Allowable Bearing Pressure, T/m^2	Settlement @ $1kg/cm^2$ (as read off from graph), mm	R_w	Fox's Depth Factor, d_r	Rigidity Factor, d_r	Computed Settlement, mm
3.0	3.0	3.5	square	20.0	25.3	14.0	0.50	0.70	1.0	49.7
3.0	3.0	4.0	square	20.0	26.1	14.0	0.50	0.68	1.0	49.8
3.5	3.5	3.5	square	20.0	23.6	14.4	0.50	0.73	1.0	49.7
3.5	3.5	4.0	square	20.0	24.7	14.4	0.50	0.70	1.0	49.8



BEARING CAPACITY ANALYSIS FOR SHALLOW FOUNDATIONS

Analysis as per IS 6403-1981

Project : Soil Investigations works for the proposed 400/220KV substation at maheswaram, Meerkhanpet(V), Kandukur (M), RR Dist, T.S.
BH-04

The bearing capacity equation is as follows :

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

where:

$q_{\text{net safe}}$ = safe net bearing capacity	c = cohesion intercept
q = overburden pressure	B = Foundation width
γ = Bulk density of soil below founding level	
R_w = Water table correction factor	FS = Factor of safety
N_c, N_q, N_γ = bearing capacity factors, which are a function of ϕ	
d_c, d_q, d_γ = Depth factors	
$\zeta_c, \zeta_q, \zeta_\gamma$ = Shape factors	

Soil parameters :

$c = 0.00 \text{ T/m}^2$	$\phi = 32.0 \text{ degrees}$	GENERAL SHEAR FAILURE
$c' = 0.00 \text{ T/m}^2$	$\phi' = 22.6 \text{ degrees}$	LOCAL SHEAR FAILURE
General Shear Failure :	$N_c = 35.49$ $N_q = 23.18$ $N_\gamma = 30.21$	
Local Shear Failure :	$N_c' = 17.59$ $N_q' = 8.33$ $N_\gamma' = 7.77$	

Bulk Density Profile		
Depth, m		γ
From	To	T/m^3
0.0	2.0	1.72
2.0	3.0	1.83
3.0	7.2	2.00

Factor of safety = 2.5 as per IS 1904-1986

Design Water Table depth = GL
 R_w factor: Constant value(V) for worst condition or
 calculate(C) based on WT Depth ? :
 Depth factor to be considered ?

For computation of Depth Factor, depth below GL to be ignored to account for loose soils, poorly compacted backfill above foundation, scour etc. = 0.1 m
 FAILURE CRITERIA : average OF LOCAL & GENERAL SHEAR FAILURE

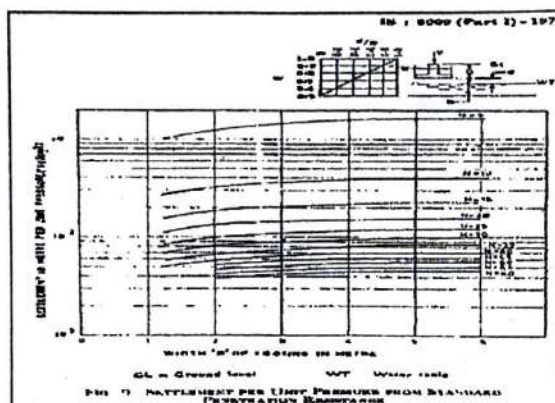
Foundation Dimensions		FOUN-DATION SHAPE	Depth, m	R_w	Shape Factors			Depth factors (GSF)			Depth factors (LSF)			$q_{\text{net safe}}$ T/m^2		Safe Net Bearing Capacity T/m^2
B, m	L, m				ζ_c	ζ_q	ζ_γ	d_c	d_q	d_γ	d_c'	d_q'	d_γ'	GSF	LSF	
3.0	3.0	square	3.5	0.50	1.30	1.20	0.80	1.41	1.20	1.20	1.00	1.17	1.17	53.0	15.8	34.4
3.0	3.0	square	4.0	0.50	1.30	1.20	0.80	1.47	1.24	1.24	1.00	1.20	1.20	60.9	18.2	39.6
3.5	3.5	square	3.5	0.50	1.30	1.20	0.80	1.35	1.18	1.18	1.00	1.15	1.15	54.5	16.2	35.3
3.5	3.5	square	4.0	0.50	1.30	1.20	0.80	1.40	1.20	1.20	1.00	1.17	1.17	62.1	18.5	40.3



SETTLEMENT ANALYSIS FOR SHALLOW FOUNDATIONS BASED ON N - VALUES

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

Project : Soil Investigations works for the proposed 400/220KV substation
at maheswaram, Meerkhanpet(V), Kandukur (M), RR Dist, T.S.



Design Water Table Depth : GL

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

or Fixed Value(V) for worst condition :

C

Fox's Depth Factor to be considered ?

Y

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

0.1 m

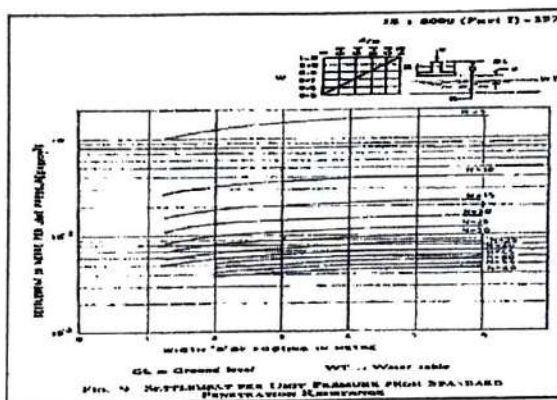
Foundation Width, m	Foundation Length, m	Foundation Depth, m	Shape	Design N-value	Net Allowable Bearing Pressure, T/m^2	Settlement @ $1kg/cm^2$ (as read off from graph), mm	R_w	Fox's Depth Factor, d_f	Rigidity Factor, d_r	Computed Settlement, mm
3.0	3.0	3.5	square	40.0	34.4	6.5	0.50	0.70	1.0	31.1
3.0	3.0	4.0	square	40.0	39.6	6.5	0.50	0.68	1.0	34.7
3.5	3.5	3.5	square	40.0	35.3	6.6	0.50	0.73	1.0	34.1
3.5	3.5	4.0	square	40.0	40.3	6.6	0.50	0.70	1.0	37.4



SETTLEMENT ANALYSIS FOR SHALLOW FOUNDATIONS BASED ON N - VALUES

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

Project : Soil Investigations works for the proposed 400/220KV substation
at maheswaram, Meerkhanpet(V), Kandukur (M), RR Dist, T.S.



Design Water Table Depth : GL

R_w factor : Calculate (C) based on water table depth
or Fixed Value(V) for worst condition :

Fox's Depth Factor to be considered ? Y

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

0.1 m

Foundation Width, m	Foundation Length, m	Foundation Depth, m	Shape	Design N-value	Net Allowable Bearing Pressure, T/m ²	Settlement @ 1kg/cm ² (as read off from graph), mm	R_w	Fox's Depth Factor, d_r	Rigidity Factor, d_r	Computed Settlement, mm
3.0	3.0	3.5	square	40.0	35.5	6.5	0.50	0.70	1.0	32.1
3.0	3.0	4.0	square	40.0	40.7	6.5	0.50	0.68	1.0	35.7
3.5	3.5	3.5	square	40.0	36.4	6.6	0.50	0.73	1.0	35.2
3.5	3.5	4.0	square	40.0	41.4	6.6	0.50	0.70	1.0	38.4



BEARING CAPACITY ANALYSIS FOR SHALLOW FOUNDATIONS

Analysis as per IS 6403-1981

Project : Soil Investigations works for the proposed 400/220KV substation
at maheswaram, Meerkanpet(V), Kandukur (M), RR Dist, T.S.
BH-03

The bearing capacity equation is as follows :

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

where:

$q_{\text{net safe}}$ = safe net bearing capacity	c = cohesion intercept
q = overburden pressure	B = Foundation width
γ = Bulk density of soil below founding level	
R_w = Water table correction factor	FS = Factor of safety
N_c, N_q, N_γ = bearing capacity factors, which are a function of ϕ	
d_c, d_q, d_γ = Depth factors	
$\zeta_c, \zeta_q, \zeta_\gamma$ = Shape factors	

Soil parameters :

$c = 0.00 \text{ T/m}^2$	$\phi = 32.0 \text{ degrees}$	GENERAL SHEAR FAILURE	
$c' = 0.00 \text{ T/m}^2$	$\phi' = 22.6 \text{ degrees}$	LOCAL SHEAR FAILURE	
General Shear Failure :	$N_c = 35.49$	$N_q = 23.18$	$N_\gamma = 30.21$
Local Shear Failure :	$N_c = 17.59$	$N_q = 8.33$	$N_\gamma = 7.77$

Bulk Density Profile		
Depth, m		γ
From	To	T/m^3
0.0	1.5	1.72
1.5	3.5	1.91
3.5	7.5	2.00

Factor of safety = 2.5 as per IS 1904-1986

Design Water Table depth = GL

R_w factor: Constant value(V) for worst condition or

calculate(C) based on WT Depth ? : C

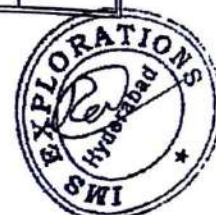
Depth factor to be considered ? Y

For computation of Depth Factor, depth below GL to be ignored to account for loose soils, poorly compacted backfill above foundation, scour etc. =

0.1 m

FAILURE CRITERIA : average OF LOCAL & GENERAL SHEAR FAILURE

Foundation Dimensions		FOUN-DATION SHAPE	Depth, E	R_w	Shape Factors			Depth factors (GSF)			Depth factors (LSF)			$q_{\text{net safe}}$ T/m^2		Safe Net Bearing Capacity T/m^2
B, m	L, m				ζ_c	ζ_q	ζ_γ	d_c	d_q	d_γ	d'_c	d'_q	d'_γ	GSF	LSF	
3.0	3.0	square	3.5	0.50	1.30	1.20	0.80	1.41	1.20	1.20	1.00	1.17	1.17	54.6	16.3	35.5
3.0	3.0	square	4.0	0.50	1.30	1.20	0.80	1.47	1.24	1.24	1.00	1.20	1.20	62.6	18.7	40.7
3.5	3.5	square	3.5	0.50	1.30	1.20	0.80	1.35	1.18	1.18	1.00	1.15	1.15	56.2	16.7	36.4
3.5	3.5	square	4.0	0.50	1.30	1.20	0.80	1.40	1.20	1.20	1.00	1.17	1.17	63.8	19.0	41.4



BEARING CAPACITY ANALYSIS FOR SHALLOW FOUNDATIONS

Analysis as per IS 6403-1981

Project : Soil Investigations works for the proposed 400/220KV substation
at maheswaram, Meerkhanpet(V), Kandukur (M), RR Dist, T.S.
BH-05

The bearing capacity equation is as follows :

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

where:

$q_{\text{net safe}}$ = safe net bearing capacity	c = cohesion intercept
q = overburden pressure	B = Foundation width
γ = Bulk density of soil below founding level	
R_w = Water table correction factor	FS = Factor of safety
N_c, N_q, N_γ = bearing capacity factors, which are a function of ϕ	
d_c, d_q, d_γ = Depth factors	
$\zeta_c, \zeta_q, \zeta_\gamma$ = Shape factors	

Soil parameters :

$c = 0.00 \text{ T/m}^2$	$\phi = 32.0 \text{ degrees}$	GENERAL SHEAR FAILURE
$c' = 0.00 \text{ T/m}^2$	$\phi' = 22.6 \text{ degrees}$	LOCAL SHEAR FAILURE
General Shear Failure :	$N_c = 35.49$ $N_q = 23.18$ $N_\gamma = 30.21$	
Local Shear Failure :	$N_c' = 17.59$ $N_q' = 8.33$ $N_\gamma' = 7.77$	

Bulk Density Profile		
Depth, m		γ
From	To	T/m^3
0.0	2.0	1.76
2.0	4.0	1.91
4.0	8.0	2.00

Factor of safety = 2.5 as per IS 1904-1986

Design Water Table depth = GL

R_w factor: Constant value(V) for worst condition or

calculate(C) based on WT Depth ? :

Depth factor to be considered ? Y

For computation of Depth Factor, depth below GL to be ignored to account for loose soils, poorly compacted backfill above foundation, scour etc. =

0.1 m

FAILURE CRITERIA : average OF LOCAL & GENERAL SHEAR FAILURE

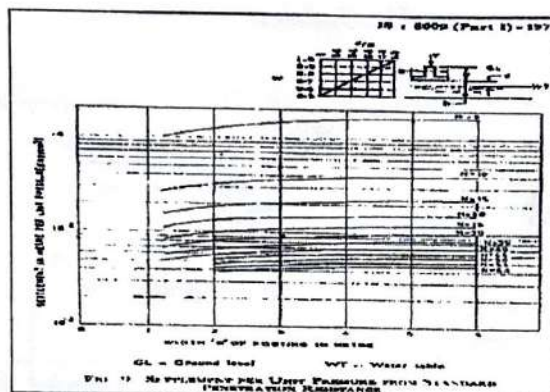
Foundation Dimensions		FOUN-DATION SHAPE	Depth, m	R_w	Shape Factors			Depth factors (GSF)			Depth factors (LSF)			$q_{\text{net safe}}$ T/m^2		Safe Net Bearing Capacity T/m^2
B, m	L, m				ζ_c	ζ_q	ζ_γ	d_c	d_q	d_γ	d_c'	d_q'	d_γ'	GSF	LSF	
3.0	3.0	square	3.5	0.50	1.30	1.20	0.80	1.41	1.20	1.20	1.00	1.17	1.17	54.3	16.2	35.3
3.0	3.0	square	4.0	0.50	1.30	1.20	0.80	1.47	1.24	1.24	1.00	1.20	1.20	61.8	18.5	40.2
3.5	3.5	square	3.5	0.50	1.30	1.20	0.80	1.35	1.18	1.18	1.00	1.15	1.15	55.8	16.6	36.2
3.5	3.5	square	4.0	0.50	1.30	1.20	0.80	1.40	1.20	1.20	1.00	1.17	1.17	63.0	18.8	40.9



SETTLEMENT ANALYSIS FOR SHALLOW FOUNDATIONS BASED ON N - VALUES

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

Project : Soil Investigations works for the proposed 400/220KV substation
at maheswaram, Meerkhanpet(V), Kandukur (M), RR Dist, T.S.



Design Water Table Depth :

GL

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

or Fixed Value(V) for worst condition :

C

Fox's Depth Factor to be considered ?

Y

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

0.1 m

Foundation Width, m	Foundation Length, m	Foundation Depth, m	Shape	Design N-value	Net Allowable Bearing Pressure, T/m^2	Settlement @ $1kg/cm^2$ (as read off from graph), mm	R_w	Fox's Depth Factor, d_f	Rigidity Factor, d_r	Computed Settlement, mm
3.0	3.0	3.5	square	50.0	35.3	5.1	0.50	0.70	1.0	25.1
3.0	3.0	4.0	square	50.0	40.2	5.1	0.50	0.68	1.0	27.8
3.5	3.5	3.5	square	50.0	36.2	5.2	0.50	0.73	1.0	27.6
3.5	3.5	4.0	square	50.0	40.9	5.2	0.50	0.70	1.0	29.8



BEARING CAPACITY ANALYSIS FOR SHALLOW FOUNDATIONS

Analysis as per IS 6403-1981

Project : Soil Investigations works for the proposed 400/220KV substation
at maheswaram, Meerkhanpet(V), Kandukur (M), RR Dist, T.S.
BH-06

The bearing capacity equation is as follows :

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

where:

$q_{\text{net safe}}$ = safe net bearing capacity	c = cohesion intercept
q = overburden pressure	B = Foundation width
γ = Bulk density of soil below founding level	
R_w = Water table correction factor	FS = Factor of safety
N_c, N_q, N_γ = bearing capacity factors, which are a function of ϕ	
d_c, d_q, d_γ = Depth factors	
$\zeta_c, \zeta_q, \zeta_\gamma$ = Shape factors	

Soil parameters :

$c = 0.00 \text{ T/m}^2$	$\phi = 32.0 \text{ degrees}$	GENERAL SHEAR FAILURE	
$c' = 0.00 \text{ T/m}^2$	$\phi' = 22.6 \text{ degrees}$	LOCAL SHEAR FAILURE	
General Shear Failure :	$N_c = 35.49$	$N_q = 23.18$	$N_\gamma = 30.21$
Local Shear Failure :	$N_c = 17.59$	$N_q = 8.33$	$N_\gamma = 7.77$

Bulk Density Profile		
Depth, m		γ
From	To	T/m^3
0.0	3.0	1.76
3.0	6.0	1.91
6.0	10.0	2.00

Factor of safety = 2.5 as per IS 1904-1986

Design Water Table depth = GL

R_w factor: Constant value(V) for worst condition or

calculate(C) based on WT Depth ? :

C

Depth factor to be considered ? Y

For computation of Depth Factor, depth below GL to be ignored to account for loose soils, poorly compacted backfill above foundation, scour etc. =

0.1 m

FAILURE CRITERIA : average OF LOCAL & GENERAL SHEAR FAILURE

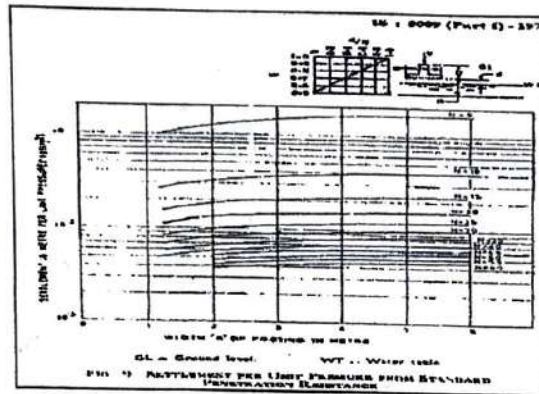
Foundation Dimensions		FOUN-DATION SHAPE	Depth, m	R_w	Shape Factors			Depth factors (GSF)			Depth factors (LSF)			$q_{\text{net safe}}, \text{ T/m}^2$		Safe Net Bearing Capacity T/m^2
B, m	L, m				ζ_c	ζ_q	ζ_γ	d_c	d_q	d_γ	d'_c	d'_q	d'_γ	GSF	LSF	
3.0	3.0	square	3.5	0.50	1.30	1.20	0.80	1.41	1.20	1.20	1.00	1.17	1.17	51.9	15.5	33.7
3.0	3.0	square	4.0	0.50	1.30	1.20	0.80	1.47	1.24	1.24	1.00	1.20	1.20	59.3	17.7	38.5
3.5	3.5	square	3.5	0.50	1.30	1.20	0.80	1.35	1.18	1.18	1.00	1.15	1.15	53.5	15.8	34.7
3.5	3.5	square	4.0	0.50	1.30	1.20	0.80	1.40	1.20	1.20	1.00	1.17	1.17	60.6	18.0	39.3



SETTLEMENT ANALYSIS FOR SHALLOW FOUNDATIONS BASED ON N - VALUES

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

Project : Soil Investigations works for the proposed 400/220KV substation
at maheswaram, Meerkhanpet(V), Kandukur (M), RR Dist, T.S.



Design Water Table Depth : GL

R_w factor : Calculate (C) based on water table depth
or Fixed Value(V) for worst condition :

Fox's Depth Factor to be considered ? Y

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

0.1 m

Foundation Width, m	Foundation Length, m	Foundation Depth, m	Shape	Design N-value	Net Allowable Bearing Pressure, T/m^2	Settlement @ $1kg/cm^2$ (as read off from graph), mm	R_w	Fox's Depth Factor, d_f	Rigidity Factor, d_r	Computed Settlement, mm
3.0	3.0	3.5	square	40.0	33.7	6.5	0.50	0.70	1.0	30.4
3.0	3.0	4.0	square	40.0	38.5	6.5	0.50	0.68	1.0	33.8
3.5	3.5	3.5	square	40.0	34.7	6.6	0.50	0.73	1.0	33.5
3.5	3.5	4.0	square	40.0	39.3	6.6	0.50	0.70	1.0	36.4

