II	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1375/1								
Location of Bore Hole	Depth of Sample below E.G.L. (m)	рН	Chlorides(ppm)	Sulphates (ppm)					
BH-01	7.50	7.89	31,05	40.63					

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1375/1 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 7.50m depth below)
Type of Strata

Type of Strata Silty Fine Sand
Colour Greyish
Thickness of Layer 7.50m
SPT of the layer 26

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 34.80 Deg.

Layer-2 (from 7.50m to 12.00m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, \$\phi\$

Silty Fine Sand

Greyish

4.50m

42

Dense

39.20 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of August 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

0.00

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m²)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.00	16	32

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.



RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of silty sand and can
 be considered as bearing strata for the proposed impending loads from the
 superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.00

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 1.00 m

Minimum Width of Foundation (B): 1.00

1 Soil Data :

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 21

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$ 33.30 Deg

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) $_{17.00}$ kN/m^3

Effective Overburden pressure at foundation level (q) 7.00

Water Table Correction Factor (w) 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = {}_{28.23}$

k Pa

 $N_{\gamma} = 39.32$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $s_{\gamma} = _{1.00}$

Depth Factors :

 $D_e = \frac{1}{N/A}$

 $\mathbf{D}_q = \frac{1.00}{1.00}$

 $D_y = 1.00$

Inclination Factor

 $l_c = \frac{1}{N/A}$

 $I_q = \begin{array}{c} \\ 1.00 \end{array}$

 $I_y = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = \frac{}{424.02 \text{ kPa}}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 169.61 kPa

Limited to an allowable bearing pressure per running meter width; 160.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 160kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 160kPa and SPT of 21 are computed to be in the order of 32mm which is within the permissible limits of 50mm for individual column footines as per IS1904.

INTRODUCTION

1.0 Preamble

Dedicated Freight Corridor Corporation of India Ltd. proposed to perform operations pertaining to staking out alignment, detail engineering construction survey for detour at any location(s) as directed by the Engineer In Charge, preparation of Land Plan for section 4 & 6 notification under Indian Land Acquisition Act, 1894, identification & preparation of Land acquisition plan for dumping locations for ballast/ blanket material etc, Geotechnical investigation, preparation of G.A.D. for Minor & Major bridges along with preparation of schedule of quantities & Tender document for construction of Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre.(Works)/MTC and the responsibility for carrying out the above is entrusted to M/s. Monarch Surveyors & Contractors Pvt. Ltd., Pune.

This report includes field and Laboratory test results for the borehole location at Chainage: 1376/1 in the proposed construction area like Major, Minor Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.

1.1 Scope of Work

1.1.1 Field Work

- ❖ Sinking Standard Soil Investigation Bore Hole of 150mm diameter borehole for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) or as directed by the engineer-in-charge.
- Conducting Standard Penetration Test (SPT) at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

- Collection of Split Spoon Soil Samples from the boreholes.
- Collection of disturbed soil samples from the boreholes.
- Collection of undisturbed soil samples from cohesive or semi cohesive soil samples whose SPT lies between 4 and 15.
- Collection of rock core samples and carrying out various laboratory testing as per relevant IS codes.

1.1.2. Laboratory Work

1.1.2.1 Soil Samples

- (a) Visual and Engineering Classification
- (b) Sieve Analysis/ Particle Size Analysis/ Grain Size Distribution Analysis
 - (i) Hydrometer Analysis/ Wet Sieve Analysis
- (c) Atterberg Limits on the cohesive soils (LL, PL, SL) on fine-grained soils
- (d) Specific Gravity
- (e) Chemical Properties on sub-soil water/ soil sample to determine the presence of pH, Cl, SO₄ contents.
- (f) Swelling Pressure Tests & Free Swelling Index
- (g) Bulk Density and Moisture Content
- (h) Unconfined Compression Tests on Clay Soils
- (i) Box Shear Test in case of sand
- (j) Tri-Axial Shear TestsUnconsolidated undrained.Consolidated Undrained Test with the Pressure
- (k) Drained Consolidation Test representing e, Cc & Pc

1.1.2.2 Rock Samples

- Visual classification
- Moisture content, porosity and Density
- Specific gravity
- Unconfined compression test (both saturated and at in-situ water content)
- Point load strength index

1.2 Structure of the Report

- Contents
- Introduction
- Investigation Methodology & Test Results

- Tables & Figures
- Subsurface Stratification
- * Foundation System
- * Recommendations

3

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to 12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

Standard penetration tests (SPT) were conducted at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

The disturbed soil samples were collected as directed by the engineer-incharge at every change in the sub-soil strata. These samples were used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

The standard penetration tests were conducted at an interval of 1.50m up to 10.0m depth below the existing ground level or at every change in the sub-soil strata as per IS: 2131-1981 or as directed by the engineer-in-charge. Split spoon samples collected were further used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.3 Undisturbed Soil Samples

At the borehole locations, the undisturbed soil samples were collected and presented in Fig. 2.1.

2.4 Laboratory Testing: Soil Samples

2.4.1 Visual and Engineering Classification, Sieve Analysis Tests/ Grain Size Analysis Tests

On the soil samples visual and engineering, grain size distribution tests were conducted as per I.S.2720 (Part 4)-1985, to know the gradation characteristics and to classify them. These results are presented in Table 2.1.

2.4.2 Atterberg Limits

Atterberg Limits were carried out on fine-grained soil samples to evaluate the limits of different consistency states. Generally Liquid limits, Plastic limits and Shrinkage Limits tests were conducted as per I.S.2720 (Part-V)-1985 and I.S.2720 (Part 6)-1972. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.3 Specific Gravity

On the soil samples, specific gravity tests were conducted as per I.S: 2720 (Part-III, Sec.1)-1986. The test results are presented in Table 2.1.

2.4.4 Chemical Tests on Water Sample

These tests are being conducted on water sample as per I.S: 456-1978 and the test results are presented in table 2.2.

2.4.5 Swelling Pressure & Free Swell Tests

Generally, these tests are conducted over the fines passing through 0.075mm sieve. Since, the soil samples obtained are heterogeneous, the soil samples are sieved and the percentage of fines passing was used to determine the free swell percentage of soil. As no such type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.6 Bulk Density & Natural Moisture Content

On the soil samples, Bulk Density and natural moisture content tests were conducted as per I.S: 2720 (Part-II)-1973. The bulk density of the soil sample was determined through water displacement method and the test results are presented in Table 2.1.

2.4.7 Unconfined Compression Tests

These tests are normally conducted on clayey soils, which can stand without confinement. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.8 Box Shear Tests

The tests are being conducted on the remoulded compacted soil samples and were conducted under undrained conditions. The test results are presented in table 2.1.

2.4.9 Triaxial Shear Tests

These tests are normally conducted on the soil samples to determine their shear strength characteristics. The test results are presented in table 2.1.

2.4.10 Consolidation Tests

These tests are conducted to determine the compressibility characteristics of the soil. The tests are conducted in a consolidation cell with minimum diameter to thickness ratio as 3. The thickness of soil sample is taken as 20mm to get uniform distribution of pressure on the soil sample. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

Rock Samples

As no rock strata were encountered at the investigation locations, no tests on rock samples could be conducted.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Fastern Freight Corridor in line with Tender No. HO/FN/Pre. (Works)/MTC Location: At Chainage: 1376/1

Sta	irte	d O	n:08/0	08/2008; Ended On: 09					8.00			
					SP	T - D	etail	s	rapl	nical Representation of SP	25	
					200				##	10 2 3 (4 (5) 6 (7 (8) 9 0	one	
Depth of Top of	Lay er(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
				Greyish	1.50	4	4	8	12	٩	Loose	SS
4	50	200000000000000000000000000000000000000		Loose Silty Fine Sand	3.00				talled		Loose M.Dense	UDS
	50			Greyish Medium Dense Silty Fine Sand	6.00	10	12	15	27		M.Dense M.Dense	SS
G.V	-	*		Greyish Dense	9.00	15	17	22	39		Dense	ss
12.	00			Silty Fine Sand	10,50	17	20	23	43		Dense Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1376/1 Location

es10 - .

		IS-Classification	165	SIVI	SM		SM
		Consolidation Tests, Cc			1		,
	(Fa)	Unconfined Compression Tests, Cu (1		
l E	Box	ф (Deg.)					1
catic	Box	c (r/N/m ₂)					
1 Lo	Triaxial Test	ф (Deg.)		20.0	1		•
376/	Tris	c (KN/m ₃)		C.71	ı		
e:1		(%) (%)	0		0		0
inas	Sis	(%) tliS	-	±	19		77
Cha	naly	(%) ani ⁷	à	8	81		28
III	Sieve Analysis	(%) muibəM		1	0		0
fro	Sie	Coarse (%)	0		0		0
cted		Gravel (%)	<		0		0
est Results on the Soil Samples Collected from Chainage:1376/1 Location		Relative Density/ Consistency		LOOSE	M.Dense.		Dense
a		Swelling Pressure (kPa)			1		1
San		Free Swell (%)		1	1		1
oi		Bulk Density, kN/m³	4	CI	17		61
he S		Void Ratio, e					
on 1		Specific Gravity, G	0,70	7.00	2.66		2.65
ults		Consistency, I _C			1		1
Res	Clay	Id		·I	1		1
est	٥	PL (%)		·L	ı		1
V T		rr (%)		•	1		1
tor		NMC(%)	2		11	-	6
Table 2.1: Laboratory		Visual & Engineering Classification of Soil	S:14-: S 13	Sinty Salid	Silty.Sand	,	Silty Sand
Table		Type of Sample	00	cc	SS	i de	SS
		oldms2 to TA2	¢.	7	22		38
	p	R.L of Sample below Existing Groun level(m)	037133	L.U.L.4.30	4.50-7.50		7.50-12.00

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	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1376/1								
Location of Bore Hole Depth of Sample Delow E.G.L. m) Chlorides(ppm)									
BH-01	9.00	7.89	33.57	65.12					

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1376/1 Location

(As presented in the site plan)

Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	12
Relative Density	Loose
Angle of Shearing Resistance, φ	30.60 Deg.

* Layer-2 (from 4.50m to 7.50m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	22
Relative Density	Medium Dense
Angle of Shearing Resistance, φ	33.60 Deg.

* Layer-3 (from 7.50m to 12.00m depth below)

Type of Strata		Silty Fine Sand
Colour		Greyish
Thickness of Layer		4.50m
SPT of the layer		38
Relative Density		Dense
Angle of Shearing Resistance, of	ф	38.20 Deg.

The ground water table was encountered at a depth of 8.00m within the explored depth of investigation in the second week of August 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m²)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	14	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of silty sand and can
 be considered as bearing strata for the proposed impending loads from the
 superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing: Isolated Column

Depth of foundation below the E.G.L. 2,00

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2,00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data :

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 12

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$ 30.60 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) $_{15.00}$ kN/m^3

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w) 0,50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 20.19$

 $N_{\gamma} = 25.48$

Shape Factors:

 $S_c = \frac{N}{A}$

 $S_q = 1.30$

 $s_{\text{y}} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_q = 1.00$

 $\mathbf{D}_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_q = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu^*Nc^*Sc^*D_c^*I_{c^2q^*}(Nq-1)^*Sq^*Dq^*I_{q} + 0.5^*B^*\gamma^*N\gamma^*S\gamma^*D\gamma^*I_{g^*w'}$

 $Q_u = \frac{357.98 \text{ kPa}}{}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.):

2.50

Qsafe : Limited to an allowable bearing pressure per running meter width.

Qsafe: 143.19 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 140kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 140kPa and SPT of 12 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per LS-1904.

INTRODUCTION

1.0 Preamble

Dedicated Freight Corridor Corporation of India Ltd. proposed to perform operations pertaining to staking out alignment, detail engineering construction survey for detour at any location(s) as directed by the Engineer In Charge, preparation of Land Plan for section 4 & 6 notification under Indian Land Acquisition Act, 1894, identification & preparation of Land acquisition plan for dumping locations for ballast/ blanket material etc, Geotechnical investigation, preparation of G.A.D. for Minor & Major bridges along with preparation of schedule of quantities & Tender document for construction of Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre.(Works)/MTC and the responsibility for carrying out the above is entrusted to M/s. Monarch Surveyors & Contractors Pvt. Ltd., Pune.

This report includes field and Laboratory test results for the borehole location at Chainage: 1377/1 in the proposed construction area like Major, Minor Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.

1.1 Scope of Work

1.1.1 Field Work

- ❖ Sinking Standard Soil Investigation Bore Hole of 150mm diameter borehole for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) or as directed by the engineer-in-charge.
- Conducting Standard Penetration Test (SPT) at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

- Collection of Split Spoon Soil Samples from the boreholes.
- Collection of disturbed soil samples from the boreholes.
- Collection of undisturbed soil samples from cohesive or semi cohesive soil samples whose SPT lies between 4 and 15.
- Collection of rock core samples and carrying out various laboratory testing as per relevant IS codes.

1.1.2. Laboratory Work

1.1.2.1 Soil Samples

- (a) Visual and Engineering Classification
- (b) Sieve Analysis/ Particle Size Analysis/ Grain Size Distribution Analysis
 - (i) Hydrometer Analysis/ Wet Sieve Analysis
- (c) Atterberg Limits on the cohesive soils (LL, PL, SL) on fine-grained soils
- (d) Specific Gravity
- (e) Chemical Properties on sub-soil water/ soil sample to determine the presence of pH, Cl, SO₄ contents.
- (f) Swelling Pressure Tests & Free Swelling Index
- (g) Bulk Density and Moisture Content
- (h) Unconfined Compression Tests on Clay Soils
- (i) Box Shear Test in case of sand
- (j) Tri-Axial Shear TestsUnconsolidated undrained.Consolidated Undrained Test with the Pressure
- (k) Drained Consolidation Test representing e, Cc & Pc

1.1.2.2 Rock Samples

- Visual classification
- Moisture content, porosity and Density
- Specific gravity
- Unconfined compression test (both saturated and at in-situ water content)
- Point load strength index

1.2 Structure of the Report

- Contents
- Introduction
- Investigation Methodology & Test Results

- * Tables & Figures
- Subsurface Stratification
- Foundation System
- * Recommendations

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to 12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

Standard penetration tests (SPT) were conducted at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

The disturbed soil samples were collected as directed by the engineer-incharge at every change in the sub-soil strata. These samples were used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

The standard penetration tests were conducted at an interval of 1.50m up to 10.0m depth below the existing ground level or at every change in the sub-soil strata as per IS: 2131-1981 or as directed by the engineer-in-charge. Split spoon samples collected were further used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.3 Undisturbed Soil Samples

At the borehole locations, the undisturbed soil samples were collected and presented in Fig. 2.1.

2.4 Laboratory Testing:

Soil Samples

2.4.1 Visual and Engineering Classification, Sieve Analysis Tests/ Grain Size Analysis Tests

On the soil samples visual and engineering, grain size distribution tests were conducted as per I.S.2720 (Part 4)-1985, to know the gradation characteristics and to classify them. These results are presented in Table 2.1.

2.4.2 Atterberg Limits

Atterberg Limits were carried out on fine-grained soil samples to evaluate the limits of different consistency states. Generally Liquid limits, Plastic limits and Shrinkage Limits tests were conducted as per I.S.2720 (Part-V)-1985 and I.S.2720 (Part 6)-1972. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.3 Specific Gravity

On the soil samples, specific gravity tests were conducted as per I.S: 2720 (Part-III, Sec.1)-1986. The test results are presented in Table 2.1.

2.4.4 Chemical Tests on Water Sample

These tests are being conducted on water sample as per I.S: 456-1978 and the test results are presented in table 2.2.

2.4.5 Swelling Pressure & Free Swell Tests

Generally, these tests are conducted over the fines passing through 0.075mm sieve. Since, the soil samples obtained are heterogeneous, the soil samples are sieved and the percentage of fines passing was used to determine the free swell percentage of soil. As no such type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.6 Bulk Density & Natural Moisture Content

On the soil samples, Bulk Density and natural moisture content tests were conducted as per I.S: 2720 (Part-II)-1973. The bulk density of the soil sample was determined through water displacement method and the test results are presented in Table 2.1.

2.4.7 Unconfined Compression Tests

These tests are normally conducted on clayey soils, which can stand without confinement. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.8 Box Shear Tests

The tests are being conducted on the remoulded compacted soil samples and were conducted under undrained conditions. The test results are presented in table 2.1.

2.4.9 Triaxial Shear Tests

These tests are normally conducted on the soil samples to determine their shear strength characteristics. The test results are presented in table 2.1.

2.4.10 Consolidation Tests

These tests are conducted to determine the compressibility characteristics of the soil. The tests are conducted in a consolidation cell with minimum diameter to thickness ratio as 3. The thickness of soil sample is taken as 20mm to get uniform distribution of pressure on the soil sample. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

Rock Samples

As no rock strata were encountered at the investigation locations, no tests on rock samples could be conducted.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Fastern Freight Corridor in line with Tender No. HO/FN/Pre. (Works)/MTC

Location: At Chainage: 1377/1

				08/2008; Ended On: 09.					8.30	m		
					SPT - Details				rapl	hical Representation of SP	y	
of			n.				Γ-	Ι .	##	10 2:3(4(5:6(7(8:90	istenc	<u>ə</u>
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
					1.50	4	7	11	18	9	M.Dense	SS
					3.00	UDS	Samp	ler Ins	l stalled		M.Dense	UDS
				Greyish Medium Dense Silty Fine Sand	4.50	7	10	15	25	\	M.Dense	ss
					6.00	8	13	17	30		M.Dense	SS
7.	50				7.50	10	12	19	31		Dense	ss
G.V	V.T	♦		Greyish	9.00	11	15	21	36	· ·	Dense	SS
				Dense Silty Fine Sand	10.50	13	16	25	41		Dense	SS
12	.00	<u> </u>			12.00	13	17	27	44	J	Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1377/1 Location

7.50-12.00	E.G.L-7.50	R.L of Sample below Existing Grounlevel(m)	nd						
36	24	SPT of Sample	SPT of Sample						
SS	SS	Type of Sample			Table				
Silty Sand	Silty Sand	Visual & Engineering Classification of Soil			2.1: Laboratory				
8	9	NMC(%)			Or.				
1	Ţ.	LL (%)	1000						
		PL (%)	0		est				
-	1	PI	Clay		Res				
1	1	Consistency, I _C			ults				
2.65	2.66	Specific Gravity, G			est Results on the Soil				
,	1	Void Ratio, e	Void Ratio, e						
19	17	Bulk Density, kN/m ³							
-	-								
	1	Swelling Pressure (kPa)							
Dense	M.Dense	Relative Density/ Consistency							
0	0	Gravel (%)			Collected				
0	0	Coarse (%)	S		d fr				
0	0	Medium (%)	Sieve A		(0m				
79	83		Inalysis		Cha				
21	17	Silt (%)	Sis		ina				
0	0	Clay (%)			ge:1				
ı	15.2	c (kN/m²)	7	Tri	377,				
	33.6	φ (Deg.)	c (kN/m²) Test † (Deg.)						
	1	c (kN/m²)							
ī	1	Box Box (Deg.)							
1	1	Unconfined Compression Tests, Cu (kP	a)					
ī	1	Consolidation Tests, Cc							
SM	SM	IS-Classification							

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Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1377/1								
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)				
BH-01	9.00	7.86	75.32	86.31				

 $d \cap$

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1377/1 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 7.50m depth below)

Type of Strata	Silty Fine Sand	
Colour	Greyish	
Thickness of Layer	7.50m	
SPT of the layer	24	
Relative Density	Medium Dense	
Angle of Shearing Resistance, φ	34.20 Deg.	

* Layer-2 (from 7.50m to 12.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	36
Relative Density	Dense
Angle of Shearing Resistance, φ	37.65 Deg.

The ground water table was encountered at a depth of 8.30m within the explored depth of investigation in the first week of August 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Minimum	Safe Bearing Capacity (t/m²)	Elastic Settlements
	Structure	Depth of Footing below	(t/m)	(mm)
		N.G.L		
		(m)		
1	Isolated	1.50	19	38
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of silty sand and can
 be considered as bearing strata for the proposed impending loads from the
 superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.

- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 1,50

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 18

Type of Shear Failure: General

Angle of Shearing Resistance, 6: 32.40 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17,00 kN/m³

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w) 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 25.55$

 $N_y = 34.70$

Shape Factors:

 $S_c = N/A$

 $S_q = _{1.30}$

 $\mathbf{S}_{y} = 1.00$

Depth Factors :

 $D_c = N/A$

 $D_q = 1.00$

 $D_{y} = 1.00$

Inclination Factor.

 $I_c = N/A$

 $I_q = \frac{1.00}{1.00}$

 $I_y = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu^*Nc^*Sc^*D_{C}{}^*I_{C}{}^+q^*(Nq-1)^*Sq^*Dq^*Iq + 0.5^*B^*\gamma^*N\gamma^*S\gamma^*D\gamma^*Ig^*w'$

 $Q_u = 496.27 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 198.51 kPa

Limited to an allowable bearing pressure per running meter width. 190.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 190kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 190kPa and SPT of 18 are computed to be in the order of 38mm which is within the permissible limits of 50mm for individual column footings as ner IS:1904

CHAPTER-1

INTRODUCTION

1.0 Preamble

Dedicated Freight Corridor Corporation of India Ltd. proposed to perform operations pertaining to staking out alignment, detail engineering construction survey for detour at any location(s) as directed by the Engineer In Charge, preparation of Land Plan for section 4 & 6 notification under Indian Land Acquisition Act, 1894, identification & preparation of Land acquisition plan for dumping locations for ballast/ blanket material etc, Geotechnical investigation, preparation of G.A.D. for Minor & Major bridges along with preparation of schedule of quantities & Tender document for construction of Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre.(Works)/MTC and the responsibility for carrying out the above is entrusted to M/s. Monarch Surveyors & Contractors Pvt. Ltd., Pune.

This report includes field and Laboratory test results for the borehole location at Chainage: 1378/1 in the proposed construction area like Major, Minor Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.

1.1 Scope of Work

1.1.1 Field Work

- ❖ Sinking Standard Soil Investigation Bore Hole of 150mm diameter borehole for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) or as directed by the engineer-in-charge.
- Conducting Standard Penetration Test (SPT) at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

- Collection of Split Spoon Soil Samples from the boreholes.
- Collection of disturbed soil samples from the boreholes.
- Collection of undisturbed soil samples from cohesive or semi cohesive soil samples whose SPT lies between 4 and 15.
- Collection of rock core samples and carrying out various laboratory testing as per relevant IS codes.

1.1.2. Laboratory Work

1.1.2.1 Soil Samples

- (a) Visual and Engineering Classification
- (b) Sieve Analysis/ Particle Size Analysis/ Grain Size Distribution Analysis
 - (i) Hydrometer Analysis/ Wet Sieve Analysis
- (c) Atterberg Limits on the cohesive soils (LL, PL, SL) on fine-grained soils
- (d) Specific Gravity
- (e) Chemical Properties on sub-soil water/ soil sample to determine the presence of pH, Cl, SO₄ contents.
- (f) Swelling Pressure Tests & Free Swelling Index
- (g) Bulk Density and Moisture Content
- (h) Unconfined Compression Tests on Clay Soils
- (i) Box Shear Test in case of sand
- (j) Tri-Axial Shear TestsUnconsolidated undrained.Consolidated Undrained Test with the Pressure
- (k) Drained Consolidation Test representing e, Cc & Pc

1.1.2.2 Rock Samples

- Visual classification
- Moisture content, porosity and Density
- Specific gravity
- Unconfined compression test (both saturated and at in-situ water content)
- Point load strength index

1.2 Structure of the Report

- Contents
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- * Tables & Figures
- Subsurface Stratification
- * Foundation System
- * Recommendations

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INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to 12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

Standard penetration tests (SPT) were conducted at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

The disturbed soil samples were collected as directed by the engineer-incharge at every change in the sub-soil strata. These samples were used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

The standard penetration tests were conducted at an interval of 1.50m up to 10.0m depth below the existing ground level or at every change in the sub-soil strata as per IS: 2131-1981 or as directed by the engineer-in-charge. Split spoon samples collected were further used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.3 Undisturbed Soil Samples

At the borehole locations, the undisturbed soil samples were collected and presented in Fig. 2.1.

2.4 Laboratory Testing:

Soil Samples

2.4.1 Visual and Engineering Classification, Sieve Analysis Tests/ Grain Size Analysis Tests

On the soil samples visual and engineering, grain size distribution tests were conducted as per I.S.2720 (Part 4)-1985, to know the gradation characteristics and to classify them. These results are presented in Table 2.1.

2.4.2 Atterberg Limits

Atterberg Limits were carried out on fine-grained soil samples to evaluate the limits of different consistency states. Generally Liquid limits, Plastic limits and Shrinkage Limits tests were conducted as per I.S.2720 (Part-V)-1985 and I.S.2720 (Part 6)-1972. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.3 Specific Gravity

On the soil samples, specific gravity tests were conducted as per I.S: 2720 (Part-III, Sec.1)-1986. The test results are presented in Table 2.1.

2.4.4 Chemical Tests on Water Sample

These tests are being conducted on water sample as per I.S: 456-1978 and the test results are presented in table 2.2.

2.4.5 Swelling Pressure & Free Swell Tests

Generally, these tests are conducted over the fines passing through 0.075mm sieve. Since, the soil samples obtained are heterogeneous, the soil samples are sieved and the percentage of fines passing was used to determine the free swell percentage of soil. As no such type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.6 Bulk Density & Natural Moisture Content

On the soil samples, Bulk Density and natural moisture content tests were conducted as per I.S: 2720 (Part-II)-1973. The bulk density of the soil sample was determined through water displacement method and the test results are presented in Table 2.1.

2.4.7 Unconfined Compression Tests

These tests are normally conducted on clayey soils, which can stand without confinement. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.8 Box Shear Tests

The tests are being conducted on the remoulded compacted soil samples and were conducted under undrained conditions. The test results are presented in table 2.1.

2.4.9 Triaxial Shear Tests

These tests are normally conducted on the soil samples to determine their shear strength characteristics. The test results are presented in table 2.1.

2.4.10 Consolidation Tests

These tests are conducted to determine the compressibility characteristics of the soil. The tests are conducted in a consolidation cell with minimum diameter to thickness ratio as 3. The thickness of soil sample is taken as 20mm to get uniform distribution of pressure on the soil sample. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

Rock Samples

As no rock strata were encountered at the investigation locations, no tests on rock samples could be conducted.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Fastern Freight Corridor in line with Tender No. HO/FN/Pre. (Works)/MTC

Location: At Chainage: 1378/1

Starte	a O	n:0//	08/2008; Ended On: 08					8.50	hical Representation of SP		т—
				SPT - Deta			3	##	10 2: 3(4(5: 6(7(8: 90	ncy	
Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	102.3(4,30), (8,30)	Density/Consistency	Type of Sample
			Greyish	1.50	5	6	7	13		Loose	SS
			Loose Silty Fine Sand	3.00	UDS	Samp	ler Ins	talled		Loose	UD
4.50				4.50	7	9	15	24	l N	1.Dense	SS
6.00			Greyish Medium Dense Silty Fine Sand	6.00	8	14	21	35		Dense	SS
			Greyish	7.50	11	14	23	37		Dense	SS
G.W.T	*		Dense Silty Fine Sand	9.00	13	15	23	38		Dense	SS
10.50			-	10.50	16	30	55	8.5		'.Dense	S
12.00			Greyish Very Dense Silty Fine Sand	12.00	21	35	56	91		.Dense	S

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1378/1 Location

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	·	-		1	1					_
			IS-Classification		SM	SM		SM		SM
			Consolidation Tests, Cc		1			,		
	(g4	Unconfined Compression Tests, Cu (kPa)				1		1		1
u	X	Ja L	φ (Deg.)			1		,		1
catio	Box	Shear	c (kN/m²)		1			,		
Lo	xial		ф (Deg.)		30.3	1.		1		
378/	Triaxial		c (kN/m²)		12.4	T	T			-
e:1.		T	(%) (%)		0	0	T	0		0
inag	9,01	e E	(%) ilis		12	21		24		59
Cha	You		(%) эпіЯ		88	79		92		71
om (Cioxo A nolycic		(%) muibəM		0	0		0		0
d fr	3		Coarse (%)		0	0		0		0
ecte		L	Gravel (%)		0	0		0		0
Samples Collected from Chainage:1378/1 Location		Relative Density/ Consistency				M.Dense		Dense		V.Dense
ldu		Swelling Pressure (kPa)				1		1		1
Saı		Free Swell (%)				1		E		1
Soil			Bulk Density, kN/m3		15	17		19		20
the			Void Ratio, e		1	'		t		,
ou			Specific Gravity, G		2.68	2.66		2.65		2.63
ults		L	Consistency, I _C		•	1		-		1
Res	٥		Id		1	1		ı.		_
[est		<u> </u>	(%) Jd	=	1	-		1	_	+
	-		(%) 7.7 (%) 7.7	_	15 -	 		- 6	\dashv	2
Table 2.1: Laboratory Test Results on the Soil		Visual & Engineering Classification of Soil				Silty Sand		Silty Sand		Silty Sand
Table		Type of Sample				SS		SS		SS
			oldms2 to TA2		13	24		36		85
	ı	uno	R.L of Sample below Existing Gr level(m)		E.G.L-4.50	4.50-6.00		6.00-10.50		10.50-12.00

	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1378/1								
Location of Bore Hole	Depth of Sample below E.G.L. (m)	hф	Chlorides(ppm)	Sulphates (ppm)					
ВН-01	9.00	7.87	54.21	57,43					

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SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1378/1 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata	Silty Fine San
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, φ	30.90 Deg.

* Layer-2 (from 4.50m to 6.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance, φ	34.20 Deg.

* Layer-3 (from 6.00m to 10.50m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	36
Relative Density	Dense
Angle of Shearing Resistance, φ	37.65 Deg.

* Layer-4 (from 10.50m to 12.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	85
Relative Density	Very Dense
Angle of Shearing Resistance, φ	42.50 Deg.

The ground water table was encountered at a depth of 8.50m within the explored depth of investigation in the second week of August 2008.

CHAPTER-4

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m²)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	15	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.



RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of silty sand and can
 be considered as bearing strata for the proposed impending loads from the
 superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing: Isolated Column Depth of foundation below the E.G.L: 2,00 Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2 00

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata . Silty Sand

Least SPT-value of the Bearing Strata: 13

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 30.90

1 Design Parameters:

Bulk Density of Soil above the foundation detph $(\gamma_{bulk})_{15,00}$ k N/m3

Effective Overburden pressure at foundation level (q) 10.00

Water Table Correction Factor (w) 0.50

Bearing Capacity Factors

 $N_c = N/A$

Deg

 $N_q = 21.08$

 $N_{y} = 27.01$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_y = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_q = \frac{1.00}{1.00}$

 $D_{y} = 1.00$

Inclination Factor;

 $l_c = N/A$

 $I_q = 1.00$

 $I_y = 1.00$

I Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = \frac{375.37 \text{ kPa}}{375.37 \text{ kPa}}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.) 2.50

Qsafe : 150.15 kPa

Limited to an allowable bearing pressure per running meter width: 150.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 150kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 150kPa and SPT of 13 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per IS:1904.

INTRODUCTION

1.0 Preamble

Dedicated Freight Corridor Corporation of India Ltd. proposed to perform operations pertaining to staking out alignment, detail engineering construction survey for detour at any location(s) as directed by the Engineer In Charge, preparation of Land Plan for section 4 & 6 notification under Indian Land Acquisition Act, 1894, identification & preparation of Land acquisition plan for dumping locations for ballast/ blanket material etc, Geotechnical investigation, preparation of G.A.D. for Minor & Major bridges along with preparation of schedule of quantities & Tender document for construction of Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre.(Works)/MTC and the responsibility for carrying out the above is entrusted to M/s. Monarch Surveyors & Contractors Pvt. Ltd., Pune.

This report includes field and Laboratory test results for the borehole location at Chainage: 1379/1 in the proposed construction area like Major, Minor Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.

1.1 Scope of Work

1.1.1 Field Work

- Sinking Standard Soil Investigation Bore Hole of 150mm diameter borehole for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) or as directed by the engineer-in-charge.
- Conducting Standard Penetration Test (SPT) at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

- Collection of Split Spoon Soil Samples from the boreholes.
- Collection of disturbed soil samples from the boreholes.
- Collection of undisturbed soil samples from cohesive or semi cohesive soil samples whose SPT lies between 4 and 15.
- Collection of rock core samples and carrying out various laboratory testing as per relevant IS codes.

1.1.2. Laboratory Work

1.1.2.1 Soil Samples

- (a) Visual and Engineering Classification
- (b) Sieve Analysis/ Particle Size Analysis/ Grain Size Distribution Analysis
 - (i) Hydrometer Analysis/ Wet Sieve Analysis
- (c) Atterberg Limits on the cohesive soils (LL, PL, SL) on fine-grained soils
- (d) Specific Gravity
- (e) Chemical Properties on sub-soil water/ soil sample to determine the presence of pH, Cl, SO₄ contents.
- (f) Swelling Pressure Tests & Free Swelling Index
- (g) Bulk Density and Moisture Content
- (h) Unconfined Compression Tests on Clay Soils
- (i) Box Shear Test in case of sand
- (j) Tri-Axial Shear Tests
 Unconsolidated undrained.
 Consolidated Undrained Test with the Pressure
- (k) Drained Consolidation Test representing e, Cc & Pc

1.1.2.2 Rock Samples

- Visual classification
- Moisture content, porosity and Density
- Specific gravity
- Unconfined compression test (both saturated and at in-situ water content)
- Point load strength index

1.2 Structure of the Report

- Contents
- Introduction
- Investigation Methodology & Test Results

- * Tables & Figures
- Subsurface Stratification
- * Foundation System
- * Recommendations

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to 12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

Standard penetration tests (SPT) were conducted at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

The disturbed soil samples were collected as directed by the engineer-incharge at every change in the sub-soil strata. These samples were used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

The standard penetration tests were conducted at an interval of 1.50m up to 10.0m depth below the existing ground level or at every change in the sub-soil strata as per IS: 2131-1981 or as directed by the engineer-in-charge. Split spoon samples collected were further used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.3 Undisturbed Soil Samples

At the borehole locations, the undisturbed soil samples were collected and presented in Fig. 2.1.

2.4 Laboratory Testing: Soil Samples

2.4.1 Visual and Engineering Classification, Sieve Analysis Tests/ Grain Size Analysis Tests

On the soil samples visual and engineering, grain size distribution tests were conducted as per I.S.2720 (Part 4)-1985, to know the gradation characteristics and to classify them. These results are presented in Table 2.1.

2.4.2 Atterberg Limits

Atterberg Limits were carried out on fine-grained soil samples to evaluate the limits of different consistency states. Generally Liquid limits, Plastic limits and Shrinkage Limits tests were conducted as per I.S.2720 (Part-V)-1985 and I.S.2720 (Part 6)-1972. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.3 Specific Gravity

On the soil samples, specific gravity tests were conducted as per I.S: 2720 (Part-III, Sec.1)-1986. The test results are presented in Table 2.1.

2.4.4 Chemical Tests on Water Sample

These tests are being conducted on water sample as per I.S: 456-1978 and the test results are presented in table 2.2.

2.4.5 Swelling Pressure & Free Swell Tests

Generally, these tests are conducted over the fines passing through 0.075mm sieve. Since, the soil samples obtained are heterogeneous, the soil samples are sieved and the percentage of fines passing was used to determine the free swell percentage of soil. As no such type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.6 Bulk Density & Natural Moisture Content

On the soil samples, Bulk Density and natural moisture content tests were conducted as per I.S: 2720 (Part-II)-1973. The bulk density of the soil sample was determined through water displacement method and the test results are presented in Table 2.1.

2.4.7 Unconfined Compression Tests

These tests are normally conducted on clayey soils, which can stand without confinement. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.8 Box Shear Tests

The tests are being conducted on the remoulded compacted soil samples and were conducted under undrained conditions. The test results are presented in table 2.1.

2.4.9 Triaxial Shear Tests

These tests are normally conducted on the soil samples to determine their shear strength characteristics. The test results are presented in table 2.1.

2.4.10 Consolidation Tests

These tests are conducted to determine the compressibility characteristics of the soil. The tests are conducted in a consolidation cell with minimum diameter to thickness ratio as 3. The thickness of soil sample is taken as 20mm to get uniform distribution of pressure on the soil sample. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

Rock Samples

As no rock strata were encountered at the investigation locations, no tests on rock samples could be conducted.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Fastern Freight Corridor in line with Tender No. HO/FN/Pre. (Works)/MTC Location: At Chainage: 1379/1

Botanion in Chainage, 15	1311	
Started On : 06/08/2008:	Ended On : 07/08/2008	G W T- 10.00m

SIE	irte	a O	n:06/0	08/2008; Ended On: 07.	/08/200)8	G.V	<i>N</i> .T:	10.0	Om				
					SP	SPT - Details raphical Representation of SP					7			
						## 10 21 3(4(5) 6(7(8) 90				Suc				
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value				Relative Density/Consistency	Type of Sample
					1.50	9	11	13	24	9			M.Dense	SS
					3,00	UDS	Samp	ler Ins	talled				M.Dense	UDS
				Greyish	4.50	8	10	10	20	d			M.Dense	SS
				Medium Dense Silty Fine Sand	6.00	7	9	12	21		n.		M.Dense	ss
					7.50	9	12	14	26				M.Dense	SS
5					9.00	8	12	18	30		i.		M.Dense	SS
G.V		*		Greyish	10.50	10	13	20	33				Dense	ss
12.	00		M	Dense Silty Fine Sand	12.00	12	17	24	41	/			Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1379/1 Location

10.50-12.00	E.G.L-10.50	R.L of Sample below Existing Groulevel(m)	ınd						
33	24	SPT of Sample	SPT of Sample						
SS	SS	Type of Sample			Table 2.1:				
Silty Sand	Silty Sand	Visual & Engineering Classification of Soil							
∞	∞	NMC(%)			or				
1	1	LL (%)			T				
	1	PL (%)			est				
,	,	PI	Clay		Res				
,	,	Consistency, I _C			sult				
2.65	2.66	Specific Gravity, G			s on				
,	1	Void Ratio, e			Laboratory Test Results on the Soil Samples Collected from				
19	17	Bulk Density, kN/m ³							
1	,	Free Swell (%)							
1		Swelling Pressure (kPa)							
Dense	M.Dense	Relative Density/ Consistency							
0	0	Gravel (%)			cte				
0	0	Coarse (%)	Si		d fr				
0	0	Medium (%)	Sieve An		om				
79	81	Fine (%)	nal		\Box				
21	19	Silt (%)	nalysis		nainage:1379/1				
0	0	Clay (%)	Clay (%)						
-	14.7	c (kN/m ²)	c (kN/m²)						
	33.6	φ (Deg.)	φ (Deg.)						
1	1	c (kN/m²)	c (kN/m²) b (Deg.)						
	,	φ (Deg.)	ar	×	p				
-	1	Unconfined Compression Tests, Cu	(kP	a)					
r	ı	Consolidation Tests, Cc							
SM	SM	IS-Classification							

∞

The state of the s	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1379/1							
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)				
BH-01	10,50	7.89	24.79	45.21				

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SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1379/1 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 10.50m depth below)

Type of Strata	Silty Fine Sand	
Colour	Greyish	
Thickness of Layer	10.50m	
SPT of the layer	24	
Relative Density	Medium Dense	
Angle of Shearing Resistance, φ	34.20 Deg.	

Layer-2 (from 10.50m to 12.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	33
Relative Density	Dense
Angle of Shearing Resistance, φ	36.825 Deg.

The ground water table was encountered at a depth of 10.00m within the explored depth of investigation in the first week of August 2008.

CHAPTER-4

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m²)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.00	18	36

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

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RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of silty sand and can
 be considered as bearing strata for the proposed impending loads from the
 superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

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- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

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DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1,00 m

Observed Maximum thickness of Filled up Soil: 0.00

Effective Depth of Foundation below E.G.L: 1.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data :

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 24

Type of Shear Failure. General

Angle of Shearing Resistance, \$\phi\$ 34.20 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (youk) 17.00 kN/m³

Effective Overburden pressure at foundation level (q) 7.00 kPa

Water Table Correction Factor (w) 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = _{30.92}$

 $N_y = 43.93$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = \frac{1}{N/A}$

 $D_q = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor.

 $I_c = \frac{1}{N/A}$

 $l_q = 1.00$

 $I_{\gamma} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = \frac{}{468.03 \text{ kPa}}$

2 Safe Bearing Capacity (Qsafe);

Factor of Safety (F.S.): 2.50

Qsafe: 187.21 kPa

Limited to an allowable bearing pressure per running meter width: 180,00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 180kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 180kPa and SPT of 24 are computed to be in the order of 36mm which is within the permissible limits of 50mm for individual column footings as ner 18:1904

CHAPTER-1

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INTRODUCTION

1.0 Preamble

Dedicated Freight Corridor Corporation of India Ltd. proposed to perform operations pertaining to staking out alignment, detail engineering construction survey for detour at any location(s) as directed by the Engineer In Charge, preparation of Land Plan for section 4 & 6 notification under Indian Land Acquisition Act, 1894, identification & preparation of Land acquisition plan for dumping locations for ballast/ blanket material etc, Geotechnical investigation, preparation of G.A.D. for Minor & Major bridges along with preparation of schedule of quantities & Tender document for construction of Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre.(Works)/MTC and the responsibility for carrying out the above is entrusted to M/s. Monarch Surveyors & Contractors Pvt. Ltd., Pune.

This report includes field and Laboratory test results for the **borehole location**at Chainage: 1380/1 in the proposed construction area like Major, Minor
Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.

1.1 Scope of Work

1.1.1 Field Work

- ❖ Sinking Standard Soil Investigation Bore Hole of 150mm diameter borehole for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) or as directed by the engineer-in-charge.
- Conducting Standard Penetration Test (SPT) at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

- Collection of Split Spoon Soil Samples from the boreholes.
- Collection of disturbed soil samples from the boreholes.
- Collection of undisturbed soil samples from cohesive or semi cohesive soil samples whose SPT lies between 4 and 15.
- Collection of rock core samples and carrying out various laboratory testing as per relevant IS codes.

1.1.2. Laboratory Work

1.1.2.1 Soil Samples

- (a) Visual and Engineering Classification
- (b) Sieve Analysis/ Particle Size Analysis/ Grain Size Distribution Analysis
 - (i) Hydrometer Analysis/ Wet Sieve Analysis
- (c) Atterberg Limits on the cohesive soils (LL, PL, SL) on fine-grained soils
- (d) Specific Gravity
- (e) Chemical Properties on sub-soil water/ soil sample to determine the presence of pH, Cl, SO₄ contents.
- (f) Swelling Pressure Tests & Free Swelling Index
- (g) Bulk Density and Moisture Content
- (h) Unconfined Compression Tests on Clay Soils
- (i) Box Shear Test in case of sand
- (j) Tri-Axial Shear TestsUnconsolidated undrained.Consolidated Undrained Test with the Pressure
- (k) Drained Consolidation Test representing e, Cc & Pc

1.1.2.2 Rock Samples

- Visual classification
- Moisture content, porosity and Density
- Specific gravity
- Unconfined compression test (both saturated and at in-situ water content)
- Point load strength index

1.2 Structure of the Report

- Contents
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- * Foundation System
- * Recommendations

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to 12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

Standard penetration tests (SPT) were conducted at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

The disturbed soil samples were collected as directed by the engineer-incharge at every change in the sub-soil strata. These samples were used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

The standard penetration tests were conducted at an interval of 1.50m up to 10.0m depth below the existing ground level or at every change in the sub-soil strata as per IS: 2131-1981 or as directed by the engineer-in-charge. Split spoon samples collected were further used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.3 Undisturbed Soil Samples

At the borehole locations, the undisturbed soil samples were collected and presented in Fig. 2.1.

2.4 Laboratory Testing:

Soil Samples

2.4.1 Visual and Engineering Classification, Sieve Analysis Tests/ Grain Size Analysis Tests

On the soil samples visual and engineering, grain size distribution tests were conducted as per I.S.2720 (Part 4)-1985, to know the gradation characteristics and to classify them. These results are presented in Table 2.1.

2.4.2 Atterberg Limits

Atterberg Limits were carried out on fine-grained soil samples to evaluate the limits of different consistency states. Generally Liquid limits, Plastic limits and Shrinkage Limits tests were conducted as per I.S.2720 (Part-V)-1985 and I.S.2720 (Part 6)-1972. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.3 Specific Gravity

On the soil samples, specific gravity tests were conducted as per I.S: 2720 (Part-III, Sec.1)-1986. The test results are presented in Table 2.1.

2.4.4 Chemical Tests on Water Sample

These tests are being conducted on water sample as per I.S: 456-1978 and the test results are presented in table 2.2.

2.4.5 Swelling Pressure & Free Swell Tests

Generally, these tests are conducted over the fines passing through 0.075mm sieve. Since, the soil samples obtained are heterogeneous, the soil samples are sieved and the percentage of fines passing was used to determine the free swell percentage of soil. As no such type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.6 Bulk Density & Natural Moisture Content

On the soil samples, Bulk Density and natural moisture content tests were conducted as per I.S: 2720 (Part-II)-1973. The bulk density of the soil sample was determined through water displacement method and the test results are presented in Table 2.1.

2.4.7 Unconfined Compression Tests

These tests are normally conducted on clayey soils, which can stand without confinement. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.8 Box Shear Tests

The tests are being conducted on the remoulded compacted soil samples and were conducted under undrained conditions. The test results are presented in table 2.1.

2.4.9 Triaxial Shear Tests

These tests are normally conducted on the soil samples to determine their shear strength characteristics. The test results are presented in table 2.1.

2.4.10 Consolidation Tests

These tests are conducted to determine the compressibility characteristics of the soil. The tests are conducted in a consolidation cell with minimum diameter to thickness ratio as 3. The thickness of soil sample is taken as 20mm to get uniform distribution of pressure on the soil sample. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

Rock Samples

As no rock strata were encountered at the investigation locations, no tests on rock samples could be conducted.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Fastern Freight Corridor in line with Tender No. HO/FN/Pre (Works)/MTC

Location: At Chainage: 1380

				08/2008; Ended On : 06					9.70)m		
				en or an index or an index	SP	T - D	etail	s	rapl	hical Representation of SP	₹:	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	th of	0-15 cm	15-30 cm	30-45 cm	N-Value ##	10 2:3(4(5:6(7(8:90	Relative Density/Consistency	Type of Sample
ă	La	G	So		Dep (m)	-0	15.	30.	ż		Re	Ty
					1.50	7	8	8	16	9	M.Dense	ss
					3.00	UDS	Samp	ler Ins	talled		M.Dense	UDS
				Greyish Medium Dense	4.50	7	10	12	22		M.Dense	ss
				Silty Fine Sand	6.00	8	13	15	28		M.Dense	ss
					7.50	9	14	14	28	q	M.Dense	SS
					9.00	9	14	16	30		M.Dense	ss
	V.T .50				10.50	10	15	18	33		Dense	ss
12	.00			Greyish Dense Silty Fine Sand	12.00	13	19	21	40	Ì	Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage: 1380 Location

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		_		1	_	_	_	_
			IS-Classification		SM		SM	
			Consolidation Tests, Cc		1		4	
	(sq:	() n	Unconfined Compression Tests, C		1		,	
u	Вох		ф (Deg.)		1		,	
catic	Box		c (k//m _z)		1		1	
$1 L_0$	Triaxial Test		ф (Deg.)		33.7		i	
380/	Triaxi		c (k//m²)		15.3		-	
ge:1			Clay (%)		0		0	
ina	Sis		(%) ili8		18		23	
Cha	Sieve Analysis		Fine (%)		82		77	
mo.	y dAd		(%) muibəM		0		0	
d fr	i,	L	Coarse (%)		0		0	
ecte			Gravel (%)	L	0		0	12
Test Results on the Soil Samples Collected from Chainage: 1380/1 Location			Relative Density/ Consistency		M.Dense		Dense	
ldu			Swelling Pressure (kPa)		1		1	
Sai			Free Swell (%)		1		•	
Soil			Bulk Density, kN/m ³		17		19	
the			Void Ratio, e		1		'	
on			Specific Gravity, G		2.66		2.65	
sults	15	L	Consistency, I _C		ı		ı	
Re	Clav	L	Id		1		٠	
rest		L	(%) Ta		1		-	
ry 1			(%) TT		- 6	_	~	
ato			NMC(%)	_	9,		~	_
Table 2.1: Laboratory			Visual & Engineering Classification of Soil		Silty Sand		Silty Sand	
Table			Jype of Sample		SS		SS	
			oldms2 to TA2		25		33	
	р	uno.	R.L of Sample below Existing Gr level(m)		E.G.L-10.50		10.50-12.00	

0220 - 0191

	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1380/1							
Location of Bore Hole	Depth of Sample below E.G.L. (m)	hH	Chlorides(ppm)	Sulphates (ppm)				
BH-01	10.50	7,88	31.13	42.36				

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SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1380/11 Location (As presented in the site plan)

* Layer-1 (from E.G.L to 10.50m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	10.50m
SPT of the layer	25
Relative Density	Dense
Angle of Shearing Resistance, φ	34.50 Deg.

Layer-2 (from 10.50m to 12.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	33
Relative Density	Dense
Angle of Shearing Resistance, φ	36.825 Deg.

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the first week of August 2008.

CHAPTER-4

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m²)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	16	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

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RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of silty sand and can
 be considered as bearing strata for the proposed impending loads from the
 superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER 1S:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50

Observed Maximum thickness of Filled up Soil: 0.00

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data :

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 16

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 31.80 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) $_{16.00}$ kN/m3

Effective Overburden pressure at foundation level (q) 9.00 kPa

Water Table Correction Factor (w) 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = \frac{}{23.76}$

 $N_{\gamma} = 31.63$

Shape Factors:

 $S_c = N/A$

 $\mathbf{S}_{\mathfrak{q}} = \mathbf{1.30}$

 $S_y = 1.00$

Depth Factors:

 $D_c = \frac{1}{N/A}$

 $D_q = 1.00$

 $D_{y} = 1.00$

Inclination Factor.

 $I_c = N/A$

 $I_q = 1.00$

 $I_y = 1.00$

1 Ultimate Bearing Capacity (Qu);

 $Qu = Cu^*Nc^*Sc^*D_C^*I_{C^{+}q^*}(Nq-1)^*Sq^*Dq^*Iq + 0.5^*B^*\gamma^*N\gamma^*S\gamma^*D\gamma^*Ig^*w'$

 $Q_u = -\frac{}{404.55 \text{ kPa}}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.) 2,50

Qsafe: 161.82 kPa

Limited to an allowable bearing pressure per running meter width:

160,00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 160kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 160kPa and SPT of 16 are computed to be in the order of $48\,\mathrm{mm}$ which is within the permissible limits of $50\,\mathrm{mm}$ for individual column footings as per IS:1904.

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CHAPTER-1

INTRODUCTION

1.0 Preamble

Dedicated Freight Corridor Corporation of India Ltd. proposed to perform operations pertaining to staking out alignment, detail engineering construction survey for detour at any location(s) as directed by the Engineer In Charge, preparation of Land Plan for section 4 & 6 notification under Indian Land Acquisition Act, 1894, identification & preparation of Land acquisition plan for dumping locations for ballast/ blanket material etc, Geotechnical investigation, preparation of G.A.D. for Minor & Major bridges along with preparation of schedule of quantities & Tender document for construction of Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre.(Works)/MTC and the responsibility for carrying out the above is entrusted to M/s. Monarch Surveyors & Contractors Pvt. Ltd., Pune.

This report includes field and Laboratory test results for the borehole location at Chainage: 1381/1 in the proposed construction area like Major, Minor Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.

1.1 Scope of Work

1.1.1 Field Work

- ❖ Sinking Standard Soil Investigation Bore Hole of 150mm diameter borehole for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) or as directed by the engineer-in-charge.
- Conducting Standard Penetration Test (SPT) at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

- Collection of Split Spoon Soil Samples from the boreholes.
- Collection of disturbed soil samples from the boreholes.
- Collection of undisturbed soil samples from cohesive or semi cohesive soil samples whose SPT lies between 4 and 15.
- Collection of rock core samples and carrying out various laboratory testing as per relevant IS codes.

1.1.2. Laboratory Work

1.1.2.1 Soil Samples

- (a) Visual and Engineering Classification
- (b) Sieve Analysis/ Particle Size Analysis/ Grain Size Distribution Analysis
 - (i) Hydrometer Analysis/ Wet Sieve Analysis
- (c) Atterberg Limits on the cohesive soils (LL, PL, SL) on fine-grained soils
- (d) Specific Gravity
- (e) Chemical Properties on sub-soil water/ soil sample to determine the presence of pH, Cl, SO₄ contents.
- (f) Swelling Pressure Tests & Free Swelling Index
- (g) Bulk Density and Moisture Content
- (h) Unconfined Compression Tests on Clay Soils
- (i) Box Shear Test in case of sand
- (j) Tri-Axial Shear TestsUnconsolidated undrained.Consolidated Undrained Test with the Pressure
- (k) Drained Consolidation Test representing e, Cc & Pc

1.1.2.2 Rock Samples

- Visual classification
- Moisture content, porosity and Density
- Specific gravity
- Unconfined compression test (both saturated and at in-situ water content)
- Point load strength index

1.2 Structure of the Report

- Contents
- Introduction
- Investigation Methodology & Test Results

- * Tables & Figures
- Subsurface Stratification
- * Foundation System
- Recommendations

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INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to 12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

Standard penetration tests (SPT) were conducted at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

The disturbed soil samples were collected as directed by the engineer-incharge at every change in the sub-soil strata. These samples were used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

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The standard penetration tests were conducted at an interval of 1.50m up to 10.0m depth below the existing ground level or at every change in the sub-soil strata as per IS: 2131-1981 or as directed by the engineer-in-charge. Split spoon samples collected were further used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.3 Undisturbed Soil Samples

At the borehole locations, the undisturbed soil samples were collected and presented in Fig. 2.1.

2.4 Laboratory Testing:

Soil Samples

2.4.1 Visual and Engineering Classification, Sieve Analysis Tests/ Grain Size Analysis Tests

On the soil samples visual and engineering, grain size distribution tests were conducted as per I.S.2720 (Part 4)-1985, to know the gradation characteristics and to classify them. These results are presented in Table 2.1.

2.4.2 Atterberg Limits

Atterberg Limits were carried out on fine-grained soil samples to evaluate the limits of different consistency states. Generally Liquid limits, Plastic limits and Shrinkage Limits tests were conducted as per I.S.2720 (Part-V)-1985 and I.S.2720 (Part 6)-1972. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.3 Specific Gravity

On the soil samples, specific gravity tests were conducted as per I.S: 2720 (Part-III, Sec.1)-1986. The test results are presented in Table 2.1.

2.4.4 Chemical Tests on Water Sample

These tests are being conducted on water sample as per I.S: 456-1978 and the test results are presented in table 2.2.

2.4.5 Swelling Pressure & Free Swell Tests

Generally, these tests are conducted over the fines passing through 0.075mm sieve. Since, the soil samples obtained are heterogeneous, the soil samples are sieved and the percentage of fines passing was used to determine the free swell percentage of soil. As no such type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.6 Bulk Density & Natural Moisture Content

On the soil samples, Bulk Density and natural moisture content tests were conducted as per I.S: 2720 (Part-II)-1973. The bulk density of the soil sample was determined through water displacement method and the test results are presented in Table 2.1.

2.4.7 Unconfined Compression Tests

These tests are normally conducted on clayey soils, which can stand without confinement. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.8 Box Shear Tests

The tests are being conducted on the remoulded compacted soil samples and were conducted under undrained conditions. The test results are presented in table 2.1.

2.4.9 Triaxial Shear Tests

These tests are normally conducted on the soil samples to determine their shear strength characteristics. The test results are presented in table 2.1.

2.4.10 Consolidation Tests

These tests are conducted to determine the compressibility characteristics of the soil. The tests are conducted in a consolidation cell with minimum diameter to thickness ratio as 3. The thickness of soil sample is taken as 20mm to get uniform distribution of pressure on the soil sample. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

Rock Samples

As no rock strata were encountered at the investigation locations, no tests on rock samples could be conducted.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Fastern Freight Corridor in line with Tender No. HO/FN/Pre. (Works)/MTC Location: At Chainage: 1381/1

Sta	irte	d O	n:04/0	08/2008; Ended On: 05	08/20	80	G.V	W.T:	9,00	m									
					SI	T D	etail	ls	rapl	nical	Rej	pre	sen	tati	on	of	SP	>	
1		1				access and			##	10	213	3(4	1 (5	16(7(81	90	nc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
				Greyish	1.50	3	4	4	8	٩								Loose	SS
				Loose Silty Fine Sand	3.00	UDS	Samp	ler Ins	stalled	\	\							Loose	UDS
4.	50				4.50	5	8	10	18									M.Dense	SS
				Greyish	6.00	7	9	11	20									M.Dense	ss
				Medium Dense Silty Fine Sand	7.50	9	10	13	23		1							M.Dense	SS
G.V	V.T	★ .			9.00	12	13	17	30		1	\						M.Dense	SS
10.	50			Greyish	10.50	15	18	20	38			1						Dense	SS
12.	00			Dense Silty Fine Sand	12.00	15	19	23	42			ļ	l					Dense	ss

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1381/1 Location

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SS SS Type of Sample	10.50-12.00	4.50-10.50	E.G.L-4.50		d	
Silly Sand Sil	38	23	∞	SPT of Sample		
Silty Sand Sil	SS	SS	SS			Table
S	Silty Sand	Silty Sand	Silty Sand	Visual & Engineering Classification of Soil		2.1: I
77	∞	9	15	NMC(%)		0
77	1	ì	ī	LL (%)		T
77	1	1		PL (%)	2	est
77	1	1	1	PI	lav V	Res
77	i		1	Consistency, I _C		ult
77	2.65	2.60	2.68	Specific Gravity, G		on
Triaxial Chainage: 1381/1				Void Ratio, e		the
77	19	17	15	Bulk Density, kN/m ³		Soil
77		i				Sa
77		1		Swelling Pressure (kPa)		mp
77	Dense	M.Dense	Loose	Relative Density/ Consistency		es Coll
77	0	T	0	Gravel (%)		ecte
77	0	0	0	Coarse (%)	Ž.	d fr
Triaxial Chainage: 1381/1	0	0	0	Medium (%)	AVA	om
Sist (%) Sist (%)	77	81	90	Fine (%)	ngl	\square
	23	19		Silt (%)	zeie	ina
	0	0	0	Clay (%)		ge:]
c (kN/m²) c (kN/m²) do (Deg.) Unconfined Compression Tests, Cu (kPa) Consolidation Tests, Cc	1	ı	10.1	c (kN/m²)	Tri	381/
Unconfined Compression Tests, Cu (kPa) Consolidation Tests, Cc		1	29.0	φ (Deg.)	ıxial	1 Lo
Unconfined Compression Tests, Cu (kPa) Consolidation Tests, Cc	r	1	-	c (kN/m²)	G B	catio
Consolidation Tests, Cc	ı	r	-	φ (Deg.)	0X	ĭ
			t	Unconfined Compression Tests, Cu (k	Pa)	
S S S IS-Classification	1		1	Consolidation Tests, Cc		
	SM	SM	SM	IS-Classification		

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			esults conducte Tole at Chaina	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.89	30.01	46.84

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1381/1 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	08
Relative Density	Loose
Angle of Shearing Resistance, φ	29.60 Deg.

* Layer-2 (from 4.50m to 10.50m depth below)

Type of Strata	Silty Fine Sand		
Colour	Greyish		
Thickness of Layer	6.00m		
SPT of the layer	23		
Relative Density	Medium Dense		
Angle of Shearing Resistance, φ	33.90 Deg.		

* Layer-3 (from 10.50m to 12.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	38
Relative Density	Dense
Angle of Shearing Resistance, φ	38.20 Deg.

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the first week of August 2008.

CHAPTER-4

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m²)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	12	50

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.



RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER 1S:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 8

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$ 29.60 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) $_{15.00}$ kN/m³

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w) 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = \frac{17.78}{}$

 $N_{y} = 21.48$

Shape Factors:

 $S_c = N/A$

 $S_q = \frac{1.30}{1.30}$

 $S_{y} = 1.00$

Depth Factors:

 $D_c = \frac{1}{N/A}$

 $D_q = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor

 $I_c = N/A$

 $I_q = \begin{array}{c} \\ 1.00 \end{array}$

 $I_{\gamma} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*I_{Q} + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*I_{Q}*w'$

 $Q_u = 311.69 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 124.68 kPa

Limited to an allowable bearing pressure per running meter width:

120.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and SPT of 08 are computed to be in the order of 50mm which is within the permissible limits of 50mm for individual column footings as per LS-1904

CHAPTER-1

INTRODUCTION

1.0 Preamble

Dedicated Freight Corridor Corporation of India Ltd. proposed to perform operations pertaining to staking out alignment, detail engineering construction survey for detour at any location(s) as directed by the Engineer In Charge, preparation of Land Plan for section 4 & 6 notification under Indian Land Acquisition Act, 1894, identification & preparation of Land acquisition plan for dumping locations for ballast/ blanket material etc, Geotechnical investigation, preparation of G.A.D. for Minor & Major bridges along with preparation of schedule of quantities & Tender document for construction of Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre.(Works)/MTC and the responsibility for carrying out the above is entrusted to M/s. Monarch Surveyors & Contractors Pvt. Ltd., Pune.

This report includes field and Laboratory test results for the borehole location at Chainage: 1382/1 in the proposed construction area like Major, Minor Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.

1.1 Scope of Work

1.1.1 Field Work

- ❖ Sinking Standard Soil Investigation Bore Hole of 150mm diameter borehole for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) or as directed by the engineer-in-charge.
- Conducting Standard Penetration Test (SPT) at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

- Collection of Split Spoon Soil Samples from the boreholes.
- Collection of disturbed soil samples from the boreholes.
- Collection of undisturbed soil samples from cohesive or semi cohesive soil samples whose SPT lies between 4 and 15.
- Collection of rock core samples and carrying out various laboratory testing as per relevant IS codes.

1.1.2. Laboratory Work

1.1.2.1 Soil Samples

- (a) Visual and Engineering Classification
- (b) Sieve Analysis/ Particle Size Analysis/ Grain Size Distribution Analysis
 - (i) Hydrometer Analysis/ Wet Sieve Analysis
- (c) Atterberg Limits on the cohesive soils (LL, PL, SL) on fine-grained soils
- (d) Specific Gravity
- (e) Chemical Properties on sub-soil water/ soil sample to determine the presence of pH, Cl, SO₄ contents.
- (f) Swelling Pressure Tests & Free Swelling Index
- (g) Bulk Density and Moisture Content
- (h) Unconfined Compression Tests on Clay Soils
- (i) Box Shear Test in case of sand
- (j) Tri-Axial Shear TestsUnconsolidated undrained.Consolidated Undrained Test with the Pressure
- (k) Drained Consolidation Test representing e, Cc & Pc

1.1.2.2 Rock Samples

- Visual classification
- Moisture content, porosity and Density
- Specific gravity
- Unconfined compression test (both saturated and at in-situ water content)
- Point load strength index

1.2 Structure of the Report

- Contents
- Introduction
- Investigation Methodology & Test Results

- * Tables & Figures
- Subsurface Stratification
- ❖ Foundation System
- * Recommendations

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INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to 12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

Standard penetration tests (SPT) were conducted at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

The disturbed soil samples were collected as directed by the engineer-incharge at every change in the sub-soil strata. These samples were used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

The standard penetration tests were conducted at an interval of 1.50m up to 10.0m depth below the existing ground level or at every change in the sub-soil strata as per IS: 2131-1981 or as directed by the engineer-in-charge. Split spoon samples collected were further used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.3 Undisturbed Soil Samples

At the borehole locations, the undisturbed soil samples were collected and presented in Fig. 2.1.

2.4 **Laboratory Testing:** Soil Samples

2.4.1 Visual and Engineering Classification, Sieve Analysis Tests/ Grain Size **Analysis Tests**

On the soil samples visual and engineering, grain size distribution tests were conducted as per I.S.2720 (Part 4)-1985, to know the gradation characteristics and to classify them. These results are presented in Table 2.1.

2.4.2 Atterberg Limits

Atterberg Limits were carried out on fine-grained soil samples to evaluate the limits of different consistency states. Generally Liquid limits, Plastic limits and Shrinkage Limits tests were conducted as per I.S.2720 (Part-V)-1985 and I.S.2720 (Part 6)-1972. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.3 Specific Gravity

On the soil samples, specific gravity tests were conducted as per I.S: 2720 (Part-III, Sec.1)-1986. The test results are presented in Table 2.1.

2.4.4 Chemical Tests on Water Sample

These tests are being conducted on water sample as per I.S: 456-1978 and the test results are presented in table 2.2.

2.4.5 Swelling Pressure & Free Swell Tests

Generally, these tests are conducted over the fines passing through 0.075mm sieve. Since, the soil samples obtained are heterogeneous, the soil samples are sieved and the percentage of fines passing was used to determine the free swell percentage of soil. As no such type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.6 Bulk Density & Natural Moisture Content

On the soil samples, Bulk Density and natural moisture content tests were conducted as per I.S: 2720 (Part-II)-1973. The bulk density of the soil sample was determined through water displacement method and the test results are presented in Table 2.1.

2.4.7 Unconfined Compression Tests

These tests are normally conducted on clayey soils, which can stand without confinement. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

2.4.8 Box Shear Tests

The tests are being conducted on the remoulded compacted soil samples and were conducted under undrained conditions. The test results are presented in table 2.1.

2.4.9 Triaxial Shear Tests

These tests are normally conducted on the soil samples to determine their shear strength characteristics. The test results are presented in table 2.1.

2.4.10 Consolidation Tests

These tests are conducted to determine the compressibility characteristics of the soil. The tests are conducted in a consolidation cell with minimum diameter to thickness ratio as 3. The thickness of soil sample is taken as 20mm to get uniform distribution of pressure on the soil sample. As no fine-grained type of sub-soil strata were encountered at the investigation location, no such tests could be conducted.

Rock Samples

As no rock strata were encountered at the investigation locations, no tests on rock samples could be conducted.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Fastern Freight Corridor in line with Tender No. HO/FN/Pre. (Works)/MTC

Location: At Chainage: 1382/1

				08/2008; Ended On: 04/					8.50			
		SPT-Details raphical Representation of SP							c _S			
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value ##	10 21 3(4(5) 6(7(8) 90	Relative Density/Consistency	Type of Sample
				Greyish Dense	1.50	6	16	24	40	ſ	Dense	ss
4.	50			Silty Fine Sand	3.00 4.50	UDS 9	Samp	ler Ins	talled 22		Dense M.Dense	UDS
				Greyish Medium Dense Silty Fine Sand	6.00	10	13	16	29		M.Dense	ss
7.	50	H			7,50	10	13	19	32		Dense	SS
G.V	V.T	*			9,00	11	15	20	35		Dense	ss
				Greyish Dense Silty Fine Sand	10.50	13	17	22	39		Dense	ss
12.	.00				12.00	17	21	24	45	J	Dense	ss

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1382/1 Location

l e	Box	\$ (Deg.)			ı	1	
cati	B &	c (k/V/m²)		,	818	1	
4 L	xial	ф (Deg.)		38.1	1	ı	
382/1	Triaxia Test	c (KV/m²)		16.9	1	1	
e: 1.		Clay (%)		0	0	0	
inag	vsis	(%) His		22	17	19	
Chaj	Sieve Analysis	(%) aniA		78	83	81	
E	ve A	(%) muibəM		0	0	0	
fro	Sie	Coarse (%)		0	0	0	
cted		Gravel (%)		0	0	0	
S Colle		Relative Density/ Consistency		Dense	M.Dense	Dense	
nple		Swelling Pressure (kPa)		1	ī	-	
San		Free Swell (%)		1	1	ı	
oil		Bulk Density, kN/m3		61	17	19	
he S		Void Ratio, e			1	ı	
on t		Specific Gravity, G	3	2.66	2.66	2.66	
ults		Consistency, I _C		,		r	
Resi	Clay	Id		1	•	ı	
st		PL (%)		1	ı	1	
Į		LL (%)		•	,	1.	
0.7		NMC(%)		×	11	∞	
Table 2.1: Laboratory Test Results on the Soil Samples Collected from Chainage: 1382/14 Location		Visual & Engineering Classification of Soil		Silty Sand	Silty Sand	Silty Sand	
Table		eldms2 to oqyT	5	22	SS	SS	

oldms2 to TA2

R.L of Sample below Existing Ground level(m)

SM

IS-Classification

Consolidation Tests, Cc

Unconfined Compression Tests, Cu (kPa)

SM

SM

00

4.50-7.50

40

35

7.50-12.00

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1382/1						
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)		
BH-01	9.00	7.87	40.07	76.53		

Silty Fine Sand

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1382/1 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata

Colour

Colour Greyish
Thickness of Layer 4.50m

SPT of the layer 40

Relative Density Dense

Angle of Shearing Resistance, φ 38.75 Deg.

* Layer-2 (from 4.50m to 7.50m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 34.50 Deg.

* Layer-3 (from 7.50m to 12.00m depth below)

Type of Strata
Colour
Greyish
Thickness of Layer
SPT of the layer
Relative Density
Angle of Shearing Resistance, φ
Silty Fine Sand
Greyish
4.50m
35
Dense
37.375 Deg.

The ground water table was encountered at a depth of 8.50m within the explored depth of investigation in the first week of August 2008.

CHAPTER-4

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of	Safe Bearing Capacity (t/m²)	Elastic Settlements (mm)
		Footing below N.G.L (m)		
1	Isolated Column Footing/Raft	1.00	40	40

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

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CHAPTER-5

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of silty sand and can
 be considered as bearing strata for the proposed impending loads from the
 superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.