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: 1370/1 Started On: 18/08/2008; Ende

Sta	arte	d O	n:18/0	08/2008; Ended On: 19	/08/20	80	G.	W.T:	8.00	)m			
		T			SP	Τ - Ε	etai	ls	rapl	hical Representation	on of SP	>	
1							~~~~~~		##	10 2(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	5	8	10	18	9		M.Dense	ss
		2000		Greyish Medium Dense	3.00	UDS	Samp	ler Ins	talled			M Dense	UDS
				Silty Fine Sand	4.50	6	8	11	19			M.Dense	ss
					6.00	10	14	16	30			M.Dense	ss
7.: G.V	_	<b>*</b>		3	7.50	13	15	17	32			Dense	ss
				Greyish	9,00	13	16	22	38			Dense	ss
	*			Dense Silty Fine Sand	10.50	13	18	25	43			Dense	ss
12.	00				12.00	17	20	26	46	J		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1370/1 Location

7.50-12.00	E.G.L-7.50	R.L of Sample below Existing Groulevel(m)	ınd		
38	22	SPT of Sample			
SS	SS	Type of Sample			Table
Silty Sand	Silty Sand	Visual & Engineering Classification of Soil			able 2.1: Laboratory
∞	11	NMC(%)			or
1	i	LL (%)			T
-	1	PL (%)	0		est
ı	-	PI	Clay		Res
1	,	Consistency, I <sub>C</sub>			ults
2.65	2.67	Specific Gravity, G			on i
i	t	Void Ratio, e			the S
19	17	Bulk Density, kN/m <sup>3</sup>			Oi.
	·	Free Swell (%)			Sai
1	1	Swelling Pressure (kPa)			npl
Dense	M.Dense	Relative Density/ Consistency			Test Results on the Soil Samples Collected from
0	0.	Gravel (%)			cte
0	0	Coarse (%)	Si		d fr
0	0	Medium (%)	Sieve A		om
77	80	Fine (%)	\nal		$\square$
23	20	Silt (%)	nalysis		hainage:
0	0	Clay (%)			ge:
1	13.6	c (kN/m²)	T	Tri	370
	33.0	φ (Deg.)	Test	rigyigl	/1 Lc
1	1	c (kN/m²)	Shear	R	ocation
I	ı	φ (Deg.)	ear	Rov	ĭ
	1	Unconfined Compression Tests, Cu	(kPa	)	
1	ı	Consolidation Tests, Cc			
MS	SM	IS-Classification			

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		. V <del>.</del>	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	7.88	45.74	85.21

# 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-1370/1 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 22
Relative Density Medium Dense
Angle of Shearing Resistance,  $\phi$  33.60 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

38

Dense

38

Dense

38.20 Deg.

The ground water table was encountered at a depth of 8.00m within the explored depth of investigation in the third 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	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	$(t/m^2)$	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	17	42
	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.

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- 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, \$\phi\$ 32.40 Deg.

#### 1 Design Parameters:

Bulk Density of Soil above the foundation detph ( $\gamma_{bulk}$ )  $_{16.00}$ 

Effective Overburden pressure at foundation level (q) 9.00

Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors:

 $N_c = N/A$ 

 $N_q = 25.55$ 

 $N_y = 34.70$ 

#### Shape Factors:

 $S_c = N/A$ 

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

 $S_y = 1.00$ 

#### Depth Factors:

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

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

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

#### Inclination Factor.

 $I_c = N/A$ 

 $l_g = 1.00$ 

 $I_y = 1.00$ 

 $\begin{array}{l} \textbf{1 Ultimate Bearing Capacity (Qu):} \\ Qu = Cu^*Nc^*Sc^*D_{C}^*l_{C^*}q^*(Nq\text{-}1)^*Sq^*Dq^*Iq + 0.5^*B^*\gamma^*N\gamma^*S\gamma^*D\gamma^*Jg^*w' \end{array}$ 

 $Q_u = \frac{437.77 \text{ kPa}}{437.77 \text{ kPa}}$ 

#### 2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.):

Qsafe: 175.11 kPa

Limited to an allowable bearing pressure per running meter width: 170,00 kPa

#### 2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 170kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 170kPa and SPT of 18 are computed to be in the order of 42mm which is within the permissible limits of 50mm for individual column footings as per 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: 1371/1 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, SO<sub>4</sub> 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: 1371/1 Started On: 17/08/2008: Ended On: 18/08/2008 G.W.T: 7.80

Sta	arte	d O	n:17/0	08/2008; Ended On: 18.	08/200	98	G.V	W.T:	7.80	m											
					SP	T - D	etail	ls	rap	ical	Rej	pre	ser	itat	tio	n c	fSl	Р	2		٦
									##	10	213	3(4	1( 5	6	(7	7(8	190	0	enc		ı
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	
				e	1.50	4	7	10	17	ţ	Ì								M Dense	ss	
					3.00	UDS	Samp	ler Ins	talled										M,Dense	UDS	s
				Greyish Medium Dense Silty Fine Sand	4.50	6	9	13	22		9								M.Dense	ss	
				***	6.00	8	10	15	25		1								M.Dense	ss	200
G.V	v.T	*			7.50	10	11	16	27		1								M.Dense	ss	
9.	00				9.00	12	14	19	33										Dense	SS	
				Greyish Dense	10.50	15	18	22	40				١						Dense	ss	
12.	.00			Sifty Fine Sand	12.00	17	21	24	45										Dense	SS	

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1371/1 Location

			_				_
		IS-Classification		SM		SM	
		Consolidation Tests, Cc		1		,	
	кРа)	Unconfined Compression Tests, Cu (		,		,	
	)X	φ (Deg.)				,	
ation	Box	c (F/J/m <sub>z</sub> )		,	Ī	,	
Loc	xial St	ф (Deg.)		33.4		,	
1371	Triaxial Test	c (k/J/m²)		14.8		,	
age:		(%) (%)		0		0	
naing	ysis	(%) His		19		25	
C	lual	(%)		81		75	
rom	Sieve Analysis	(%) muibəl/		0		0	
d f	Sie	Coarse (%)		0		0	
ecte		Gravel (%)		0		0	
est Results on the Soil Samples Collected from Chainage: 1371 Location		Relative Density/ Consistency		M.Dense		Dense	
ш		Swelling Pressure (kPa)		1		1	
l Sa		Free Swell (%)		ı		1	
Soi		Bulk Density, kN/m3		17		19	
the		Void Ratio, e		ī		'	
ts on		Specific Gravity, G		2.67		2.65	
lns		Consistency, I <sub>C</sub>		-		1	
t Re	Clay	Id		1		1	
res		PL (%)		1		,	
Z		LL (%)		ı		1	
ato		NMC(%)		Ξ		∞	
Table 2.1: Laboratory		Visual & Engineering Classification of Soil		Silty Sand		Silty Sand	
Tab		Type of Sample		SS		SS	
		oldmg2 to TA2		23		36	
	pu	R.L of Sample below Existing Grou level(m)		E.G.L-9.00		9.00-12.00	

			esults conducte Hole at Chaina	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Н	Chlorides(ppm)	Sulphates (ppm)
BH-01	9,00	7,89	24.79	43.24

# 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-1371/1 Location (As presented in the site plan)

\* Layer-1 (from E.G.L to 9.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	9.00m
SPT of the layer	23
Relative Density	Medium Dense
Angle of Shearing Resistance, φ	33.90 Deg.

#### Layer-2 (from 9.00m to 12.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
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 7.80m 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 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.

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#### 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 m 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: 17 Type of Shear Failure: General Angle of Shearing Resistance, ¢: 32.10 Deg.

#### 1 Design Parameters:

Bulk Density of Soil above the foundation detph (youk) 16.00 kN/m3 Effective Overburden pressure at foundation level (q) 9.00 Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:  $N_c = \frac{N_c}{N/A}$  $N_q = \frac{1}{24.66}$  $N_{\gamma} = 33.16$ 

Shape Factors:  $S_c = \frac{1}{N/A}$  $s_q = \frac{1.30}{1.30}$  $S_{y} = 1.00$ 

Depth Factors :  $D_c = \frac{1}{N/A}$  $D_q = \frac{1.00}{1.00}$  $D_{y} = 1.00$ 

# Inclination Factor: $I_c = \frac{1}{N/A}$

 $\mathbf{1}_q = \mathbf{1.00}$  $I_y = 1.00$ 

 $\begin{array}{l} \textbf{1. Ultimate Bearing Capacity (Qu):} \\ Qu = Cu^*Nc^*Sc^*D_{C^*}l_{C^*}q^*(Nq\text{-}1)^*Sq^*Dq^*lq \pm 0.5^*B^*\gamma^*N\gamma^*S\gamma^*D\gamma^*lg^*w \end{array}$ 

 $Q_u = 421.16 \text{ kPa}$ 

#### 2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.)

Qsafe: 168.46 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 17 are computed to be in the order of 48mm which is within the permissible limits of 50mm

# 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:1372/01 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, SO<sub>4</sub> 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

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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 to12m 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

0

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 Eastern Freight Corridor in line with Tender No. HO/EN/Pre. (Works)/MTC. Location: At Chainage; 1372/1 (BR.No.176)

П	1	/08/2008; Ended Or			Detai	ls	G. V	V.T:			cpre	sent:	atio	n of	SPT	_	1	Т
				_			##	10			40						1	-
Laver(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	
	300000		1.50	6	8	9	11		ſ								M Dense	
w.t 🖢	0000000		3.00	L DS	Colle	ated											M Dens-	
-		Genyash	4.50	7	9	10	19										M Depar	
-		Medium Dense Silty Fine Sand	6.00	9	11	13	21										M Dense	
-			Y.5-1	Ια	n	15	26										M Dense	
-			9 00	10	12	12	29			1							M Dense	
150	3		10.5α	13	19	77	40										Derse	
-			12.00	14	20	23	43										Dense	
-		Greyish Dense Silty Fine Sand	13.50	20	23	26	49										Dense	
<u>-</u>			15.00	20	23	14	50										Dense	
(5)			16.50	21	25	1.	52										V Dense	
-		Greyich Very Dense Sidty Fane Sand	18.00	13	26	2"	53										V Dense	

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talberi at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works/MTC. Location: At Chainage:1372/1

T		108/2008, Ended Or	_	- I		ils	Г	W.T Gr	-	-		pre	se n	itat	ion	of	SP	Γ	Т		Т
- 11							##	1	0	20	30	40	50	0 6	0 '	70	80	90	]	Density/Consistency	ı
Laverim) 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							MANY AND THE PERSON OF THE PER					Relative	Type of Sample	
-			1950	22	28	10	58							ſ					V	Dense:	SS
-	2000		21 00	22	29	32	ด												VI	Dense	225
-		Greyash Very Dense	22 Sri	24	30	35	65								1				VI	Dense	229
-	355555	Silty Fine Sand	24.00	23	3]	38	69								1	\			v	Dense	SS
-			26 00	20	35	40	73									1			v	Deme	38
-			21.50	18	35	44	79												V.I	Dense	.53
10.00		12	29.50	20	3*	47	84										1		VI	Sense	.55

0

0

Bore Hole Terminated at a depth of 30.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1372/1 Location

R.L. of Sample   Post   Results on the Soil   Sample   Post   Post								
SS   SS   Type of Sample	16.50-30.00	10.50-16.50	E.G.L-10.50	11 - 1				
Silty Sand   Sil	60	46	23	SPT of Sample				
Silty Sand   Sil	SS	SS	SS		Table 2			
S	Silty Sand	Silty Sand	Silty Sand	Visual & Engineering Classification of Soil				
Collected   Coll	5	9	10	NMC(%)	·			
Collected   Coll	1	.		LL (%)	es			
Collected   Coll	1	1	1	PL (%)	R			
Collected   Coll		1	1	PI	esu			
Collected   Coll	1	1.1	1	Consistency, I <sub>C</sub>				
Collected   Coll	2.63	2.60	2.67	Specific Gravity, G				
Collected   Coll		TT	T	Void Ratio, e				
Collected   Coll	20	15	17	Bulk Density, kN/m <sup>3</sup>				
Collected   Coll		TT		Free Swell (%)				
Collected   Coll		1	1	Swelling Pressure (kPa)				
Color   Colo	V.Dense	Dense	M.Dense					
Chainage   Chainage	0	0		Gravel (%)	Ted			
Chainage   Chainage	0	0	0	Coarse (%)				
Clay (%)	0	0	0	Medium (%)				
Clay (%)	72	78	84	Fine (%)				
	28	22	16	Silt (%)	age			
	0	0	0	Clay (%)	No			
c (kN/m²)  b c (kN/m²)  c (kN/m²)  b c (kN/m²)  b c (kN/m²)  b c (kN/m²)  b c (kN/m²)  c (kN/m²)  b c (kN/m²)  b c (kN/m²)  c (kN/m²)  b c (kN/m²)  b c (kN/m²)  c (kN/m²)  c (kN/m²)  b c (kN/m²)			16.7	c (kN/m²)				
ψ (Deg.)  Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	1	ı	33.3	φ (Deg.)				
Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	1	-		c (kN/m²)				
Consolidation Tests, Cc		1	,	φ (Deg.)				
				Unconfined Compression Tests, Cu (kPa)				
S S S IS-Classification			i	Consolidation Tests, Cc				
	SM	SM	SM	IS-Classification				

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			esults conducte le at Chainage	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
BH-01	4.50	7,83	103.57	89.36

# 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-1372/1 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 23
Relative Density Medium Dense

Angle of Shearing Resistance,  $\phi$  33.90 Deg.

\* Layer-2 (from 10.50m to 16.50m 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

6.00m

46

Dense

46

Dense

40.10 Deg.

\* Layer-3 (from 16.50m to 30.00m 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

17.50m

60

Very Dense

42.50 Deg.

The ground water table was encountered at a depth of 3.00m within the explored depth of investigation in the third 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 are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

However, the sub-soil strata encountered at a depth of 16.50m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

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

#### 4.2 Foundation System

#### 4.2.1 Deep 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 below a depth of 16.50m below the existing ground level.

Hence, the foundation system can be 22.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 22.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

S.No.	Diameter of	Safe Load	Safe Pull Out	Safe Lateral Load	
	Pile	Carrying	carrying		
	(mm)	Capacity	Capacity	carrying	
		(kN)	(kN)	Capacity	
				(kN)	
1	1000	11000	2887	600	

The details of the computations are annexed to this report.

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# RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. The sub-soil strata encountered at a depth of 16.50m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
- 3. The bearing strata of the proposed foundation system can be the sub soil strata encountered below a depth of 16.50m below the existing ground level. Hence, the foundation system can be 22.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
- 4. The safe load carrying capacity of 22.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 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 PILE FOUNDATION(Refer:BH-01) Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile 1.1 Geometrical Data	Bored (	ast in Situ
Assumed Diameter of pile(D)		
Assumed R.L of E.G.L: Length of pile below E.G.L.(1):	0,000	
R.L. of Bot. of Pile		
1.2 Design of Pile for Vertical Compression 1.2.1 Computation of Skin Resistance:		
1.2.1.1 Layer-I		
Type of Strata: Average SPT of the strata,N:	23	
Bulk Density of the strata,γ:		kN/m³
Angle of Shearing Resistance, ¢: Depth of top of Strata:		Deg. m
Depth of bottom of Strata:		m
Average Thickness of Strata,Ic:	10.50	m
Effective overburden pressure over the top of strata, $\sigma_{top}$ .	0.00	kN/m <sup>2</sup>
Effective overburden pressure over the bottom of strata, Ghottom	73.50	kN/m <sup>2</sup>
Effective overburden pressure at the middle of the strata, omiddle	36.75	kN/m <sup>2</sup>
Coeff. Of Earth Pressure,k:	1.50	
Skin Resistance of the pile,q,	1221.91	kN
$(q_i:\sigma^*k^*tan\phi^*pi()^*d^*Ie)$		
1.2.1.2 Layer-II		
Type of Strata:	Silty Sar	ıd
Average SPT of the strata,N:		
Bulk Density of the strata,y:	19	kN/m3
Angle of Shearing Resistance, 6:		Deg
Depth of top of Strata: Depth of bottom of Strata:		m
Average Thickness of Strata,I <sub>c</sub> :		m m
Effective overburden pressure over the top of strata, $\sigma_{top}$ .		kN/m <sup>2</sup>
Effective overburden pressure over the bottom of strata, obottom		kN/m <sup>2</sup>
Effective overburden pressure at the middle of the strata, $\sigma_{middle}$ :		kN/m <sup>2</sup>
Coeff. Of Earth Pressure,k;		KL WIII
Skin Resistance of the pile,q.:		kN
$(q_s:\sigma^*k^*tan\phi^*pi()^*d^*le)$		
1.2.1.3 Layer-III Type of Strata:	Cilty Con	d
Average SPT of the strata,N:		u
Bulk Density of the strata,γ:	20	kN/m3
Angle of Shearing Resistance, 4:		Deg.
Depth of top of Strata:		m
Depth of bottom of Strata:  Average Thickness of Strata, I.:		m m
Effective overburden pressure over the top of strata, $\sigma_{ton}$ :		m kN/m <sup>2</sup>
Effective overburden pressure over the bottom of strata, obottom		kN/m <sup>2</sup>
Effective overburden pressure at the middle of the strata, $\sigma_{midde}$ :		kN/m <sup>2</sup>
Coeff. Of Earth Pressure &:		KIN/III
Skin Resistance of the pile,q.		kN
$(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$		
Ultimate Skin Resistance,q,:	7219.3	kN
1.2.2 Computation of End Bearing Resistance:		
Type of Bearing Strata	Silty San	d
Cross-Sectional Area of pile, Ap:		m <sup>2</sup>
R.L of bottom of pile:		
Minimum SPT-value of the Bearing Strata Angle of Shearing Resistance(ASR)		D
Bearing Capacity Factor(Nq)		Degrees
Effective Over Burden Pressure at the bottom of pile (q)		kPa
(limited to a maximum value produced by a soil layer of thickness equal to 20 times the diameter of pile from the		
N.G.L.) Ultimate End Bearing Resistance (Qp)	20734 5	kN
(Qp=Ap*q*Nq)	20.04.0	
1.3.0 Ultimate Load Carrying Capacity (Qu=Qp+q <sub>p</sub> )		
Safe Load Carrying Capacity (Qsafe =Qu/2.5) However, limit Q <sub>safe</sub> to the structural capacity of pile:		
Case of the Case o		37.3

#### DESIGN OF PILE FOUNDATION(Refer:BH-01) Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

```
1.0 Type of Installation of Pile
                                                                              Rored Cast in Situ
    1.1 Geometrical Data
                                            Assumed Diameter of pile(D). 1000.0 mm
                                          Assumed R.L of E.G.L: 0.000 m
Length of pile below E.G.L.(1): 22.000 m
                                                       R.L. of Bot. of Pile
                                                                               -22.00 m
    1.2 Design of Pile for Vertical Compression
  1.2.1 Computation of Skin Resistance:
1.2.1.1
                                                                    Layer-I
                                                             Type of Strata: Silty Sand
                                              Average SPT of the strata, N: 23
                                               Bulk Density of the strata,y: 17
                                           Angle of Shearing Resistance, 6: 33.9
                                                                                         Deg.
                                                Depth of top of Strata: 0.00
Depth of bottom of Strata: 10.50
                                                                                         m
                                           Average Thickness of Strata, Ic: 10.50
               Effective overburden pressure over the top of strata, \sigma_{top}: 0.00
                                                                                         kN/m<sup>2</sup>
         Effective overburden pressure over the bottom of strata, \sigma_{bottom} \!\!: 73.50
                                                                                         kN/m2
        Effective overburden pressure at the middle of the strata, \sigma_{midd\,k} \!\!: 36.75
                                                                                         kN/m2
                                               Coeff. Of Earth Pressure,k: 1,50
                                             Skin Resistance of the pile,q,: 1221.91 kN
                                                 (q_s:\sigma^*k^*tan\phi^*pi()^*d^*lc)
1,2,1,2
                                                                  Laver-II
                                                             Type of Strata: Silty Sand
                                              Average SPT of the strata, N: 46
                                              Bulk Density of the strata,y: 19
                                                                                         1-N/m
                                          Angle of Shearing Resistance, 6: 40 1
                                                                                        Deg.
                                                    Depth of top of Strata: 10.50
                                                Depth of bottom of Strata: 16.50
                                                                                         m
                                           Average Thickness of Strata, Ic. 6.00
                                                                                         m
               Effective overburden pressure over the top of strata, \sigma_{top}.\ 73.50
                                                                                        kN/m2
        Effective overburden pressure over the bottom of strata, \sigma_{bottom}. 127.50 kN/m<sup>2</sup>
        Effective overburden pressure at the middle of the strata, \sigma_{middle}: 100.50 kN/m<sup>2</sup>
                                               Coeff. Of Earth Pressure k: 1.50
                                             Skin Resistance of the pile,q: 2392.8 kN
                                                 (q_s: \sigma^*k^*tan\phi^*pi()^*d^*lc)
1.2.1.3
                                                                  Layer-III
                                             Type of Strata, Silty Sand
Average SPT of the strata,N: 56
                                              Bulk Density of the strata, y: 20
                                                                                         kN/m
                                          Angle of Shearing Resistance, 6: 41.9
                                                                                        Deg.
                                                   Depth of top of Strata: 16.50
                                                Depth of bottom of Strata: 22.00
                                                                                        m
                                           Average Thickness of Strata, Ic: 5.50
               Effective overburden pressure over the top of strata, \sigma_{top}: 127.50 kN/m<sup>2</sup>
        Effective overburden pressure over the bottom of strata, \sigma_{bottom}. 182.50 \, kN/m^2
       Effective overburden pressure at the middle of the strata, \sigma_{middk}: 155.00 kN/m<sup>2</sup>
                                               Coeff. Of Earth Pressure,k; 1.50
                                            Skin Resistance of the pile,q: 3604.5 kN
                                                 (q_s \sigma^* k^* tan \phi^* pi()^* d^* lc)
                                           Ultimate Skin Resistance,q,: 7219,3 kN
 1.2.2 Computation of End Bearing Resistance:
                                                   Type of Bearing Strata Silty Sand
                                         Cross-Sectional Area of pile, Ap: 0.785 m<sup>2</sup>
R.L of bottom of pile: -22.00
                              Minimum SPT-value of the Bearing Strata 60
                                     Angle of Shearing Resistance(ASR) 42.50
Bearing Capacity Factor(Nq) 220.00
               Effective Over Burden Pressure at the bottom of pile (q) 120.00 kPa
           (limited to a maximum value produced by a soil layer of thickness equal to 20 times the diameter of pile from the
                                                                  N.G.L.)
                               Ultimate End Bearing Resistance (Qp) 20734.5 kN
                                                          (Qp=Ap*q*Nq)
 1,3,0
                     Ultimate Load Carrying Capacity (Qu=Qp+q<sub>p</sub>) 27953.8 kN
                      Safe Load Carrying Capacity (Qsafe =Qu/2.5) 11181.5 kN
              However, limit Qsafe to the structural capacity of pile: 11000.0 kN
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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:1372/2 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, SO<sub>4</sub> 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

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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 Km 156 on Eastern Freight Corridor in line with Tender No. HO/EN/Pre. (Works)/MTC. Location: At Chainage:1372/2
Started On: 12/08/2008; Ended On: 14/08/2008 G.W.T: 0.00m

	П		708/2008; Ended On : 1			Detai		Gra	,00m aphica	l Rep	rese	ntati	on	of S	PT	У.	Г
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	20 30	40 3	50 60		80	90	Relative Density/Consistency	Type of Sample
			Greyish Loose Silty Fine Sand	1.50	4	5	6	11	(							Loose	S
3.50				3.00	UDS	Colle	cted		\	١						Loose	SS
			Greyish Medium Dense	4.50	5	10	13	23								M Dense	SS
6.00	7		Silty Fine Sand	6.00	7	13	19	32		1						Dense	SS
				7.50	10	13	21	34								Dense	S
				9.00	10	16	21	37			Ì					Dense	S
			Greyish Dense	10.50	13	17	22	39								Dense	S
	-		Silty Fine Sand	12.00	16	20	23	43			1					Dense	S
				13.50	15	21	24	45			-					Dense	S
			*	15,00	17	22	25	47								Dense	St
17.50				16.50	17	24	25	49								Dense	SS
17.30			Greyish Very Dense Silty Fine Sand	18.00	19	24	27	51				1				V.I\(\text{knse}\)	55

Project: Proposed 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. Location: At Chainage:1372/2

Started On : 12/08/2008:	Ended On × 14/08/2008	G W T: 0.00m

		T			SP	Γ-Ι	)etai	ls	Gra	phi	cal	Rep	rese	ntati	on c	f SPT	2	1
t	- 1						20 10		0	10	0 2	030	40 :	50 60	70	80 90	1 8	1
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Descriptio of Soil	Depth of SPT	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
					19.50	20	25	30	55					1			V.Dense	SS
					21.00	20	25	33	58					1			V.Dense	SS
				Greyish Very Dense	22.50	22	25	37	62					1			V.Dense	SS
				Silty Fine Sand	24.00	20	27	40	67								V.Dense	SS
					26.00	21	28	42	70						1		V Dense	SS
					27.50	21	32	43	75						1		V.Dense	SS
30.0	00				29.50	25	37	45	82							ľ	V.Dense	SS

Bore Hole Terminated at a depth of 30.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1372/2 Location

			_								
	17.50-30.00	6.00-17.50		3.50-6.00		E.G.L-3.50		R.L of Sample below Existing Gro level(m)	und		
	58	41		23		11		SPT of Sample			
	SS	SS		SS		SS		Type of Sample		e e e e e e e e e e e e e e e e e e e	Table 2
	Silty Sand	Silty Sand		Silty Sand		Silty Sand		Visual & Engineering Classification of Soil			Table 2.1: Laboratory
	7	∞		9		12		NMC(%)			2
		1	Ī	,		,		LL (%)	T		Tes
	1	1	Γ	1				PL (%)	1	,	R
	1	1		,		1		PI	Clay	•	esu
r	1	ı				ı	٦	Consistency, I <sub>C</sub>	1		lts o
F	2.65	2.66		2.67		2.68		Specific Gravity, G	<u> </u>		on et
r	,			7 -		1		Void Ratio, e			est Results on the Soil
Г	20	19		17		15		Bulk Density, kN/m <sup>3</sup>			SIE
		1		ı				Free Swell (%)			Samples
F	,			1		,		Swelling Pressure (kPa)			ples
	V.Dense	Dense		M.Dense		Loose		Relative Density/ Consistency			Collected
	0	0		0		0		Gravel (%)	Γ		ted
	0	0		0		0	٦	Coarse (%)	S		from
	0	0		0		0		Medium (%)	Sieve Ar		n C
	72	78		83		89		Fine (%)	Anal	20.	hair
	28	22		17		=		Silt (%)	nalysis		inage
	0	0	Ī	0		0		Clay (%)			No
				1		11.4		c (kN/m²)	T	Tri	. 13
	-			1	-	29.7		φ (Deg.)	Test	<b>Friaxial</b>	72/2
	1			1	T	1		c (kN/m²)	Sh	В	Loca
	,	-		•				φ (Deg.)	Shear	Box	tion
	1	1		i				Unconfined Compression Tests, Cu	(kP	a)	
	-							Consolidation Tests, Cc			
	SM	SM		SM		MS		IS-Classification			

(

2000 00	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage No. 1372/2												
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)									
BH-01	0.00	7.89	34,79	21,12									

 $\cap$ 

# **CHAPTER-3**

# 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-1372/2 Location

(As presented in the site plan)

\* Layer-1 (from E.G.L to 3.50m depth below)

Type of Strata Silty Fine Sand
Colour Greyish
Thickness of Layer 3.50m
SPT of the layer 11

Relative Density Loose

Angle of Shearing Resistance,  $\phi$  30.30 Deg.

\* Layer-2 (from 3.50m to 6.00m depth below)

Type of Strata Silty Fine Sand
Colour Greyish
Thickness of Layer 2.50m

SPT of the layer 23

Relative Density Medium Dense

Angle of Shearing Resistance, φ 33.90 Deg.

\* Layer-3 (from 6.00m to 17.50m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

SPT of the layer

Relative Density

SPT of the layer

All

Dense

Relative Density Dense Angle of Shearing Resistance,  $\phi$  38.975 Deg.

\* Layer-4 (from 17.50m to 30.00m depth below)

Type of Strata

Colour

Colour

Thickness of Layer

SPT of the layer

Relative Density Very Dense

Angle of Shearing Resistance, φ 42.20 Deg.

The ground water table was encountered at a depth of 0.00m within the explored depth of investigation in the third 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 are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

However, the sub-soil strata encountered at a depth of 17.50m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

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

# 4.2 Foundation System

# 4.2.1 Deep Foundation System

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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 below a depth of 17.50m below the existing ground level.

Hence, the foundation system can be 23.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 23.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

S.No.	Diameter of Pile (mm)	Safe Load Carrying Capacity	Safe Pull Out carrying Capacity	Safe Lateral Load carrying
8		(kN)	(kN)	Capacity (kN)
1	1000	11000	3674	650

The details of the computations are annexed to this report.



# RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- The sub-soil strata encountered at a depth of 17.50m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
- 3. The bearing strata of the proposed foundation system can be the sub soil strata encountered below a depth of 17.50m below the existing ground level. Hence, the foundation system can be 23.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
- 4. The safe load carrying capacity of 23.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 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 PILE FOUNDATION(Refer:BH-01)

Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile

**Bored Cast in Situ** 

1.1 Geometrical Data

Assumed Diameter of pile(D): 1000.0 mm
Assumed R.L of E.G.L: 0.000 m

Length of pile below E.G.L.(l): 23.000 m

R.L. of Bot. of Pile -23.00 m

#### 1.2 Design of Pile for Vertical Compression

#### 1.2.1 Computation of Skin Resistance:

1.2.1.1 Layer-I

Type of Strata: Silty Sand

Average SPT of the strata, N: 11

Bulk Density of the strata,γ: 15 kN/m³
Angle of Shearing Resistance,φ: 30.3 Deg.
Depth of top of Strata: 0.00 m
Depth of bottom of Strata: 3.50 m
Average Thickness of Strata, I<sub>c</sub>: 3.50 m

Effective overburden pressure over the top of strata,  $\sigma_{top}$ : 0.00  $kN/m^2$ 

Effective overburden pressure over the bottom of strata,  $\sigma_{bottom}$ : 17.50 kN/m<sup>2</sup>

Effective overburden pressure at the middle of the strata,  $\sigma_{\text{middle}}$ : 8.75 kN/m<sup>2</sup>

Coeff. Of Earth Pressure,k: 1.00

Skin Resistance of the pile, q<sub>s</sub>: 56.22 kN

 $(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$ 

1.2.1.2 Laver-II

Type of Strata: Silty Sand

Average SPT of the strata, N: 23

Bulk Density of the strata, y: 17 kN/m³

Angle of Shearing Resistance, φ: 33.9 Deg.

Depth of top of Strata: 3.50 m

Depth of bottom of Strata: 6.00 m

Average Thickness of Strata, I<sub>c</sub>: 2.50 m

Effective overburden pressure over the top of strata,  $\sigma_{top}$ : 17.50 kN/m<sup>2</sup>

Effective overburden pressure over the bottom of strata,  $\sigma_{bottom}$ : 35.00 kN/m<sup>2</sup>

Effective overburden pressure at the middle of the strata,  $\sigma_{\text{middle}}$ : 26.25 kN/m<sup>2</sup>

Coeff. Of Earth Pressure,k: 1.50

Skin Resistance of the pile, q<sub>s</sub>: 207.81 kN

 $(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$ 

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1.2.1.3	Layer-III	
	Type of Strata: Silty San	nd
	Average SPT of the strata, N: 41	
	Bulk Density of the strata,γ: 19	$kN/m^3$
	Angle of Shearing Resistance,φ: 38.975	Deg.
	Depth of top of Strata: 6.00	m
	Depth of bottom of Strata: 17.50	m
	Average Thickness of Strata, I <sub>c</sub> : 11.50	m
	Effective overburden pressure over the top of strata, $\sigma_{top}$ : 35.00	$kN/m^2$
	Effective overburden pressure over the bottom of strata, $\sigma_{bottom}$ : 138.50	kN/m <sup>2</sup>
· E	ffective overburden pressure at the middle of the strata, $\sigma_{middle}$ : 86.75	$kN/m^2$
	Coeff. Of Earth Pressure,k: 1.50	
	Skin Resistance of the pile,q <sub>s</sub> : 3803.6	kN
	$(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$	
1.2.1.4	Layer-IV	
	Type of Strata: Silty San	ıd
	Average SPT of the strata, N: 57	
	Bulk Density of the strata,γ: 20	kN/m <sup>3</sup>
	Angle of Shearing Resistance,φ: 42.05	Deg.
	Depth of top of Strata: 17.50	m
	Depth of bottom of Strata: 23.00	m
	Average Thickness of Strata, I <sub>c</sub> : 5.50	m
	Effective overburden pressure over the top of strata, $\sigma_{top}$ : 138.50	kN/m <sup>2</sup>
Е	Effective overburden pressure over the bottom of strata, $\sigma_{\text{bottom}}$ : 193.50	kN/m <sup>2</sup>
Et	ffective overburden pressure at the middle of the strata, $\sigma_{middle}$ : 166.00	kN/m <sup>2</sup>
	Coeff. Of Earth Pressure,k: 2.00	
	Skin Resistance of the pile, q <sub>s</sub> : 5174.3	kN
	$(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$	
	Ultimate Skin Resistance,q <sub>s</sub> : 9185.6	kN
1.2.2 Co	omputation of End Bearing Resistance:	
	Type of Bearing Strata Silty San	d
	Cross-Sectional Area of pile, Ap: 0.785	$m^2$
	R.L of bottom of pile: -23.00	
	Minimum SPT-value of the Bearing Strata 60	
	Angle of Shearing Resistance(ASR) 42.50	Degrees
	Bearing Capacity Factor(Nq) 220.00	
	Effective Over Burden Pressure at the bottom of pile (q) 120.00	kPa
	(limited to a maximum value produced by a soil layer of thickness equal to 20 times the diameter of pile from the	
	N.G.L.)	
	Ultimate End Bearing Resistance (Qp) 20734.5	kN
	(Qp=Ap*q*Nq)	
1.3.0	Ultimate Load Carrying Capacity (Qu=Qp+q <sub>p</sub> ) 29920.2	kN
	Safe Load Carrying Capacity (Qsafe =Qu/2.5) 11968.1	

However, limit  $Q_{\text{safe}}$  to the structural capacity of pile: 11000.0 kN

# 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:1372/3 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, SO<sub>4</sub> 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

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

**CHAPTER-2** 

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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.

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## 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:1372/3
Started On:12/08/2008; Ended On:14/08/2008 G.W.T: 3.50m

Starte	d O	n:12/	08/2008; Ended On: 14.	/08/20	80	G.	W.T:	3.50	m						1				
	П					etai		rap	hic	al F	₹ep	res	enta	atio	on	of	SP	>	
1	П							##	1	102	213	(40	51	6(	7(	8+ 9	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								3		Relative Density/Consistency	Type of Sample
			Greyish Loose Silty Fine Sand	1.50	4	4	6	10										Loose	SS
3.50	¥			3.00	UDS	Colle	cted											Loose	SS
			Greyish	4.50	6	9	15	24										M.Dense	ss
			Medium Dense Silty Fine Sand	6,00	7	12	17	29										M.Dense	SS
7,50				7.50	7	12	20	32										Dense	ss
				9,00	9	14	21	35										Dense	ss
			Greyish Dense	10,50	12	16	23	39										Dense	ss
	 		Silty Fine Sand	12.00	16	20	25	45										Dense	ss
				13.50	16	21	27	48										Dense	SS
15,00				15,00	19	24	29	53										V.Dense	SS
			Greyish Very Dense	16.50	20	24	31	55	85									V.Dense	SS
			Silty Fine Sand	18.00	20	27	33	60										V.Dense	SS

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 VMTC Location: At Chainage: 1372/3

Started On: 12/08/2008; Ended On: 14/08/2008 G.W.T: 3.50m

Die	arte	u O	11 , 12/	08/2008; Ended On: 14				N.1:	3.20	[11]			100								
					SP	T - D	etail	S	rapl	nical	Re	pre	sei	ntati	on	of	SP		3	T	
4		П			,				##	10	121	3(	4( 5	5: 6(	7(	819	90		ten		
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/Consistenc	y	Type of Sample
					19.50	21	28	34	62									V.1	Dense		ss
					21.00	20	28	35	63									V.1	Dense		ss
				Greyish Very Dense	22.50	20	30	37	67									V.I	Dense		ss
				Silty Fine Sand	24.00	22	31	40	71									V.I	Dense		SS
					26,00	24	33	43	76									V.I	Dense		SS
					27.50	27	35	46	81	***								V.I	Dense		ss
30	.00				29.50	27	37	48	85									V.I	Dense		ss

Bore Hole Terminated at a depth of 30.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1372/3 Location

 $\Omega$ 

				1	_		_	_	_	
			IS-Classification	SM		SM		SM		SM
			Consolidation Tests, Cc	1		'		r		.1.
	(rd	Си (К	Unconfined Compression Tests,			-		1		-
tion	X	Sar	ф (Deg.)			ı		,		
Location	Box	Shear	c (F/N/m <sub>5</sub> )	Ħ,		,	İ	,		1
2/3 L	xial	st	ф (Deg.)	29.5		,		3		1
137.	Triaxia	Test	c (F/N/m <sub>5</sub> )	1,0	-	,		,		1
No.			Clay (%)	-		0		0		0
age		SIS	(%) ilis	2		19	Г	23		29
ain	7	Sieve Analysis	(%) əni <sup>7</sup>	8		18	İ	77		71
S		Ne A	(%) muibəM	0		0		0		0
rom	5	ole	Coarse (%)	0	Γ	0		0		0
ed f			Gravel (%)	0		0		0		0
Samples Collected from Chainage No. 1372/3		la la	Relative Density/ Consistency	Loose		M.Dense		Dense		V.Dense
les			Swelling Pressure (kPa)	1		1		1		1
amr			Free Swell (%)			1		1		an l
			Bulk Density, kN/m3	15		17		19		20
e Soil			Void Ratio, e			'		1		1
Results on the			Specific Gravity, G	2.68		2.67		2.66		2.65
lts o			Consistency, I <sub>C</sub>	1		1		ı		ı
esu	100	à L	Id	$\vdash$		'		1		1
11			(%) Jd		Ц	•		1	_	1
Test			LL (%)		Н	-	Ц	-	4	1
			NMC(%)	14	Н	=	Н	8	4	9
Table 2.1: Laboratory			Visual & Engineering Classification of Soil	Silty Sand		Silty Sand		Silty Sand		Silty Sand
Table 2			Type of Sample	SS		SS		SS		SS
			oldmas to TAS	10		26		40	Ī	63
		Lonuq	O SanitsixX wolod oldme& Yo. J.A Devel(m)	E.G.L-3.50		3.50-7.50		7.50-15.00		15.00-30.00

20000000	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage No. 1372/3											
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)								
BH-01	4.50	7.85	64.21	75.35								

# 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-1372/3 Location

(As presented in the site plan)

\* Layer-1 (from E.G.L to 3.50m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.50m
SPT of the layer	10
Relative Density	Loose
Angle of Shearing Resistance, φ	30.00 Deg.

#### \* Layer-2 (from 3.50m to 7.50m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.00m
SPT of the layer	26
Relative Density	Medium Dense

Angle of Shearing Resistance,  $\phi$  34.80 Deg.

## \* Layer-3 (from 7.50m to 15.00m depth below)

Type of Strata	Silty Fine Sand	
Colour	Greyish	
Thickness of Layer	7.50m	
SPT of the layer	40	
Relative Density	Dense	
Angle of Shearing Resistance, φ	38.75 Deg.	

# \* Layer-4 (from 15.00m to 30.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	15.00m
SPT of the layer	63
Relative Density	Very Dense
Angle of Shearing Resistance, φ	42.50 Deg.

The ground water table was encountered at a depth of 3.50m 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 are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

However, the sub-soil strata encountered at a depth of 15.00m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

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

# 4.2 Foundation System

#### 4.2.1 Deep 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 below a depth of 15.00m below the existing ground level.

Hence, the foundation system can be 21.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 21.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

S.No.	Diameter of	Safe Load	Safe Pull Out	Safe Lateral
	Pile	Carrying	carrying	Load
	(mm)	Capacity	Capacity	carrying
	,	(kN)	(kN)	Capacity
				(kN)
1	1000	11000	3040	600

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 are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. The sub-soil strata encountered at a depth of 15.00m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
- 3. The bearing strata of the proposed foundation system can be the sub soil strata encountered below a depth of 15.00m below the existing ground level. Hence, the foundation system can be 21.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
- 4. The safe load carrying capacity of 21.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 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 PILE FOUNDATION(Refer:BH-01) Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile
1.1 Geometrical Data

Assumed Diameter of pile(D):
Assumed R.L of E.G.L:
Length of pile below E.G.L.(l):
R.L. of Bot. of Pile

-21.00 m

Layer-I Type of Strata: Silty Sand
ensity of the strata,N: 10 therefore Resistance, $\phi$ : 30 the period of top of Strata: 0.00 to of bottom of Strata: 3.50 the top of Strata, $\sigma$ bettom of Strata: 3.50 the top of strata, $\sigma$ bottom: 17.50 the top of strata, $\sigma$ bottom: 17.50 the of the strata, $\sigma$ bottom: 17.50 to of Earth Pressure,k: 1.00 sistance of the pile, $\sigma$ by the strata, $\sigma$ bottom: $\sigma$ kN/m <sup>2</sup> $\sigma$ kN/m <sup>2</sup> $\sigma$ kN/m <sup>2</sup> $\sigma$ kN/m <sup>2</sup> $\sigma$ kN/m <sup>2</sup> $\sigma$ kN/m <sup>2</sup> $\sigma$ kN/m <sup>2</sup> $\sigma$ kN/m <sup>2</sup> $\sigma$ kN/m <sup>2</sup> $\sigma$ kN/m <sup>2</sup>
Layer-II Type of Strata: Silty Sand SPT of the strata,N: 26
tensity of the strata, $\gamma$ : 17 kN/m³ hearing Resistance, $\phi$ : 34.8 Deg. tepth of top of Strata: 3.50 m m to of bottom of Strata: 7.50 m m thickness of Strata, $I_c$ : 4.00 m the top of strata, $\sigma_{top}$ : 17.50 kN/m² ttom of strata, $\sigma_{bottom}$ : 45.50 kN/m² of the strata, $\sigma_{middle}$ : 31.50 kN/m² Of Earth Pressure,k: 1.50

8713-71-

Skin Resistance of the pile,q<sub>s</sub>: 412.67 kN  $(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$ 

1.2.1.3	Layer-III		
	Type of Strata:		nd
	Average SPT of the strata,N:		3
	Bulk Density of the strata, y:		kN/m <sup>3</sup>
	Angle of Shearing Resistance, φ: Depth of top of Strata:		Deg. m
	Depth of bottom of Strata:		m
	Average Thickness of Strata, I <sub>c</sub> :		m
	Effective overburden pressure over the top of strata, $\sigma_{top}$ :		kN/m <sup>2</sup>
	Effective overburden pressure over the bottom of strata, $\sigma_{bottom}$ :		kN/m <sup>2</sup>
	Effective overburden pressure at the middle of the strata, $\sigma_{middle}$ :		kN/m <sup>2</sup>
	Coeff. Of Earth Pressure,k:		
	Skin Resistance of the pile, qs:		kN
	$(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$		
1.2.1.4	Layer-IV		
	Type of Strata:	1152	nd
	Average SPT of the strata,N:		127/ 3
	Bulk Density of the strata,γ: Angle of Shearing Resistance,φ:		kN/m <sup>3</sup>
	Angle of Stearing Resistance,ψ: Depth of top of Strata:		Deg. m
	Depth of bottom of Strata:		m
	Average Thickness of Strata, I <sub>c</sub> :		m
	Effective overburden pressure over the top of strata, $\sigma_{top}$ :		$kN/m^2$
	Effective overburden pressure over the bottom of strata, $\sigma_{bottom}$ :		kN/m <sup>2</sup>
	Effective overburden pressure at the middle of the strata, $\sigma_{\text{middle}}$ :		kN/m <sup>2</sup>
	Coeff. Of Earth Pressure.k:		Ki Willi
	Skin Resistance of the pile, q <sub>s</sub> :		kN
	$(q_c:\sigma^*k^*tan\phi^*pi()^*d^*lc)$	1757.7	ILI (
	(15-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-		
	Ultimate Skin Resistance,qs:	7600.6	kN
1.2.2	Computation of End Bearing Resistance:		
	Type of Bearing Strata	Silty San	d
	Cross-Sectional Area of pile, Ap:		$m^2$
	R.L of bottom of pile:	- 1	
	Minimum SPT-value of the Bearing Strata		
	Angle of Shearing Resistance(ASR)		Degrees
	Bearing Capacity Factor(Nq)		1.0
	Effective Over Burden Pressure at the bottom of pile (q) (limited to a maximum value produced by a soil layer of	120.00	kPa
	thickness equal to 20 times the diameter of pile from the		
	N.G.L.)		
	Ultimate End Bearing Resistance (Qp)	20734.5	kN
	(Qp=Ap*q*Nq)		
1.3.0	Ultimate Load Carrying Capacity (Qu=Qp+q <sub>p</sub> )	28335 1	ĿN
11010	Safe Load Carrying Capacity (Qu=Qp+ $q_p$ )		
	However, limit Q <sub>safe</sub> to the structural capacity of pile:		

## 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:1373/1 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, SO<sub>4</sub> 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
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- \* 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

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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: 1373/1

				ainage: 1373/1								
Sta	arte	d O	n: 11/0	08/2008; Ended On: 12	/08/200	98			8.00			
				,	SP	T - D	etai	S		hical Representation of SP	5	
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 2:3(4(5:6(7(8:90	Relative Density/Consistency	Type of Sample
Ď	La	G.	So	in the second se	Dep (m)	0-1	15.	30.	ż		Re	Ty
				Greyish Dense	1,50	10	17	21	38	1	Dense	SS
				Silty Fine Sand	3.00	LIDS	Samp	ler Ins	l talled	/	Dense	UDS
4.	50			3.11, 2.11, 3.11, 1	4.50	6	7	9	16		M.Dense	SS
				Greyish Medium Dense	6.00	7	8	10	18		M.Dense	SS
G.V	V.T	<b>*</b>		Silty Fine Sand	7.50	10	13	15	28	\	M.Dense	SS
9.	00			,	9,00	13	15	18	33		Dense	SS
				Greyish Dense	10.50	16	21	22	43		Dense	SS
12	.00			Silty Fine Sand	12,00	17	22	25	47	J	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1373/1 Location

	9.00-12.00	4.50-9.00	E.G.L-4.50	R.L of Sample below Existing Grou	ınd						
	2.00	.00	4.50	level(iii)							
	38	21	38	SPT of Sample							
	SS	SS	SS	Type of Sample	1.5						
	Silty Sand	Silty Sand	Silty Sand	Visual & Engineering Classification of Soil							
	7	9	7	NMC(%)			70				
	1	ı	i	LL (%)			Te				
	,	,		PL (%)	2		st I				
		,		PI	Clay		Res				
	1	<u> </u>	,	Consistency, I <sub>C</sub>							
	2.65	2.66	2.65	Specific Gravity, G							
	•	1	-	Void Ratio, e							
	19	17	19	Bulk Density, kN/m <sup>3</sup>							
	ı	1	ı	Free Swell (%)							
	,			Swelling Pressure (kPa)							
	Dense	M.Dense	Dense	Relative Density/ Consistency							
	0	0	0	Gravel (%)			Laboratory Test Results on the Soil Samples Collected from				
	0	0	0	Coarse (%)	Si		dfr				
	0	0	0	Medium (%)	eve /		0m				
	76	84	77	Fine (%)	Sieve Analysis						
	24	16	23	Silt (%)	ysis		ina				
	0	0	0	Clay (%)			hainage:				
П	,		17.3	c (kN/m²)	Ţ	Tni	1373/1				
П	,		37.6	φ (Deg.)	Test	Triaxial					
	1		1								
П	1		1	c (kN/m²)  Shear  b (Deg.)							
П	-	i	1	Unconfined Compression Tests, Cu	(kP	a)					
	1	1		Consolidation Tests, Cc							
	SM	SM	SM	IS-Classification							

	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1373/1									
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)						
BH-01	9.00	7.89	40.57	64,21						

 $\Omega$ 

# **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-1373/1 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	38
Relative Density	Dense
Angle of Shearing Resistance, φ	38.20 Deg.

#### \* Layer-2 (from 4.50m to 9.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	21
Relative Density	Medium Dense
Angle of Shearing Resistance, φ	33.30 Deg.

#### \* Layer-3 (from 9.00m to 12.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
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 8.00m 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	35	35

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.
- 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

Effective Depth of Foundation below E.G.L: 1.00 Minimum Width of Foundation (B): 1.00 m

#### 1 Soil Data :

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 38

Type of Shear Failure: General

Angle of Shearing Resistance, 6: 38.20 Deg.

#### 1 Design Parameters:

Bulk Density of Soil above the foundation detph (Ybulk) 19 00 kN/m3

Effective Overburden pressure at foundation level (q) 9.00

Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors:

 $N_c = N/A$ 

 $N_q = {}_{53.08}$ 

 $N_y = 87.31$ 

#### Shape Factors:

 $S_c = N/A$ 

 $S_q = 1.30$ 

 $S_{\gamma} = 1.00$ 

#### Depth Factors :

 $D_c = N/A$ 

 $D_q = 1.00$ 

 $D_{y} = 1.00$ 

#### Inclination Factor:

 $J_c = N/A$ 

 $I_q = 1.00$ 

 $I_{\gamma} = 1.00$ 

 $\begin{array}{l} \mbox{1 Ultimate Bearing Capacity (Qu):} \\ \mbox{Qu} = \mbox{Cu*Nc*Sc*Dc*I}_{c} + q^*(Nq-1)^* \mbox{Sq*Dq*I}_{q} + 0.5^* \mbox{B*}\gamma^* \mbox{N}\gamma^* \mbox{S}\gamma^* \mbox{D}\gamma^* \mbox{I}_{g} * \mbox{w}' \end{array}$ 

 $Q_u = {1035.73 \text{ kPa}}$ 

#### 2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Osafe: 414.29 kPa

Limited to an allowable bearing pressure per running meter width: 350.00 kPa

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 350kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 350kPa and SPT of 38 are computed to be in the order of 35mm which is within the permissible limits of 50mm for individual column footings as per I.S: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: 1374/1 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, SO<sub>4</sub> 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 Km 156 on Fastern Freight Corridor in line with Tender No. HO/FN/Pre (Works/MTC)

Location: At Chainage: 1374/1

Started On: 11/08/2008; Ended On: 12/08/2008 G.W.T: 7.50m

21	arte	a O	n:11/0	08/2008; Ended On: 12.	08/200	)8	G.V	N.T:	7.50	m							
					SP	T - D	etail	s	rapl	nical	Repr	esei	ıtati	on (	ofSP	>	
						90/9/53 -1		2007/200	##	10	2130	4(	516(	7(8	190	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
				Greyish	1,50	5	6	9	15	9						Loose	ss
				Loose Silty Fine Sand	3.00	UDS	Samp	ler Ins	talled							Loose	UDS
4	.50				4,50	6	8	11	19	d						M.Dense	ss
				Greyish Medium Dense	6.00	8	10	14	24		1					M.Dense	ss
7.	.50	¥		Silty Fine Sand	7,50	11	14	17	31		1					Dense	SS
				Greyish	9.00	13	18	20	38		1	1				Dense	ss
				Dense Silty Fine Sand	10,50	17	20	27	47							Dense	SS
12	.00	<u> </u>			12.00	20	23	30	53							Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1374/1 Location

				_					
			IS-Classification		SM	SM		SM	
			Consolidation Tests, Cc			ı	Ì		
	(sq	d) nO	Unconfined Compression Tests,		1	1		3	
l l	X	al	ф (Deg.)			1	T	,	
catic	Вох		c (KN/m <sub>5</sub> )		1	1	Ī	1	
1 Lo	xial		ф (Deg.)		30.0	1		ì	
374/	Triaxia		c (F/N/m <sub>5</sub> )		13.4	1		,	
ře: 1			(%) (%)	Г	0	0	T	0	
inag			(%) tliS	Γ	16	21	T	26	
Cha	you		(%)		8	79	T	74	
ĭ	Siove A nalveis		(%) muibəM		0	0	Ī	0	
l fro	S		Coarse (%)		0	0		0	
ctec			Gravel (%)		0	0	Ī	0	
est Results on the Soil Samples Collected from Chainage: 1374/1 Location			Relative Density/ Consistency		Loose	M.Dense		Dense	
lan			Swelling Pressure (kPa)			1	İ	1	
San			Free Swell (%)		1	1		1	
Soil			Bulk Density, kN/m <sup>3</sup>		15	17		19	
the S			Void Ratio, e			,		1	
on			Specific Gravity, G		2.68	2.66		2.65	
ults			Consistency, I <sub>C</sub>		t			•	
Res	28		Id					1	
est			(%)		'	1		1	
			LL (%)		'	1		1	
tor			/WC(%)		15	Į E		6	
Table 2.1: Laboratory			Visual & Engineering Classification of Soil		Silty Sand	Silty Sand		Silty Sand	
Table			aldms2 to aqyT		SS	SS		SS	
			oldms2 to TAS		15	21		39	
	p	nnor	R.L of Sample below Existing G level(m)		E.G.L-4.50	4.50-7.50		7.50-12.00	

	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1374/1									
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)						
BH-01	7,50	7.88	42,46	63,57						

1010 =

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-1374/1 Location

(As presented in the site plan)

*	Layer-1 (from	E.G.L t	o 4.50m	depth	below)
	Type of Strata			-	

 $\begin{array}{lll} \text{Colour} & \text{Greyish} \\ \text{Thickness of Layer} & 4.50\text{m} \\ \text{SPT of the layer} & 15 \\ \text{Relative Density} & \text{Loose} \\ \text{Angle of Shearing Resistance, } \phi & 30.60 \text{ Deg.} \\ \end{array}$ 

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

Type of Strata
Colour
Greyish
Thickness of Layer
SPT of the layer
Relative Density
Silty Fine Sand
Greyish
3.00m
21
Redium Dense

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.30 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

39

Dense

38.475 Deg.

The ground water table was encountered at a depth of 7.50m 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	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.

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 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

#### 1 Soil Data :

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 15

Type of Shear Failure: General

Angle of Shearing Resistance, 6: 31,50 Deg.

#### 1 Design Parameters:

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

Effective Overburden pressure at foundation level (q) 10.00

Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors:

 $N_c = N/A$ 

 $N_q = 22.87$ 

kPa

 $N_{\gamma} = 30.09$ 

#### Shape Factors:

 $S_c = N/A$ 

 $s_{\mathfrak{q}} = _{1.30}$ 

 $s_{y} = 1.00$ 

#### Depth Factors :

 $D_c = N/A$ 

 $D_q = 1.00$ 

 $D_{\gamma} = 1.00$ 

#### Inclination Factor

 $I_c = N/A$ 

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

 $I_y = 1.00$ 

### 1 Ultimate Bearing Capacity (Qu):

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

 $Q_u = 410.14 \text{ kPa}$ 

#### 2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.):

Qsafe: 164.06 kPa

Limited to an allowable bearing pressure per running meter width:

#### 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 15 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: 1375 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, SO<sub>4</sub> 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 Chairnes: 1375/1

Location: At Chainage: 1375/1													
Started On: 10/08/2008; Ended On: 11/08/2008 G.W.T: 7.50m													
			Soil Profile		SP	SPT - Details   raphical Rep				nical Representation o	resentation of SP		
	Layer(m)									10 21 31 41 51 61 71 81	oua		
Denth of Ton of		G.W.T. (m)		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
l													
				Greyish Medium Dense Silty Fine Sand	1.50	6	10	11	21	٩		M.Dense	ss
					3.00	UDS	Samp	ler Ins	talled			M.Dense	UDS
					4.50	7	10	16	26			M.Dense	SS
					6,00	9	12	18	30			M.Dense	ss
7.50	.50	<b>♦</b>			7.50	10	13	21	34	<b>\</b>		Dense	SS
				9.00	13	18	23	41			Dense	ss	
				Greyish Dense Silty Fine Sand	10.50	17	24	26	50			Dense	SS
				33.7				~0	50			2.5	33

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1375/1 Location

0

- G115

7.50-12.00	E.G.L-7.50	R.L of Sample below Existing Ground level(m)						
42	26	SPT of Sample						
SS	SS	Type of Sample	620	Table				
Silty Sand	Silty Sand	Visual & Engineering Classification of Soil		able 2.1: Laboratory Test Results on the Soil Samples Collected from (				
7	9	NMC(%)						
	1	LL (%)		T				
	ï	PL (%)	)	est				
	1	PI (N)		Res				
1	,	Consistency, I <sub>C</sub>		ult				
2.65	2.66	Specific Gravity, G		on				
1	-	Void Ratio, e						
19	17	Bulk Density, kN/m <sup>3</sup>						
		Free Swell (%)						
	1	Swelling Pressure (kPa)						
Dense	M.Dense	Relative Density/ Consistency						
0	○ Gravel (%)							
0	Coarse (%)		)	d fr				
0	O O Medium (%)			om				
75								
25	20							
0	0							
	15.8	c (kN/m²)	Tria	375/				
ı	34.3	φ (Deg.)	[riaxial	1 Lo				
ï	1	c (kN/m²)	Box	ocation				
ı		φ (Deg.)	ХС	ň				
1		Unconfined Compression Tests, Cu (kPa)						
1	E.	Consolidation Tests, Cc  IS-Classification						
SM	SM							