# 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/FN/Pre. (Works)/MTC Location: At Chainage: 1390/1

	rte	d O	n:25/0	07/2008; Ended On: 26					8,00			
					SP	T - D	etail	S	rapl	nical Representation of SP	8	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value #	10 21 3( 4( 5) 6( 7( 8) 90	Relative Density/Consistency	Type of Sample
					1.50	6	8	8	16	٩	M.Dense	ss
				Greyish	3.00	UDS	Samp	ler Ins	talled		M.Dense	UDS
				Medium Dense Silty Fine Sand	4.50	9	11	13	24	,	M.Dense	SS
					6.00	11	14	16	30	1	M.Dense	ss
7. G.V	50 V.T	<b>*</b>			7.50	24	19	25	44	٩	Dense	SS
				Greyish Dense Silty Fine Sand	9.00	15	20	27	47		Dense	SS
10.	50			Greyish	10,50	18	25	30	55		V.Dense	ss
12.	.00			Very Dense Silty Fine Sand	12,00	21	37	35	72	\	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1390/1 Location

	17						
		IS-Classification		SM		SM	
		Consolidation Tests, Cc		1		1	
	kPa)	Unconfined Compression Tests, Cu (		ı		,	
Ę	Box	(Deg.)		-		1	
Location	B	( <sup>2</sup> m/N <sup>3</sup> )				ā	
	Triaxial Test	(Deg.)		32.6		,	
390/	Trig	c (kN/m²)		15.1		,	
e: 1		Clay (%)		0		0	
ina	sis/	Silt (%)		17		23	
Cha	naly	(%) ani <sup>7</sup>		83		77	
m(	Sieve Analysis	(%) muibəM		0	Г	0	
fr	Sie	Coarse (%)		0	Г	0	
ectec		Gravel (%)		0		0	
Results on the Soil Samples Collected from Chainage:1390/1		Relative Density/ Consistency		M.Dense		Dense	
ldu		Swelling Pressure (kPa)		1		1	
Sar		Free Swell (%)		1		1	
Soil		Bulk Density, kN/m3		17		19	
the S		Void Ratio, e		'		1	
on		Specific Gravity, G		2.67		2.66	
ults		Consistency, I <sub>C</sub>		î		1	
Res	Clay	Id		ı		1	
	0	Mr (%)		1		-	
Y		(%) TT		1		'	_
atol		NMC(%)	_	10		∞	
Table 2.1: Laboratory Tes		Visual & Engineering Classification of Soil		Silty Sand		Silty Sand	
Table		Jype of Sample		SS		SS	
		oldms2 to TA2		21		34	
	pu	R.L of Sample below Existing Grou level(m)		E.G.L-10.50		10.50-12.00	

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1390/1							
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)			
BH-01	9.00	7,82	88.61	90,43			

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# SUB-SURFACE STRATIFICATION

#### 3.0 Preamble

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

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

## 3.1 Sub Surface Stratification:

# 3.1.1 Soil Profile at BH-1390/1 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 23
Relative Density Medium Dense

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

\* Layer-2 (from 7.50m to 10.50m 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
3.00m
45
Dense
39.875 Deg.

\* Layer-3 (from 10.50m 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
1.50m
55
Very Dense
41.75 Deg.

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

CHAPTER-5

# RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
  top sub-surface strata are coarse-grained type in the form of silty sand and can
  be considered as bearing strata for the proposed impending loads from the
  superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m 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.
- 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 18:6403

#### 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: 16

Type of Shear Failure: General

Angle of Shearing Resistance, 6: 31.80 Deg

#### 1 Design Parameters:

Bulk Density of Soil above the foundation detph (Ybuk) 16.00

Effective Overburden pressure at foundation level (q) 9.00

Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors:

 $N_c = N/A$ 

 $N_q = 23.76$ 

 $N_y = 31.63$ 

# Shape Factors:

 $S_c = N/A$ 

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

 $S_{\gamma} = 1.00$ 

#### Depth Factors

 $D_c = N/A$ 

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

 $D_{y} = 1.00$ 

#### Inclination Factor:

 $I_c = N/A$ 

 $I_q = 1.00$ 

 $I_{y} = 1.00$ 

#### 1 Ultimate Bearing Capacity (Qu):

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

 $Q_u = \phantom{-}404.55 \phantom{0} kPa$ 

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

Factor of Safety (F.S.):

2.50 Qsafe: 161.82 kPa

Limited to an allowable bearing pressure per running meter width:

160.00 kPa

# 2 Settlements

0318

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 160kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 160kPa and SPT of 16 are computed to be in the order of 48 mm which is within the permissible limits of 50 mm 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: 1391/1 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

# 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: 1391/1 Started On: 23/07/2008. Ended On: 24/07/2008. G.W.T: 8.30m.

Sta	Started On: 23/07/2008; Ended On: 24/07/2008 G.W.T: 8,30m															
					S	2T - I					Repres	entat	ion	ofSF	>	T
									##	10	2(3(4	(5)6	7(8	31 90	l G	1 1
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT	0-15 cm	15-30 cm	30-45 cm	N-Value						Relative Density/Consistency	Type of Sample
					1.50	8	9	11	20	(	Ì				M Dense	ss
				Greyish Medium Dense Silty Fine Sand	3.00	UDS	Samp	ler Ins	stalled						M.Dense	UDS
					4.50	9.	12	14	26		1				M.Dense	ss
6,0	00	H			6.00	11	15	18	33		4				Dense	ss
G.W	v. <b>T</b>	<u>¥</u> .		Greyish Dense Silty Fine Sand	7.50	13	17	21	38		}				Dense	SS
6				Sitty Pine Sand	9.00	16	20	23	43		1	\			Dense	ss
10.	50			Greyish	10.50	19	24	29	53			1			V Dense	ss
12.	00	-		Very Dense Silty Fine Sand	12.00	21	27	30	57						V.Dense	ss

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1391/1 Location

Consistency							
SS	10.50-12.00	6.00-10.50			ınd		
13   14   15   17   17   17   17   17   17   18   18	53	38	23	SPT of Sample			
13   14   15   17   17   17   17   17   17   18   18	SS	SS	SS	Type of Sample			Table
13   14   15   17   17   17   17   17   17   18   18	Silty Sand	Silty Sand	Silty Sand	Visual & Engineering Classification of Soil			2.1: Laborat
13   14   15   17   17   17   17   17   17   18   18	∞	9	10	NMC(%)			0
13   14   15   17   17   17   17   17   17   18   18	1	1	1	LL (%)			I
13   14   15   17   17   17   17   17   17   18   18	j j	1		PL (%)	0		t 18
13   14   15   16   16   17   17   17   17   17   18   18   18	1	1	1	PI	lay		Res
13   14   15   16   16   17   17   17   17   17   18   18   18	1	1	1	Consistency, I <sub>C</sub>	İ		ult
13   14   15   16   16   17   17   17   17   17   18   18   18	2.65	2.66	2.67	Specific Gravity, G	!!		on 1
13   14   15   16   16   17   17   17   17   17   18   18   18		1	,	Void Ratio, e			he S
13   14   15   16   16   17   17   17   17   17   18   18   18	20	19	17	Bulk Density, kN/m <sup>3</sup>			<u>E</u> .
13   14   15   17   17   17   17   17   17   18   18	,	1	1	Free Swell (%)			Sai
13   14   15   17   17   17   17   17   17   18   18	1	1	ı	Swelling Pressure (kPa)			
13   14   15   16   16   17   17   17   17   17   18   18   18	V.Dense	Dense	M.Dense	Relative Density/ Consistency			es Colle
13   14   15   17   17   17   17   17   17   18   18	0	0	0	Gravel (%)			cte
13   14   15   16   16   17   17   17   17   17   18   18   18	0	0	0	Coarse (%)	S		d fr
13   14   15   16   16   17   17   17   17   17   18   18   18	0	0	0	Medium (%)	eve ,		0m
0   0   0   Clay (%)   Triaxial   Triaxial   Triaxial	73	83	83	Fine (%)	nal		
Consolidation Tests, Cc   Consolidation T	27	17	17	Silt (%)	ysis		uina
Consolidation Tests, Cc   Consolidation T	0	0	0	Clay (%)			ge:
Consolidation Tests, Cc   Consolidation T		1	16.6	c (kN/m²)	T	Tri	391
ψ (Deg.)  Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	,	1	33.1	φ (Deg.)	est	axial	
ψ (Deg.)  Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	,	,		c (kN/m²)		Вс	catio
Consolidation Tests, Cc	1	1	ı	φ (Deg.)	ar	X	Ď
	ı	1	,	Unconfined Compression Tests, Cu	(kP	a)	
$\left \begin{array}{c c} S \\ X \\ X \end{array}\right  \left \begin{array}{c c} S \\ X \\ X \end{array}\right $ IS-Classification	1	,	1	Consolidation Tests, Cc			
	SM	MS	SM	IS-Classification			

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1391/1							
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)			
BH-01	BH-01 9.00 7.84 56.95 78.54						

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	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	$(t/m^2)$	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.00	16	32
	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 1.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

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

## DESIGN OF OPEN FOUNDATION SYSTEM

#### 1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

#### 1 Geometrical Data:

Type of Footing: Isolated Column

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

Observed Maximum thickness of Filled up Soil; 0,00

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

Minimum Width of Foundation (B): 1.00

#### 1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 20

Type of Shear Failure: General

Angle of Shearing Resistance, 6: 33.00 Deg.

#### 1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ<sub>buk</sub>) 17,00 k N/m3

Effective Overburden pressure at foundation level (q) 7.00 kPa

Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors:

 $N_c = N/A$ 

 $N_q = \frac{1}{27.34}$ 

 $N_{\gamma} = 37.78$ 

#### Shape Factors:

 $S_c = N/A$ 

 $s_{\mathfrak{q}}=_{1,30}$ 

 $S_y = 1.00$ 

# Depth Factors .

 $D_c = N/A$ 

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

 $D_{y} = 1.00$ 

# Inclination Factor.

 $I_c = N/A$ 

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

 $I_{\gamma} = 1.00$ 

# 1 Ultimate Bearing Capacity (Qu):

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

 $Q_u = 409.35 \text{ kPa}$ 

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

Factor of Safety (F S ): 2.50

163.74 kPa

Qsafe: 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 20 are computed to be in the order of 32mm which is within the permissible limits of 50mm for individual column footings as per LS:1904.

# 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-1391/1 Location (As presented in the site plan)

\* Layer-1 (from E.G.L to 6.00m 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

6.00m

23

Medium Dense

33.90 Deg.

\* Layer-2 (from 6.00m to 10.50m 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
38
Dense
38.20 Deg.

Layer-3 (from 10.50m 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
1.50m
53
Very Dense
41.45 Deg.

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

# **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.,

This report includes field and Laboratory test results for the **borehole location at Chainage: 1392/1** 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.

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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.

Table 2.1: Laboratory Test Results on the Soil Sample   Spr of Sample		ТТ		· · · · · · · · · · · · · · · · · · ·	-	-	
SS	10.50-12.00	4.50-10.50	E.G.L-4.50		nd		
Silty Sand	56	42	15	SPT of Sample			
71   77   87   Fine (%)	SS	SS	SS				Table
71   77   87   Fine (%)	Silty Sand	Silty Sand	Silty Sand	Visual & Engineering Classification of Soil			2.1: Laborat
71   77   87   Fine (%)	7	9	13	NMC(%)			
71   77   87   Fine (%)	1	,	1	LL (%)			T
71   77   87   Fine (%)	ı		1	PL (%)	0		est
71   77   87   Fine (%)	ı	<b>T</b> -T	ı	• PI	lay		Res
71   77   87   Fine (%)	1	1.		Consistency, I <sub>C</sub>			ults
71   77   87   Fine (%)	2.65	2.66	2.68	Specific Gravity, G			on
71   77   87   Fine (%)	ĦĦ	ΤŤ	TT	Void Ratio, e			the !
71   77   87   Fine (%)	20	19	15	Bulk Density, kN/m <sup>3</sup>			
71   77   87   Fine (%)		1	1	4 - SANG-L-A-8 - A-88 -			Sai
71   77   87   Fine (%)	1	1.	1	Swelling Pressure (kPa)			npl
71   77   87   Fine (%)	V.Dense	Dense	Loose	Relative Density/ Consistency			es Colle
71   77   87   Fine (%)		0	0	Gravel (%)			ecte
71   77   87   Fine (%)	0	0	0	Coarse (%)	Sie		1 fr
71   77   87   Fine (%)	0	0	0	Medium (%)	ve A		m
Clay (%)   Fe: 1392/1   Consolidation Tests, Cc   Clay (%)   Fe: 1392/1   Consolidation Tests, Cc   Consoli	71	77	87	Fine (%)	naly		Cha
1392/1 Location   Triaxial   1392/1 Location   Triaxial   100cation   100cat	29	23	13	Silt (%)	'sis		inas
1   1   1   1   1   1   1   1   1   1	0	0	0	Clay (%)	L		σe:1
c (kN/m²)  c (kN/m²)  phear and a second contraction Tests, Cu (kPa)  c (kN/m²)  phear and a second contraction Tests, Cu (kPa)  c (kN/m²)  phear and a second contraction Tests, Cu (kPa)  c (kN/m²)  phear and a second contraction Tests, Cu (kPa)	I	1	12.1	c (kN/m²)	7	Tri	392/
ψ (Deg.)  Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	1		30.7	φ (Deg.)	est	axial	11Lc
Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	1	1		c (kN/m <sup>2</sup> )	Sh	В	cati
Consolidation Tests, Cc	1		1:	φ (Deg.)			
	ı			Unconfined Compression Tests, Cu	(kP	a)	
S S S IS-Classification	,	1	l i	Consolidation Tests, Cc			
	MS	SM	SM	IS-Classification			

0 0 0

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1392/1							
Location of Bore Hole	Depth of Sample below E.G.L. (m)	рН	Chlorides(ppm)	Sulphates (ppm)			
BH-01	9.00	7.84	86.43	76.32			

# 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-1392/1 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	15
Relative Density	Loose
Angle of Shearing Resistance, φ	31.50 Deg.

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

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	6.00m
SPT of the layer	42
Relative Density	Dense
Angle of Shearing Resistance, φ	39.20 Deg.

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

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	56
Relative Density	Very Dense
Angle of Shearing Resistance, φ	41.90 Deg.

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

# FOUNDATION SYSTEM

#### 4.0 Preamble

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

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

#### 4.1 Bearing Strata Characteristics:

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

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

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

#### 4.2 Foundation System

#### 4.2.1 Open Foundation System

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

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

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



# 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 18:6403

#### 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, \$\phi\$ 31.50 D

#### 1 Design Parameters:

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

Effective Overburden pressure at foundation level (q) 10.00

Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors:

 $N_c = N/A$ 

 $N_q=\phantom{0}_{22.87}$ 

kPa

 $N_{\gamma} = 30.09$ 

#### Shape Factors:

 $S_c = N/A$ 

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

 $S_{\gamma} = 1.00$ 

#### Depth Factors:

 $D_c = N/A$ 

 $D_q = 1.00$ 

 $D_y = 1.00$ 

#### Inclination Factor

 $I_c = N/A$ 

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

 $I_{\gamma} = 1.00$ 

#### 1 Ultimate Bearing Capacity (Qu):

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

 $Q_u = \frac{}{410,14} \frac{}{kPa}$ 

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

Factor of Safety (F.S.): 2.50

Qsafe: 164.06 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 15 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per LS:1904.

11:00 ---

## 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: 1393/1 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: 1393/1

Sta				07/2008; Ended On: 24	07/200	8(	G.V	W.T:	8.00	m		
					SP	Γ - D	etail	s	rapl	nical Representation of SP	y	
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 Densíty/Consistency	Type of Sample
De	La	G,	Soi		Dep (m)	0-1	15-	30-	-Z		Rel Der	Tyl
					1.50	8	9	11	20	٩	M.Dense	SS
				Greyish Medium Dense Silty Fine Sand	3.00	UDS	Samp	ler Ins	talled		M.Dense	UDS
					4.50	10	12	13	25		M.Dense	SS
					6.00	9	11	14	25	4	M.Dense	SS
7. G.V	50 V.T	<b>♦</b>			7.50	12	15	18	33	1	Dense	SS
				Greyish Dense	9.00	14	17	21	38	d d	Dense	ss
				Silty Fine Sand	10.50	16	20	26	46		Dense	ss
12	.00				12.00	19	25	28	53	.)	Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1393/1 Location

	_		1	_	_	_	_
		IS-Classification		SM		SM	
		Consolidation Tests, Cc		,		li	
	(БРа)	Unconfined Compression Tests, Cu (	Γ			1	
u u	)X	þ (Deg.)		1		,	
catio	Box	c (F/N/m <sub>2</sub> )	T	1	T		
Loc	tial t	ф (Deg.)	Γ	33.1	T	,	
93/1	Triaxial Test	c (kN/m²)	r	14.5		,	
e:13		Clay (%)	는	0		0	
inag	'sis	(%) liit	T	61		21	
Cha	nak	(%) aniA		81		79	
m <sub>0</sub>	Sieve Analysis	(%) muibəM		0		0	
d fr	Sie	Coarse (%)		0		0	(X - CZ-
cte		Gravel (%)		0		0	
Samples Collected from Chainage: 1393/1 Location	,	Relative Density/ Consistency		M.Dense		Dense	
lple		Swelling Pressure (kPa)		1		1	
San		Free Swell (%)		- 1		ı	
Soil		Bulk Density, kN/m3		17		19	
the		Void Ratio, e		1		ı	
est Results on the Soil		Specific Gravity, G		2.67		2.66	
allts		Consistency, I <sub>C</sub>		I.		ı	
Re	Clay	Id	_	1		1	
est		PL (%)		ı			
		LL (%)				'	
ato		NMC(%)		10		∞	_
Table 2.1: Laboratory		Visual & Engineering Classification of Soil		Silty Sand		Silty Sand	
Table	48	Type of Sample		SS		SS	
		oldms2 to TA2		23		39	
	рı	R.L of Sample below Existing Groun level(m)		E.G.L-7.50		7.50-12.00	

	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1393/1								
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)					
BH-01	9.00	7.81	90.03	94.12					

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# SUB-SURFACE STRATIFICATION

#### 3.0 Preamble

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

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

#### 3.1 Sub Surface Stratification:

# 3.1.1 Soil Profile at BH-1394/1 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	23
Relative Density	Medium Dense
Angle of Shearing Resistance, φ	33.90 Deg.

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

Zajei z (nom neom to izioom depth below	,
Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	39
Relative Density	Dense
Angle of Shearing Resistance, φ	38.475 Deg.

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

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# 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	16	32

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

# RECOMMENDATIONS

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

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

#### DESIGN OF OPEN FOUNDATION SYSTEM

#### 1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

#### 1 Geometrical Data:

Type of Footing: Isolated Column Depth of foundation below the E.G.L: 1.00 Observed Maximum thickness of Filled up Soil: 0.00 m Effective Depth of Foundation below E.G.L: 1.00 Minimum Width of Foundation (B): 1.00

1 Soil Data :

Type of Bearing Strata: Silty Sand Least SPT-value of the Bearing Strata: 20 Type of Shear Failure: General

Angle of Shearing Resistance, 4: 33.00 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ<sub>bulk</sub>) 17 00 kN/m3 Effective Overburden pressure at foundation level (q) 7.00 kPa Water Table Correction Factor (w) 0.50

Bearing Capacity Factors:

 $N_c = N/A$  $N_q = 27.34$  $N_y = 37.78$ 

Shape Factors

 $S_c = N/A$  $s_{\mathfrak{q}} = \frac{1.30}{1.30}$  $S_{\gamma} = 1.00$ 

Depth Factors :

 $D_c = N/A$  $D_q = \frac{1.00}{1.00}$  $D_{y} = 1.00$ 

Inclination Factor.

 $I_c = N/A$  $I_q = 1.00$  $I_{y} = 1.00$ 

$$\begin{split} 1 \ \ & \text{Ultimate Bearing Capacity (Qu):} \\ & Qu = Cu^*Nc^*Sc^*D_c^*I_{c^+q^*}(Nq\text{-}1)^*Sq^*Dq^*Iq + 0.5^*B^*\gamma^*N\gamma^*S\gamma^*D\gamma^*Ig^*w^* \end{split}$$

 $Q_u = \frac{409.35 \text{ kPa}}{409.35 \text{ kPa}}$ 

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): Qsafe: 163,74 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 20 are computed to be in the order of 32mm 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: 1394 (7-9)/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 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

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: 1394 (7-9)/1

Sta	rte	d O	n:20/0	07/2008; Ended On: 21	/07/2	800	G.	W.T:	2.36	5m		
					S	PT-1	Detai	ls	rap	hical Representation of SP	×	
					L				##	10 2 3 (4 (5 ) 6 (7 (8 ) 90	enc	1 1
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
					1.50	6	7	9	16	٩	M.Dense	SS
G.W	/.T			Greyish to Brownish Medium Dense Silty Clayey Fine Sand	3.00	UD	Samp	oler In:	stalled		M.Dense	UDS
					4.50	8	10	19	29		M.Dense	ss
6.0	00	П			6,00	10	14	17	31		Dense	ss
				Greyish	7.50	10	15	18	33		Dense	ss
				Dense Silty Fine Sand	9,00	17	20	19	39		Dense	ss
10,5	50			Greyish	10.50	22	28	I 2 cm	ns Per	netration for 50 Blows	V.Dense	ss
12,0	00			Very Dense Silty Fine Sand	12.00	29	35	11cm	ns. Per	netration for 50 Blows	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1394 (7-9)/1 Location

				_							
10.50-12.00	6.00-10.50		E.G.L-6.00		R.L of Sample below Existing Ground evel(m)						
>100	34		23		SPT of Sample						
SS	SS		SS		Type of Sample			Table 2.1: Laboratory Test Results on the Soil Samples Collected from			
Silty Sand	Silty Sand		Silty Clayey Sand		Visual & Engineering Classification of Soil						
7	10		12		NMC(%)			T			
1	i		ī		LL (%)			est			
1	,		1		PL (%)			Re			
1			1		PI	Clay		sult			
1			1		Consistency, I <sub>C</sub>			S 01			
2.64	2.66		2.67		Specific Gravity, G						
ı	1		1		Void Ratio, e						
20	19		17		Bulk Density, kN/m <sup>3</sup>						
1					Free Swell (%)						
1	ı	İ	ı		Swelling Pressure (kPa)						
V.Dense	Dense		M.Dense		Relative Density/ Consistency						
0	0		0		Gravel (%)			ed fi			
0	0		0		Coarse (%)	Sie		mo.			
0	0		0		Medium (%)	Sieve A		Cha			
73	78		77		Fine (%)	nalysis		aina			
27	22		14		Silt (%)	/Sis		ge:			
0	0		9		Clay (%)			inage:1394			
ι	1		14.6		c (kN/m²)	T	Tri	4 (7-9			
ī	ī		33.4		φ (Deg.)	Test	Triaxial	9)/1			
ı	1		1		c (kN/m²)	Sh	В	Loca			
3	1		1		c (kN/m²)  Box  (Deg.)						
ı	1		,		Unconfined Compression Tests, Cu	(kP	a)				
,			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:1394(7-9)/1									
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)						
BH-01	3,00	7.84	44.22	81.34						

# 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-1394/(7-9)/1 Location

(As presented in the site plan)

\* Layer-1 (from E.G.L to 6.00m depth below)

Type of Strata

Colour

Greyish to Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Silty Clayey Fine Sand

Greyish to Brownish

6.00m

23

Medium Dense

33.90 Deg.

#### \* Layer-2 (from 6.00m to 10.50m depth below)

 $\begin{array}{lll} \mbox{Type of Strata} & \mbox{Silty Fine Sand} \\ \mbox{Colour} & \mbox{Greyish} \\ \mbox{Thickness of Layer} & \mbox{4.50m} \\ \mbox{SPT of the layer} & \mbox{34} \\ \mbox{Relative Density} & \mbox{Dense} \\ \mbox{Angle of Shearing Resistance, } \phi & \mbox{37.10 Deg.} \end{array}$ 

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

Type of Strata Silty Fine Sand Colour Greyish
Thickness of Layer 1.50m
SPT of the layer >100
Relative Density Very Dense
Angle of Shearing Resistance,  $\phi$  42.50 Deg.

The ground water table was encountered at a depth of 2.36m within the explored depth of investigation in the third week of July 2008.

# **FOUNDATION SYSTEM**

#### 4.0 Preamble

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

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

#### 4.1 Bearing Strata Characteristics:

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

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

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

#### 4.2 Foundation System

#### 4.2.1 Open Foundation System

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

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

S.No.	Type of	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	16	45
2	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.

-0404



# 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.
- 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 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

Minimum Width of Foundation (B): 1.00

#### 1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 16

Type of Shear Failure: General

Angle of Shearing Resistance, 6: 31.80 Deg

#### 1 Design Parameters:

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

Effective Overburden pressure at foundation level (q) 9.00 kPa

Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors:

 $N_c = N/A$ 

 $N_q= \begin{array}{c} \\ 23.76 \end{array}$ 

 $N_{y} = 31.63$ 

#### Shape Factors:

 $S_c = N/\Lambda$ 

 $s_{\mathsf{q}} = {}_{1,3\,0}$ 

 $S_{\gamma} = 1.00$ 

#### Depth Factors :

 $D_c = N/A$ 

 $D_q = 1.00$ 

 $D_y = 1.00$ 

#### Inclination Factor

 $J_c = N/A$ 

 $\mathbf{I}_q = \mathbf{1.00}$ 

 $I_{\gamma} = 1.00$ 

$$\label{eq:current} \begin{split} 1 \;\; & \text{Ultimate Bearing Capacity (Qu):} \\ & Qu = Cu^*Nc^*Sc^*D_c^*I_{c^*q}^*(Nq\text{-}1)^*Sq^*Dq^*Iq + 0.5^*B^*\gamma^*N\gamma^*S\gamma^*D\gamma^*Ig^*w \end{split}$$

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

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

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

> Qsafe: 161.82 kPa

Limited to an allowable bearing pressure per running meter width: 160,00 kPa

#### 2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 160kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 160kPa and SPT of 16 are computed to be in the order of 45mm 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: 1395/1 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

# 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: 1395/1

Sta	irte	d O	n:20/0	07/2008; Ended On: 21	07/20	08	G.V	W.T;	5,20	)m		
					SF	Τ-Γ	etail	s	rapl	hical Representation of SP	8	
									##	10 2:3(4(5:6(7(8:90	enc	
Depth of Top of	Layer(m)	G.W.T.(m)	Soil Profile	Engineering Description of Soil	Depth of SPT	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
					1.50	8	11	14	25	٩	M.Dense	ss
				Greyish to Brownish Medium Dense Silty Clayey Fine Sand	3.00	UDS	Samp	ler Ins	talled		M.Dense	UDS
G.V	v.T	¥			4.50	12	13	17	30		M.Dense	SS
6.					6.00	10	16	19	35	<b> </b>	Dense	ss
				Greyish	7.50	13	17	21	38		Dense	ss
				Dense Silty Fine Sand	9.00	15	19	23	42		Dense	ss
10.	50			Greyish	10.50	25	25	32	57		V.Dense	ss
12.	00			Very Dense Silty Fine Sand	12.00	27	38	12cm	s. Per	netration for 50 Blows	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1395/1 Location

_									
			IS-Classification		MS		SM		SM
			Consolidation Tests, Cc		ı				,
	(R	(kP	Unconfined Compression Tests, Cu		1		,		
u	X	ar	ф (Deg.)		,		1	İ	
Location	Box	Shear	c (FN/m <sub>z</sub> )		ı		-		
Lo	xial	st	ф (Deg.)		34.5		1	T	
395/	Triaxia	Test	c (kN/m²)		13.2		,		1
ge:1			(%) (%)		6		0	1	0
ına		Sis	(%) tlis		11		22		26
ha		naly	(%) ani <sup>7</sup>	Г	08	Г	78	1	44
) m(		Sieve Analysis	(%) muibəM		0		0	+	0
fr		Sie	Coarse (%)		0		0		
cted			Gravel (%)		0		0		
Samples Collected from Chainage: 1395/1			Relative Density/ Consistency		M.Dense		Dense	1	V.Dense
di			Swelling Pressure (kPa)		ı		1	T	ī
San			Free Swell (%)		Ĭ		1		1
Soil			Bulk Density, kN/m3		17		19	9	20
the Soil			Void Ratio, e		1		•		
on			Specific Gravity, G		2.67		2.66	Š	2.65
ults			Consistency, I <sub>C</sub>				1		1
Results		Clay	Id		1		ı		1
1 +		٥	Ja (%)		1		'		1
y Tes			(%) TT		1		1		ı
tor			NMC(%)		13		10	9	×
Table 2.1: Laboratory		-2	Visual & Engineering Classification of Soil		Silty Clayey Sand		Silty Sand		Silty Sand
Table			aldmeS to adyT		SS		SS	5	22
			oldms2 to TA2		27		38		/6
		pu	R.L of Sample below Existing Grou level(m)		E.G.L-6.00		6.00-10.50	00 01 02 01	10.50-12.00

II .	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1395/1										
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)							
BH-01	6.00	7.87	31.24	65,43							

# 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-1395/1 Location (As presented in the site plan)

\* Layer-1 (from E.G.L to 6.00m depth below)

Type of Strata

Colour

Colour

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Silty Clayey Fine Sand

Greyish to Brownish

6.00m

27

Medium Dense

35.10 Deg.

\* Layer-2 (from 6.00m to 10.50m depth below)

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

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

Type of Strata Silty Fine Sand Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 57
Relative Density Very Dense
Angle of Shearing Resistance,  $\phi$  42.05 Deg.

The ground water table was encountered at a depth of 5.20m within the explored depth of investigation in the third week of July 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	19	40

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



# RECOMMENDATIONS

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

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

#### DESIGN OF OPEN FOUNDATION SYSTEM

#### 1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

#### 1 Geometrical Data :

Type of Footing: Isolated Column

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

Observed Maximum thickness of Filled up Soil: 0.00 m

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

#### 1 Soil Data :

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 25

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$ 34.50 Deg

#### 1 Design Parameters:

Bulk Density of Soil above the foundation detph (youk) 17 00

kN/m3

Effective Overburden pressure at foundation level (q) 7.00

Water Table Correction Factor (w') 0.50

#### Bearing Capacity Factors:

 $N_c = N/A$ 

 $N_q = 31.81$ 

 $N_{\gamma} = 45.47$ 

#### Shape Factors:

 $S_c = N/A$ 

 $S_q = 1.30$ 

 $S_y = 1.00$ 

# Depth Factors .

 $D_c = N/A$ 

 $D_q = 1.00$ 

 $D_{\gamma} = 1.00$ 

#### Inclination Factor:

 $I_c = N/A$ 

 $I_q = 1.00$ 

 $I_y = 1.00$ 

#### 1 Ultimate Bearing Capacity (Qu):

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

 $Q_u = 482.71 \text{ kPa}$ 

## 2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 193.08 kPa

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

#### 2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 190kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 190kPa and SPT of 25 are computed to be in the order of 40mm 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: 1396/1 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 Tests
   Unconsolidated undrained.
   Consolidated Undrained Test with the Pressure
- (k) Drained Consolidation Test representing e, Cc & Pc

# 1.1.2.2 Rock Samples

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

# 1.2 Structure of the Report

- Contents
- Introduction
- Investigation Methodology & Test Results

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

# INVESTIGATION METHODOLOGY & TEST RESULTS

# 2.0 Field Testing:

#### 2.1 Preamble:

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

### 2.2 In-Situ Strength Tests:

#### 2.2.1 Standard Penetration Test:

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

# 2.3 Collection of Samples:

# 2.3.1 Soil:

# 2.3.1.1 Disturbed Samples

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

# 2.3.1.2 Standard Penetration Tests & Split Spoon Samples

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

## 2.3.1.3 Undisturbed Soil Samples

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

# 2.4 Laboratory Testing: Soil Samples

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

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

#### 2.4.2 Atterberg Limits

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

#### 2.4.3 Specific Gravity

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

### 2.4.4 Chemical Tests on Water Sample

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

# 2.4.5 Swelling Pressure & Free Swell Tests

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

## 2.4.6 Bulk Density & Natural Moisture Content

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

#### 2.4.7 Unconfined Compression Tests

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

#### 2.4.8 Box Shear Tests

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

#### 2.4.9 Triaxial Shear Tests

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

#### 2.4.10 Consolidation Tests

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

#### **Rock Samples**

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



 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ 

Km156 on Fastern Freight Corridor in line with Tender No. HO/FN/Pre. (Works)/MTC

Location: At Chainage: 1396/1
Started On: 18/07/2008: Ended On: 19/07/2008 G.W.T. 2.36t

Sta	irte	d O	n:18/0	07/2008; Ended On: 19/	07/20	80	G.	W.T:	2.36	m									
					SP	T - D	etai	s	rapl	nical	Rep	ore	ser	ıtat	ìo	n o	fSP	_	
		11							##	10	213	3(4	1( 4	51 61	7	(8)	90	50	
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	6	8	7	15	٩								Loose	ss
G.V	v,T			Greyish to Brownish  Loose Silty Clayey Fine Sand	3.00	UDS	Samp	ler Ins	talled									Loose	UDS
4	50		363		4.50	7	10	11	21									M. Dense	SS
				Greyish Medium Dense	6.00	8	8	8	16	₫	\							M.Dense	SS
				Silty Fine Sand	7,50	10	13	12	25		f							M. Dense	SS
9,0	00				9.00	12	15	19	34		١	4						Dense	ss
				Greyish Dense Silty Fine Sand	10.50	18	25	25	50			\	0	\				Dense	ss
12.	00				12,00	22	30	37	67					1	6			V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Chainage:1396/1 Location

R.L. of Sample below Existing Ground level(m)   Table 2.11. Laboratory Test Results on the Soil Sample   Type of Sample   Visual & Visua									
Table 2.1: Laboratory Test Results on the Soil Sample	9.00-12.00	4.50-9.00	E.G.L-4.50						
Collected from   Coll	42	21	15	SPT of Sample					
Collected from   Coll	SS	SS	SS	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Table				
Collected from   Coll	Silty Sand	Silty Sand	Silty Clayey Sand	Visual & Engineering Classification of Soil	2.1: Labora				
Collected from   Coll	8	Ξ	14	NMC(%)					
Collected from   Coll	1	1	1	LL (%)					
Collected from   Coll			1	PI (%)	est				
Collected from   Coll			-	PI	Re				
Collected from   Coll	1		1	Consistency, I <sub>C</sub>	sults				
Collected from   Coll	2.65	2.66	2.65	Specific Gravity, G					
Collected from   Coll				Void Ratio, e	the S				
Collected from   Coll	19	17	15	Bulk Density, kN/m <sup>3</sup>					
Collected from   Coll		ı			Sar				
Collected from   Coll			1	Swelling Pressure (kPa)					
Think   Chainage: 1396/1   Cha	Dense	M.Dense	Loose	Relative Density/ Consistency					
Think   Chainage: 1396/1   Cha	0	0	0	Gravel (%)	ctec				
Think   Chainage: 1396/1   Cha	0	0	0	Coarse (%)	1 fr				
12	0	0	0	Medium (%)	)m				
Clay (%)   Triaxial   Short   Consolidation Tests, Cc   Consolidation Tests, Cc   Clay (%)   Consolidation Tests, Cc	74	79	81	Fine (%)	Cha				
1396/1 Location   Triaxial   Box   Triaxial   Box   Box	26	21	=	Silt (%)	ina				
	0	0	∞	Clay (%)					
	1	í	13.6	c (kN/m²)	396/				
Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc			29.7	φ (Deg.)					
Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	ī	i		c (kN/m²)	catio				
Consolidation Tests, Cc			1	φ (Deg.)	)n				
	i i		,	Unconfined Compression Tests, Cu (kPa					
S S S IS-Classification	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:1396/1											
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)							
BH-01	3.00	7.85	40.19	59.75							

# 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-1396/1 Location

(As presented in the site plan)

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

Type of Strata	Silty Clayey Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	4.50m
SPT of the layer	15
Relative Density	Loose
Angle of Shearing Resistance, φ	31.50 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, o	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	42
Relative Density	Dense
Angle of Shearing Resistance, φ	39.20 Deg.

The ground water table was encountered at a depth of 2.36m within the explored depth of investigation in the third week of July 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.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

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

#### DESIGN OF OPEN FOUNDATION SYSTEM

#### 1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

#### 1 Geometrical Data:

Type of Footing: Isolated Column

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

Observed Maximum thickness of Filled up Soil: 0.00

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

Minimum Width of Foundation (B): 1,00

#### I 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, \$\phi\$ 31.50 Deg.

#### 1 Design Parameters:

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

Effective Overburden pressure at foundation levels(q) 10.00 kPa

Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors.

 $N_c = N/A$ 

 $N_q = 22.87$ 

 $N_{\gamma} = 30.09$ 

#### Shape Factors:

 $s_{\mathfrak{c}} = \sqrt{N/A}$ 

 $S_q = 1.30$ 

 $S_{\gamma} = 1.00$ 

#### Depth Factors:

 $D_c = N/A$ 

 $\mathbf{D}_{\text{q}} = _{1.00}$ 

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

# Inclination Factor.

 $I_c = N/A$ 

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

 $I_{\gamma} = 1.00$ 

#### 1 Ultimate Bearing Capacity (Qu):

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

 $Q_u = \frac{410.14 \text{ kPa}}{410.14 \text{ kPa}}$ 

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

Factor of Safety (F.S.): 2.50

Qsafe: 164.06 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 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.

# **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: 1398/1 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
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- \* Tables & Figures
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- Foundation System
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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

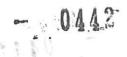
These tests are being conducted on water sample as per I.S: 456-1978 and the test results are presented in table 2.2.

#### 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/FN/Pre. (Works)/MTC Location: At Chainage: 1398/1

Sta	arte	O b	n:18/0	07/2008; Ended On: 19/	07/200	80	G.V	W.T:	2.50	)m		
				(333/1-a)	SP	T - D	etail	S	rapl	hical Representation of SP	>	
		П							##	10 2: 3( 4( 5: 6( 7( 8: 90	3uc	
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	7	5	6	11	٩	Loose	ss
G.V	V.T	<b>↓</b> .		Greyish to Brownish  Loose  Silty Clayey Fine Sand	3.00	UDS	Samp	ler Ins	stalled		Loose	UDS
4.	50				4.50	6	9	10	19	{	M.Dense	ss
7	50	  		Greyish Medium Dense Silty Fine Sand	6.00	10	11	16	27		M. Dense	ss
-	30	Н			7.50	12	17	19	36	1	M. Dense	SS
10	00			Greyish Dense Silty Fine Sand	9.00	10	14	19	33		Dense	SS
				Greyish Very Dense	10.50	18	23	30	53		V.Dense	ss
12	.00			Silty Fine Sand	12,00	29	26	l l cm	s. Pen	netration for 50 Blows	V.Dense	ss

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1398/1 Location

			-					
			IS-Classification		SM	SM	SM	SM
			Consolidation Tests, Cc			-		ı
	(R	(KP	Unconfined Compression Tests, Cu				1	
u	X	ar	ф (Deg.)		1		r	1
atio	Box	Shear	c (kN/m²)		1			
Location	Triaxial	ţ	ф (Deg.)	П	29.4	1		t.
1/86		Test	c (kN/m²)	П	11.7		11	††
e:13		┪	(%) (%)	Н	9	0	0	0
inag		sis	(%) ili8		10	61	22	27
Cha		naly	(%)		84	18	78	73
om (		Sieve Analysis	(%) muibəM		0	0	0	0
d fr		Sic	Coarse (%)		0	0	0	0
ecte			(%) Gravel		0	0	0	0
Samples Collected from Chainage: 1398/1			Relative Density/ Consistency		Loose	M.Dense	Dense	V.Dense
nple			Swelling Pressure (kPa)		1	1		
Sar			Eree Swell (%)		1	r	1	10,
Soil			Bulk Density, kN/m3		15	17	19	20
the Soil			Void Ratio, e		1	1	'	
ou			Specific Gravity, G		2.65	2.66	2.66	2.65
st Results			Consistency, I <sub>C</sub>		1	'	. 1	1
Res		Clay	Id	Ш	-	1	1	
Test	8		ьг (%)	Ц	1	1	1	
TV.			rf (%) nmc(%)	H	4	0	- 6	7
2.1: Laboratory			Visual & Engineering Classification of Soil		Silty Clayey Sand	Silty Sand	Silty Sand	Silty Sand
Table 2.1			Type of Sample		SS	SS	SS	SS
			oldmeS to TAS		11	24	34	53
		pu	R.L of Sample below Existing Grou level(m)		E.G.L-4.50	4.50-7.50	7.50-10.00	10.00-12.00

- 0445

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1398/1										
Location of Bore Hole	Depth of Sample below E.G.L. (m)	hф	Chlorides(ppm)	Sulphates (ppm)						
BH-01	3,00	7.88	33,57	55.32						