## 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:**

Relative Density

Angle of Shearing Resistance, □

#### 3.1.1 Soil Profile at BH-1398/1 Location

	(As presented in the site plan)		
*	Layer-1 (from E.G.L to 4.50m depth belo	w)	
	Type of Strata Colour Thickness of Layer SPT of the layer Relative Density Angle of Shearing Resistance, □	11	Silty Clayey Fine Sand Greyish to Brownish 4.50m Loose 30.30 Deg.
*	Layer-2 (from 4.50m to 7.50m depth below) Type of Strata Colour Thickness of Layer SPT of the layer Relative Density Angle of Shearing Resistance, □	24	Silty Fine Sand Greyish 3.00m Medium Dense 34.20 Deg.
*	Layer-3 (from 7.50m to 10.00m depth below) Type of Strata Colour Thickness of Layer SPT of the layer Relative Density Angle of Shearing Resistance, □	34	Silty Fine Sand Greyish 2.50m Dense 37.10 Deg.
*	Layer-4 (from 10.00m to 12.00m depth below) Type of Strata Colour Thickness of Layer SPT of the layer	53	Silty Fine Sand Greyish 2.00m

The ground water table was encountered at a depth of 2.50m within the explored depth of investigation in the third week of July 2008.

Very Dense

41.45 Deg.

## **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	13	48

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



## RECOMMENDATIONS

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

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

#### DESIGN OF OPEN FOUNDATION SYSTEM

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

#### 1 Geometrical Data :

Type of Footing: Isolated Column

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

Observed Maximum thickness of Filled up Soil: 0.00 m

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

Minimum Width of Foundation (B): 1.00

#### 1 Soil Data :

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 11

Type of Shear Failure: General

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

#### 1 Design Parameters:

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

Effective Overburden pressure at foundation level (q) 10,00

Water Table Correction Factor (w') 0.50

#### Bearing Capacity Factors.

 $N_c = N/A$ 

 $N_q = 19.29$ 

 $N_y = 23.94$ 

## Shape Factors:

 $S_c = N/A$ 

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

 $S_{\gamma} = 1.00$ 

## Depth Factors

 $D_c = N/A$ 

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

 $D_{\gamma} = 1.00$ 

#### Inclination Factor:

 $I_c = N/A$ 

 $I_q = 1.00$ 

 $l_{\gamma} = 1.00$ 

## 1 Ultimate Bearing Capacity (Qu):

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

 $Q_u = - \frac{}{340.59} \frac{}{kPa}$ 

## 2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.):

Osafe: 136.24 kPa

Limited to an allowable bearing pressure per running meter width. 130.00 kPa

#### 2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 130kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 130kPa and SPT of 11 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as ner IS:1904

## **CHAPTER-1**

## INTRODUCTION

#### 1.0 Preamble

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

This report includes field and Laboratory test results for the borehole location at Chainage: 1399/1 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: 1399/1

Sta	irte	d O	n ; 22i	07/2008; Ended On : 23			G.V		7.60	m hical Representation of SP		Т
		l			31	1 - L	ctan	15	##	10 2/3(4/5/6/7/8/90	ncy	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
					1.50	6	8	9	17	,	M.Dense	ss
					3.00	UDS	Samp	ler Ins	talled		M Dense	UDS
				Greyish Medium Dense	4.50	6	9	11	20	}	M.Dense	ss
				Silty Fine Sand	6,00	5	5	8	13		M.Dense	ss
					7.50	9	11	14	25	}	M.Dense	SS
G.V	v,T	<b>♦</b>			9,00	10	13	15	28		M.Dense	ss
10.	.50				10.50	13	16	18	34		Dense	SS
12.	00			Greyish Dense Silty Fine Sand	12.00	17	21	25	46		Dense	SS

Sity Fine Sand

12.00 17 21 25 46

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

Fig. 2.1 Soil Profile at Chainage:1399/1 Location

R.L. of Sample below Existing Ground level(m)   R.L. of Sample   R.L. of										
Silly Sand   Sil	10.50-12.00	E.G.L-10.50	7	nd						
Silly Sand   Sil	34	21	SPT of Sample							
∞   □   NMC(%)	SS	SS				Table				
∞   □   NMC(%)	Silty Sand	Silty Sand	Visual & Engineering Classification of Soil			e 2.1: Laborat				
PL (%)   Clay	8	10	NMC(%)			0				
PI	1	1	LL (%)			T				
Consistency, IC	1	1	PL (%)	0		st				
Son the Soil   Specific Gravity, G	-	1	PI	lay		Res				
	1	1	Consistency, I <sub>C</sub>			ult				
	2.66	2.67	Specific Gravity, G			s on				
			Void Ratio, e			the S				
Dense   Relative Density/ Consistency   Collected from Chainage: 1399/1 Location	19	17	Bulk Density, kN/m <sup>3</sup>			Oi!				
Dense   Relative Density/ Consistency   Collected from Chainage: 1399/1 Location	-	1	Free Swell (%)							
Dense   Relative Density/ Consistency   Collected from Chainage: 1399/1 Location	1		Swelling Pressure (kPa)							
Coarse (%)   Sieve Analysis   Fine (%)   Chainage: 1399/1 Location   Triaxial   Box   Triaxial   Shear   Consolidation Tests, Cc   Consolidation T	Dense	M.Dense	Relative Density/ Consistency							
Coarse (%)   Sieve Analysis   Fine (%)   Chainage: 1399/1 Location   Triaxial   Box   Triaxial   Shear   Consolidation Tests, Cc   Consolidation T	0	0	Gravel (%)			cte				
Clay (%)   Fe: 1399/1   Consolidation Tests, Cc   Clay (%)   Friaxial   Consolidation Tests, Cc   Clay (%)   Friaxial   Consolidation Tests, Cc   Friaxial   Friaxi	0	0	Coarse (%)	S						
Clay (%)   Fe: 1399/1   Consolidation Tests, Cc   Clay (%)   Friaxial   Consolidation Tests, Cc   Clay (%)   Friaxial   Consolidation Tests, Cc   Friaxial   Friaxi	0	0	Medium (%)	eve .		0m				
Clay (%)   Fe: 1399/1   Consolidation Tests, Cc   Clay (%)   Friaxial   Consolidation Tests, Cc   Clay (%)   Friaxial   Consolidation Tests, Cc   Friaxial   Friaxi	77	83	Fine (%)	Anal		Ch				
15.1   c (kN/m²)   Triaxial   1001   1002   1003	23	17	Silt (%)	ysis		uina				
Consolidation Tests, Cc   Cc   Cc   Cc   Cc   Cc   Cc   Cc	0	0	Clay (%)			ge:1				
c (kN/m²)  c (kN/m²)  p B D N	ī	15.1	c (kN/m²)	1	Tri	399,				
ψ (Deg.)  Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	1	32.6	φ (Deg.)	est	axial	/1 Lc				
Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	1		c (kN/m²)							
Consolidation Tests, Cc		t	φ (Deg.)	ear	XO	m				
		1	Unconfined Compression Tests, Cu	(kP	a)					
S S IS-Classification	1		Consolidation Tests, Cc							
	SM	SM	IS-Classification							

1000000	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1399/1									
Location of Bore Hole	Depth of Sample below E.G.L. (m)	hф	Chlorides(ppm)	Sulphates (ppm)						
BH-01	9.00	7.82	88,61	90.43						

## 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-1399/1 Location

(As presented in the site plan)

\* Layer-1 (from E.G.L 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

10.50m

21

Medium Dense

33.30 Deg.

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

 $\begin{tabular}{lll} Type of Strata & Silty Fine Sand \\ Colour & Greyish \\ Thickness of Layer & 1.50m \\ SPT of the layer & 34 \\ Relative Density & Dense \\ Angle of Shearing Resistance, $\phi$ & 37.10 Deg. \\ \end{tabular}$ 

The ground water table was encountered at a depth of 7.60m 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 IS:6403

#### 1 Geometrical Data:

Type of Footing: Isolated Column

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

Observed Maximum thickness of Filled up Soil: 0.00 m

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

Minimum Width of Foundation (B): 1.00

#### 1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 17

Type of Shear Failure: General

Angle of Shearing Resistance, & 32.10 Deg.

#### 1 Design Parameters:

Bulk Density of Soil above the foundation detph ( $\gamma_{bulk}$ )  $_{16.00}$   $kN/m^3$ 

Effective Overburden pressure at foundation level (q) 9.00

Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors

 $N_c = N/A$ 

 $N_q = {}_{24.66}$ 

kPa

 $N_y = 33.16$ 

#### Shape Factors

 $S_c = N/A$ 

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

 $S_{\gamma} = 1.00$ 

#### Depth Factors:

 $D_c = N/A$ 

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

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

#### Inclination Factor:

 $I_c = N/A$ 

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

 $I_{y} = 1.00$ 

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

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

 $Q_u = \frac{421.16 \text{ kPa}}{421.16 \text{ kPa}}$ 

## 2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 168.46 kPa

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

#### 2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 160kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 160kPa and SPT of 17 are computed to be in the order of 48mm which is within the permissible limits of 50mm 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: 1400/1 in the proposed construction area like Major, Minor Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.

### 1.1 Scope of Work

#### 1.1.1 Field Work

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

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

## 1.1.2. Laboratory Work

#### 1.1.2.1 Soil Samples

- (a) Visual and Engineering Classification
- (b) Sieve Analysis/ Particle Size Analysis/ Grain Size Distribution Analysis
  - (i) Hydrometer Analysis/ Wet Sieve Analysis
- (c) Atterberg Limits on the cohesive soils (LL, PL, SL) on fine-grained soils
- (d) Specific Gravity
- (e) Chemical Properties on sub-soil water/ soil sample to determine the presence of pH, Cl, SO<sub>4</sub> contents.
- (f) Swelling Pressure Tests & Free Swelling Index
- (g) Bulk Density and Moisture Content
- (h) Unconfined Compression Tests on Clay Soils
- (i) Box Shear Test in case of sand
- (j) Tri-Axial Shear TestsUnconsolidated undrained.Consolidated Undrained Test with the Pressure
- (k) Drained Consolidation Test representing e, Cc & Pc

### 1.1.2.2 Rock Samples

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

## 1.2 Structure of the Report

- Contents
- Introduction
- Investigation Methodology & Test Results

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

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## INVESTIGATION METHODOLOGY & TEST RESULTS

## 2.0 Field Testing:

### 2.1 Preamble:

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

### 2.2 In-Situ Strength Tests:

#### 2.2.1 Standard Penetration Test:

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

## 2.3 Collection of Samples:

#### 2.3.1 Soil:

## 2.3.1.1 Disturbed Samples

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

## 2.3.1.2 Standard Penetration Tests & Split Spoon Samples

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

#### 2.3.1.3 Undisturbed Soil Samples

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

## 2.4 Laboratory Testing: Soil Samples

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

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

#### 2.4.2 Atterberg Limits

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

#### 2.4.3 Specific Gravity

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

### 2.4.4 Chemical Tests on Water Sample

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

#### 2.4.5 Swelling Pressure & Free Swell Tests

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

## 2.4.6 Bulk Density & Natural Moisture Content

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

#### 2.4.7 Unconfined Compression Tests

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

#### 2.4.8 Box Shear Tests

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

### 2.4.9 Triaxial Shear Tests

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

#### 2.4.10 Consolidation Tests

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

### **Rock Samples**

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

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

Location: At Chainage: 1400/1

Started On: 21/07/2008; Ended On: 23/07/2008 G.W.T: 3.50m

					SP	T - D	etail	s	rapl	nical Representation of SP	ý	
									##	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 (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
					1.50	6	7	9	16	9	M.Dense	SS
G.V	v.T	₩		2	3.00	UDS	Colle	cted			M.Dense	ss
	3			Greyish	4.50	7	9	10	19		M.Dense	SS
				Medium Dense Silty Fine Sand	6.00	3	5	7	12		M.Dense	SS
					7.50	8	10	13	23		M.Dense	SS
					9.00	10	13	14	27		M.Dense	SS
10.	50				10.50	11	14	17	31		Dense	SS
					12.00	13	16	18	34		Dense	SS
	W. 10. 10. 10. 10.				13.50	13	17	21	38		Dense	SS
				Greyish Dense	15.00	15	18	22	40		Dense	ss
				Silty Fine Sand	16.50	16	20	25	45		Dense	SS
					18.00	18	23	27	50		Dense	ss
19.	00	$\sqcup$								t		

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: 1400/1

Sta	arte	d O	n:21/0	07/2008; Ended On: 23.					3.50	
					SP	T - D	etail	s	rapl	phical Representation of SP
پِ ا								1000000	##	10 2 3 ( 4 ( 5 : 6 ( 7 ( 8 : 9 0 )
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistenc Density/Consistenc Type of Sample
					19.50	19	27	29	56	V.Dense SS
					21.00	21	30	34	64	V.Dense SS
				Greyish Very Dense	22.50	22	32	36	68	V.Dense SS
				Silty Fine Sand	24.00	24	37	42	79	V.Dense SS
					25.50	25	40	45	85	V.Dense SS
				125	27.00	27	40	45	8.5	V.Dense SS
					28.50	30	40	48	88	V.Dense SS
30	.00				30.00	32	45	50	95	V.Dense SS

Bore Hole Terminated at a depth of 30.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage: 1400/1 Location

19						_				
Second   S	19.00-30.00	10.50-19.00	E.G.L-10.50		nd					
Silty Sand   Sil	75	40	19	SPT of Sample						
S	SS	SS	SS	1 2 2			Table 2			
S	Silty Sand	Silty Sand	Silty Sand	Visual & Engineering Classification of Soil						
V   Dense   Relative Density/ Consistency   Collected from Chainage   No. 1400/1 Location	O.	9	10							
V   Dense   Relative Density/ Consistency   Collected from Chainage   No. 1400/1 Location	ı			LL (%)						
V   Dense   Relative Density/ Consistency   Collected from Chainage   No. 1400/1 Location		ı	1				t R			
V   Dense   Relative Density/ Consistency   Collected from Chainage   No. 1400/1 Location	1	1.	1	PI	lay		esu			
V   Dense   Relative Density/ Consistency   Collected from Chainage   No. 1400/1 Location	1	,	ī							
V   Dense   Relative Density/ Consistency   Collected from Chainage   No. 1400/1 Location	2.6.	2.60	2.6	Specific Gravity, G	IL	-	)n tl			
V   Dense   Relative Density/ Consistency   Collected from Chainage   No. 1400/1 Location			† †				ne So			
V   Dense   Relative Density/ Consistency   Collected from Chainage   No. 1400/1 Location	2(	듄	15	Rulk Density, kN/m <sup>3</sup>						
V   Dense   Relative Density/ Consistency   Collected from Chainage   No. 1400/1 Location		TT	<del>† †</del>	Bulk Density, kN/m  Free Swell (%)						
V   Dense   Relative Density/ Consistency   Collected from Chainage   No. 1400/1 Location	$\vdash$	$\vdash$	<del></del>		Swelling Pressure (kPa)					
Coarse (%)   Coarse (%)   Chainage No. 1400/1   Chainage No. 140	V.Dense	Dense	M.Dense		1171.7					
Consolidation Tests, Cc   Consolidation Tests, Cc   Consolidation Tests, Cc   Consolidation Tests, Cc   Chainage   Consolidation Tests, Cc   Chainage   Consolidation Tests, Cc   Chainage   Chainag	FTT T	0		Gravel (%)		A Complete Co	ted			
Time (%)	0	0	0	Coarse (%)	Si		fron			
Time (%)	0	0	0	Medium (%)	eve A		n C			
O   O   Clay (%)	71	77	82	Fine (%)	\nal <sub>y</sub>		hain			
1	29	23	18	Silt (%)	ysis		age			
φ (Deg.)  c (kN/m²)  h φ (Deg.)  c (kN/m²)  h φ (Deg.)  Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	0	0	0	Clay (%)			No			
c (kN/m²)  d (Deg.)  Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc		1	15.9	c (kN/m <sup>2</sup> )	T	Tri	.140			
ψ (Deg.)  Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	1	-	32.0	φ (Deg.)	est	axial	0/1			
Unconfined Compression Tests, Cu (kPa)  Consolidation Tests, Cc	ı	ı	1							
Consolidation Tests, Cc	1	ı		φ (Deg.)	ear	XO.	tion			
	ı	,	1	Unconfined Compression Tests, Cu	(kP	a)				
S S S IS-Classification			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 No. 1400/1							
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)				
BH-01	4.50	7.85	78.53	67.30				

## 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-1400/1 Location

(As presented in the site plan)

Angle of Shearing Resistance, 6

Layer-1 (from E.G.L to 10.50m depth below)Type of StrataSilty Fine SandColourGreyishThickness of Layer10.50mSPT of the layer19Relative DensityMedium Dense

32.70 Deg.

Layer-2 (from 10.50m to 19.00m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, \$\phi\$

Silty Fine Sand

Greyish

8.50m

40

Dense

38.75 Deg.

\* Layer-3 (from 19.00m to 30.00m depth below)

Type of Strata
Colour
Greyish
Thickness of Layer
SPT of the layer
Relative Density
Angle of Shearing Resistance, φ
Silty Fine Sand
Greyish
11.00m
SPT of the layer
75
Very Dense
42.50 Deg.

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

However, the sub-soil strata encountered at a depth of 19.00m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

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

## 4.2 Foundation System

#### 4.2.1 Deep Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered below a depth of 19.00m below the existing ground level.

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

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

S.No.	Diameter of	Safe Load	Safe Pull Out	Safe Lateral	
	Pile	Carrying	carrying	Load	
	(mm)	Capacity	Capacity	carrying	
	6	(kN)	(kN)	Capacity	
				(kN)	
1	1000	11000	3043	550	

0

The details of the computations are annexed to this report.

**CHAPTER-5** 

## RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. The sub-soil strata encountered at a depth of 19.00m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
- 3. The bearing strata of the proposed foundation system can be the sub soil strata encountered below a depth of 19.00m below the existing ground level. Hence, the foundation system can be 22.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
- 4. The safe load carrying capacity of 22.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
- As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

## **DESIGN OF PILE FOUNDATION(Refer:BH-01)**

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

1.0 Type of Installation of Pile

**Bored Cast in Situ** 

1.1 Geometrical Data

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

0.000 m

Length of pile below E.G.L.(1):

22.000 m

R.L. of Bot. of Pile

-22.00 m

1.2 Design of Pile for Vertical Compression

1.2.1 Computation of Skin Resistance:

1.2.1.1

Layer-I

Type of Strata: Silty Sand

Average SPT of the strata, N: 19

Bulk Density of the strata, y: 17

kN/m<sup>3</sup>

Angle of Shearing Resistance, 6: 32.7

Deg.

Depth of top of Strata: 0.00

m m

Depth of bottom of Strata: 10.50

Average Thickness of Strata, Ic: 10.50

m

Effective overburden pressure over the top of strata,  $\sigma_{top}$ : 0.00

 $kN/m^2$ 

Effective overburden pressure over the bottom of strata,  $\sigma_{\text{bottom}}$ : 73.50

 $kN/m^2$ 

Effective overburden pressure at the middle of the strata,  $\sigma_{middle}$ : 36.75

 $kN/m^2$ 

Coeff. Of Earth Pressure, k: 1.50

Skin Resistance of the pile, q<sub>s</sub>: 1167.39 kN

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

1.2.1.2

Layer-II

Type of Strata: Silty Sand

Average SPT of the strata, N: 40

Bulk Density of the strata,γ: 19

kN/m3

Angle of Shearing Resistance, 6: 38.75

Deg.

Depth of top of Strata: 10.50

m

Depth of bottom of Strata: 19.00

m

Average Thickness of Strata, Ic: 8.50

m

Effective overburden pressure over the top of strata,  $\sigma_{top}$ : 73.50

 $kN/m^2$ 

Effective overburden pressure over the bottom of strata,  $\sigma_{bottom}$ : 150.00

 $kN/m^2$ 

Effective overburden pressure at the middle of the strata,  $\sigma_{\text{middle}}$ : 111.75

 $kN/m^2$ 

Coeff. Of Earth Pressure, k: 1.50

Skin Resistance of the pile, qs: 3592.5

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

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1.2.1.3 Layer-II	I	
Type of Strata	: Silty San	d
Average SPT of the strata, N	: 60	
Bulk Density of the strata,γ	: 20	$kN/m^3$
Angle of Shearing Resistance, ¢	: 42.5	Deg.
Depth of top of Strata	: 19.00	m
Depth of bottom of Strata		m
Average Thickness of Strata, I	: 3.00	m
Effective overburden pressure over the top of strata, $\sigma_{top}$	: 150.00	kN/m <sup>2</sup>
Effective overburden pressure over the bottom of strata, $\sigma_{bottom}$	: 180.00	kN/m <sup>2</sup>
Effective overburden pressure at the middle of the strata, $\sigma_{\text{middle}}$	: 165.00	$kN/m^2$
Coeff. Of Earth Pressure, k	: 2.00	
Skin Resistance of the pile, q	2850.0	kN
$(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic$	)	
Ultimate Skin Resistance,qs	7609.9	kN
1.2.2 Computation of End Bearing Resistance:		
Type of Bearing Strate	Silty San	d
Cross-Sectional Area of pile, Ap	0.785	$m^2$
R.L of bottom of pile	: -22.00	
Minimum SPT-value of the Bearing Strate		
Angle of Shearing Resistance(ASR		Degrees
Bearing Capacity Factor(Nq		
Effective Over Burden Pressure at the bottom of pile (q	120.00	kPa
(limited to a maximum value produced by a soil layer o	_	
and the control of th		
thickness equal to 20 times the diameter of pile from the	2	
thickness equal to 20 times the diameter of pile from the N.G.L.	<del>)</del>	1.N
thickness equal to 20 times the diameter of pile from the N.G.L. Ultimate End Bearing Resistance (Qp	20734.5	kN
thickness equal to 20 times the diameter of pile from the N.G.L.	20734.5	kN
thickness equal to 20 times the diameter of pile from the N.G.L. Ultimate End Bearing Resistance (Qp	20734.5	
thickness equal to 20 times the diameter of pile from the N.G.L.  Ultimate End Bearing Resistance (Qp (Qp=Ap*q*Nq)	20734.5	kN

### **CHAPTER-1**

## **INTRODUCTION**

#### 1.0 Preamble

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#### 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.
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- 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
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- (k) Drained Consolidation Test representing e, Cc & Pc

### 1.1.2.2 Rock Samples

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

### 1.2 Structure of the Report

- Contents
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- 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;1400/2

			nainage;1400/2 /07/2008; Ended On : 22	/07/20	08	G.	W.T:	2.00	)m			
				SP	T - D	etai	Is	rapi	hical Representation	ofSP	5:	
	П							##	10 2 (3 (4 (5) 6 (7 (	8:90	enc	1
Depth of Top of Layer(m)	G.W.T.(m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			Relative Density/Consistency	Type of Sample
			Greyish	1,50	6	7	0	1.5	2		Loose	ac
G.W.T	¥		Loose Silty Fine Sand	3.00		Colle	8 ected	15			M.Dense	SS
3,50				4.50	7	9	9	18			M.Dense	SS
			Greyish				,	10				33
	 		Medium Dense Silty Fine Sand	6.00	8	9	10	19	\		M Dense	SS
				7.50	10	12	17	29	1		M.Dense	SS
9.00			-	9.00	10	16	19	35			Dense	SS
				10,50	13	16	21	37			Dense	ss
			Greyish Dense Silty Fine Sand	12.00	15	20	23	43			Dense	ss
				13.50	16	20	25	45			Dense	ss
15.00				15.00	18	25	29	54	\		V.Dense	ss
			Greyish	16.50	19	29	30	59	\		V.Dense	ss
E.			Dense Silty Fine Sand	18.00	22	30	35	6.5			V.Dense	ss

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Fastern Freight Corridor in line with Tender No. HO/FN/Pre. (Works)/MTC Location: At Chainage: 1400/2

Started On:	Started On: 20/07/2008; Ended On: 22/07/2008 G.W.T: 2.00m																		
			SP	SPT - Details   raphical Representation of SP									၁င						
<u>~</u>							##	10	21	3(	4(	516	( 7	( 8	90		ster		
Depth of Top of Layer(m) G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative	Density/Consistenc	y	Type of Sample
			19.50	24	31	36	67						9			V.E	Dense	,	ss
-			21.00	24	32	37	69									VI	<b>D</b> ense	,	ss
		Greyish Very Dense	22.50	23	34	39	73									V.I	Dense		ss
		Silty Fine Sand	24.00	27	37	40	77							1		V.E	Dense	:	ss
			25.50	28	40	43	83							1	Ì	V.E	Dense		ss
			27.00	30	43	44	87								1	V.D	Dense		SS
30.00			29.50	30	45	46	91			*						VE	Dense	,	SS

Bore Hole Terminated at a depth of 30.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1400/2 Location

	_	_	_	_	_	-	T			_
	15.00-30.00	9.00-13.00	000 15 00	3.50-9.00		E.G.L-3.50	R.L of Sample below Existing Grou level(m)	nd		
	68	40		22		15	SPT of Sample			
	SS	33	20	SS		SS	Type of Sample			Table 2
	Silty Sand	Sury Sand	2	Silty Sand		Silty Sand	Visual & Engineering Classification of Soil			Table 2.1: Laboratory Test Results on the Soil Samples
	6	×		10		12	NMC(%)			[2,
	1	,		ı		-	LL (%)			Tes
		Ī	Ι	ı		ī	PL (%)			R
	ı	1	T				PI	Clay		esul
	1	1	T	1		1	Consistency, I <sub>C</sub>			ts o
	2.65	2.65		2.66		2.68	Specific Gravity, G			n the
	1	1		ī			Void Ratio, e			Soi
	20	19		17		15	Bulk Density, kN/m <sup>3</sup>			S
		,		1			Free Swell (%)			amı
	1	,		1		1	Swelling Pressure (kPa)			oles
	V.Dense	Dense	t	M.Dense		Loose	Relative Density/ Consistency			Collected from Ch
	0	c	,	0		0	Gravel (%)			ted
F	0	c	1	0		0	Coarse (%)	S		fro
F	0	0	†	0	T	0	Medium (%)	Sieve Analysis		m C
F	74	à	1	81	П	87	Fine (%)	Ana		222
	26	22		19		13	Silt (%)	ysis		iinage No.
П	0		T	0	П	0	Clay (%)			N
	1	,		1		14.8	e (kN/m²)	T	Tri	). 14(
	1			1		29.8	φ (Deg.)	Test	Triaxial	0/2 ]
	-			ī		ı	c (kN/m²)	Shear	Box	Location
				1		ı	φ (Deg.)	ar	ХC	tion
	1			ī			Unconfined Compression Tests, Cu	(kP	a)	
	1	1				r	Consolidation Tests, Cc			
	SM	SM		SM		SM	IS-Classification			

0 0 0

 $\infty$ 

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			sults conducte e at Chainage	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)
BH-01	4.50	7.87	48.99	70.09

# 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-1400/2 Location

(As presented in the site plan)

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

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.50m
SPT of the layer	15
Relative Density	Loose
Angle of Shearing Resistance, □	31.50 Deg.

#### Layer-2 (from 3.50m to 9.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish Thickness of Layer SPT of the layer

5.50m 22

Relative Density Medium Dense Angle of Shearing Resistance, 33.60 Deg.

#### Layer-3 (from 9.00m to 15.00m depth below)

Type of Strata Silty Fine Sand

Colour Grevish Thickness of Layer SPT of the layer Relative Density

6.00m 40 Dense Angle of Shearing Resistance, □ 38.75 Deg.

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

Type of Strata Silty Fine Sand

Colour Greyish

Thickness of Layer 15.00m SPT of the layer 68 Relative Density Very Dense 42.50 Deg. Angle of Shearing Resistance,

The ground water table was encountered at a depth of 2.00m 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 are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

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

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

#### 4.2 Foundation System

#### 4.2.1 Deep Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered below a depth of 15.00m below the existing ground level.

11

Hence, the foundation system can be 18.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 18.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

S.No.	Diameter of	Safe Load	Safe Pull Out	Safe Lateral
9	Pile	Carrying	carrying	Load
	(mm)	Capacity	Capacity	carrying
		(kN)	(kN)	Capacity
				(kN)
1	1000	10000	2140	500

The details of the computations are annexed to this report.



# RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. The sub-soil strata encountered at a depth of 15.00m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
- 3. The bearing strata of the proposed foundation system can be the sub soil strata encountered below a depth of 15.00m below the existing ground level. Hence, the foundation system can be 18.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
- 4. The safe load carrying capacity of 18.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
- As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

### DESIGN OF PILE FOUNDATION(Refer:BH-01)

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

1.0 Type of Installation of Pile

**Bored Cast in Situ** 

1.1 Geometrical Data

Assumed Diameter of pile(D): 1000.0 mm

Assumed R.L of E.G.L:

0.000 m

Length of pile below E.G.L.(1):

18.000 m

R.L. of Bot. of Pile

-18.00 m

1.2 Design of Pile for Vertical Compression

1.2.1 Computation of Skin Resistance:

1.2.1.1

Layer-I

Type of Strata: Silty Sand

Average SPT of the strata, N: 15

 $kN/m^3$ 

Bulk Density of the strata, y: 15

Angle of Shearing Resistance, ¢: 31.5

Deg.

Depth of top of Strata: 0.00

m

Depth of bottom of Strata: 3.50

m m

Average Thickness of Strata, I.: 3.50

 $kN/m^2$ 

Effective overburden pressure over the top of strata,  $\sigma_{top}$ : 0.00

 $kN/m^2$ 

Effective overburden pressure over the bottom of strata,  $\sigma_{\text{bottom}}$ : 17.50

Effective overburden pressure at the middle of the strata,  $\sigma_{middle}$ : 8.75

 $kN/m^2$ 

Coeff. Of Earth Pressure,k: 1.00

Skin Resistance of the pile, qs: 58.96

kN

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

1.2.1.2

Layer-II

Type of Strata: Silty Sand

Average SPT of the strata, N: 22

Bulk Density of the strata, y: 17

 $kN/m^3$ 

Angle of Shearing Resistance, \$\phi\$: 33.6

Deg.

Depth of top of Strata: 3.50

Depth of bottom of Strata: 9.00

m

m

Average Thickness of Strata, Ic: 5.50

m

Effective overburden pressure over the top of strata,  $\sigma_{top}$ : 17.50

 $kN/m^2$ 

Effective overburden pressure over the bottom of strata,  $\sigma_{bottom}$ : 56.00

 $kN/m^2$ 

Effective overburden pressure at the middle of the strata,  $\sigma_{\text{middle}}$ : 36.75

 $kN/m^2$ 

Coeff. Of Earth Pressure,k: 1.50

Skin Resistance of the pile, qs: 632.8

kN

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

1.2.1.3 Laye	er-III	
Type of S	trata: Silty Sa	nd
Average SPT of the stra	ita,N: 40	
Bulk Density of the stra	ata,γ: 19	$kN/m^3$
Angle of Shearing Resistan	nce,φ: 38.75	Deg.
Depth of top of Si		m
Depth of bottom of So		m
Average Thickness of Stra	ta,I <sub>c</sub> : 6.00	m
Effective overburden pressure over the top of strata	$,\sigma_{\text{top}}: 56.00$	$kN/m^2$
Effective overburden pressure over the bottom of strata, $\sigma_{t}$	bottom: 110.00	$kN/m^2$
Effective overburden pressure at the middle of the strata, $\sigma_r$	middle: 83.00	$kN/m^2$
Coeff. Of Earth Pressu	are,k: 2.00	
Skin Resistance of the pi	ile,q <sub>s</sub> : 2511.3	kN
$(q_s:\sigma^*k^*tan\phi^*pi()^*)$	d*Ic)	
	POSSA MARINE NIK	
1.2.1.4 Laye		
	trata: Silty Sa	nd
Average SPT of the stra	ita,N: 59	
Bulk Density of the stra	15	kN/m <sup>3</sup>
Angle of Shearing Resistan		Deg.
Depth of top of St		m
Depth of bottom of St		m
Average Thickness of Stra	17000=1 1500	m
Effective overburden pressure over the top of strata		$kN/m^2$
Effective overburden pressure over the bottom of strata, $\sigma_t$	bottom: 140.00	kN/m <sup>2</sup>
Effective overburden pressure at the middle of the strata, $\sigma_r$	middle: 125.00	$kN/m^2$
Coeff. Of Earth Pressu	ure,k: 2.00	
Skin Resistance of the pi	ile,q <sub>s</sub> : 2147.7	kN
$(q_s:\sigma^*k^*tan\phi^*pi()^*$	d*Ic)	
Ultimate Skin Resistance	ce,q <sub>s</sub> : 5350.8	kN
1.2.2 Computation of End Bearing Resistance:		
Type of Bearing S	Strata Silty Sa	nd
Cross-Sectional Area of pile		m <sup>2</sup>
R.L of bottom of		111
Minimum SPT-value of the Bearing S		
Angle of Shearing Resistance(A		Degrees
Bearing Capacity Factor		
Effecitve Over Burden Pressure at the bottom of pil		kPa
(limited to a maximum value produced by a soil lay		
thickness equal to 20 times the diameter of pile from		
	G.L.)	
Ultimate End Bearing Resistance (Qp=Ap*q		KIN
$(Qp-Ap^*q$	144)	
1.3.0 Ultimate Load Carrying Capacity (Qu=Qp	0+q <sub>n</sub> ) 26085.3	kN
Safe Load Carrying Capacity (Qsafe =Qu		
However, limit Q <sub>safe</sub> to the structural capacity of		
-and		

### **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: 1401/1 in the proposed construction area like Major, Minor Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.

#### 1.1 Scope of Work

#### 1.1.1 Field Work

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

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

#### 1.1.2. Laboratory Work

### 1.1.2.1 Soil Samples

- (a) Visual and Engineering Classification
- (b) Sieve Analysis/ Particle Size Analysis/ Grain Size Distribution Analysis
  - (i) Hydrometer Analysis/ Wet Sieve Analysis
- (c) Atterberg Limits on the cohesive soils (LL, PL, SL) on fine-grained soils
- (d) Specific Gravity
- (e) Chemical Properties on sub-soil water/ soil sample to determine the presence of pH, Cl, SO<sub>4</sub> contents.
- (f) Swelling Pressure Tests & Free Swelling Index
- (g) Bulk Density and Moisture Content
- (h) Unconfined Compression Tests on Clay Soils
- (i) Box Shear Test in case of sand
- (j) Tri-Axial Shear TestsUnconsolidated undrained.Consolidated Undrained Test with the Pressure
- (k) Drained Consolidation Test representing e, Cc & Pc

#### 1.1.2.2 Rock Samples

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

### 1.2 Structure of the Report

- Contents
- Introduction
- Investigation Methodology & Test Results

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

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# INVESTIGATION METHODOLOGY & TEST RESULTS

### 2.0 Field Testing:

#### 2.1 Preamble:

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

### 2.2 In-Situ Strength Tests:

#### 2.2.1 Standard Penetration Test:

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

### 2.3 Collection of Samples:

#### 2.3.1 Soil:

#### 2.3.1.1 Disturbed Samples

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

#### 2.3.1.2 Standard Penetration Tests & Split Spoon Samples

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

#### 2.3.1.3 Undisturbed Soil Samples

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

### 2.4 Laboratory Testing: Soil Samples

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

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

### 2.4.2 Atterberg Limits

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

#### 2.4.3 Specific Gravity

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

### 2.4.4 Chemical Tests on Water Sample

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

#### 2.4.5 Swelling Pressure & Free Swell Tests

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

### 2.4.6 Bulk Density & Natural Moisture Content

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

### 2.4.7 Unconfined Compression Tests

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

#### 2.4.8 Box Shear Tests

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

#### 2.4.9 Triaxial Shear Tests

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

#### 2.4.10 Consolidation Tests

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

#### **Rock Samples**

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

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

Location: At Chainage: 1401/1 Started On: 17/07/2008: Ended On: 18/07/2008 G.W.T: 2.60m

Sta	arte	d O	n:17/0	07/2008; Ended On : 18.	/07/20	08	G.V	W.T:	2.60	m								tet meneralis		200000
					SP	T - D	etail	s	rapl	nical	Re	pre	sei	ntai	io	n o	fSP		>	X .
					2 100 100				##						-		90	1	inc.	
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	6	9	15	1	Ì							Lo	ose	ss
G.V	V.T			Greyish to Brownish Loose Silty Clayey Fine Sand	3.00	UDS	Samp	ler Ins	stalled									Lo	ose	UDS
4.	50		r ata a		4.50	7	11	14	25		1							MD	ense	ss
				Greyish Medium Dense Silty Fine Sand	6,00	11	13	14	27									MD	ense	SS
7.	50				7.50	13	15	17	32			þ						MD	ense	SS
10	.00			Greyish Dense Silty Fine Sand	9.00	13	16	17	33				\					De	ıse	ss
				Greyish Very Dense	10.50	20	26	30	56					1				V.D	ense	ss
12	.00			Silty Fine Sand	12.00	26	31	37	68					'				V.D	ense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage:1401/1 Location

	_		The state of the s					_			
			Noisesification		SM		SM		SM		SM
			Consolidation Tests, Cc		•						1
	(R	(rb	Unconfined Compression Tests, Cu		ı				t		1
<b> </b>	X	ar	ф (Deg.)				ı		r.	Ī	-
Location	Box	Shear	c (kN/m²)		,					T	-
Lo	xial	st	ф (Deg.)		29.7		1			T	-
401/	Triaxia	Test	c (kN/m²)	П	12.8		ı			T	,
e:1			(%)	П	∞		0		0	T	
nag		sis	(%) માંડ		11		22		25	1	82
hai		Sieve Analysis	(%)	П	81		78		75	1	72
) m		ve A	(%) muibəM	П	0	П	0		0	T	0
fro		Sie	Coarse (%)		0		0		0	T	0
cted			Gravel (%)		0		0		0		0
s Collected from Chainage: 1401/1			Relative Density/ Consistency		Loose		M.Dense		Dense		V.Dense
nple			Swelling Pressure (kPa)		1		r		1	Ì	ı
Samples			Free Swell (%)		1		1		-		τ
Soil			Bulk Density, kN/m <sup>3</sup>		15		17		19		20
the !			Void Ratio, e		1		r		r		,
0n 1			Specific Gravity, G		2.68		2.66		2.66		2.65
Results on			Consistency, I <sub>C</sub>		ī		ı		1		1
Res		Clay	Id		ı		T.		1		i:
Test		٥	MT (%)	Ц	1				1	1	_
II			rr (%)	Н	1		1		1	1	1
ator			NMC(%)	Н	14 ld	Ц	=		6.	+	∞
Table 2.1: Laboratory			Visual & Engineering Classification of Soil		Silty Clayey Sand		Silty Sand		Silty Sand		Silty Sand
Table			Type of Sample		SS		SS		SS		SS
			oldms2 to TA2		15		26		32		56
		pu	R.L of Sample below Existing Grou level(m)		E.G.L-4.50		4.50-7.50		7.50-10.00	4	10.00-12.00

			esults conducte	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
ВН-01	3,00	7.87	33,67	50.92

# 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-1401/1 Location

(As presented in the site plan)

Layer-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 7.50m depth below)

Bayer-2 (from 4.50m to 7.50m depth be	1011	
Type of Strata	Silty Fine Sand	
Colour	Greyish	
Thickness of Layer	3.00m	
SPT of the layer	26	
Relative Density	Medium Dense	
Angle of Shearing Resistance, φ	34.80 Deg.	

#### \* Layer-3 (from 7.50m to 10.00m depth below)

Zajer e (nom neom to rotoom depth belott)	
Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.50m
SPT of the layer	32
Relative Density	Dense
Angle of Shearing Resistance, φ	36.55 Deg.

### \* Layer-4 (from 10.00m to 12.00m depth below)

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.00m
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 2.50m 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.



# 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.

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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 m Observed Maximum thickness of Filled up Soil: 0.00 Effective Depth of Foundation below E.G.L: 2.00 Minimum Width of Foundation (B): 1.00

#### 1 Soil Data :

Type of Bearing Strata: Silty Sand Least SPT-value of the Bearing Strata: 15 Type of Shear Failure: General

Angle of Shearing Resistance, \$1.50 Deg

#### 1 Design Parameters:

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

Effective Overburden pressure at foundation level (q) 10.00 k Pa Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors:

 $N_c = N/A$ 

 $N_q = 22.87$ 

 $N_{\gamma} = 30.09$ 

#### Shape Factors:

 $S_c = N/A$ 

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

 $S_y = 1.00$ 

#### Depth Factors :

 $D_c = N/A$ 

 $D_q = 1.00$ 

 $D_y = 1.00$ 

### Inclination Factor:

 $I_c = N/A$ 

 $I_{\hat{q}} = \frac{1.00}{1.00}$ 

 $I_{y} = 1.00$ 

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

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

#### 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

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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  $48\,\mathrm{mm}$  which is within the permissible limits of  $50\,\mathrm{mm}$ 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: 1402/1 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 Eastern Freight Corridor in line with Tender No. HO/FN/Pre. (Works\/MTC Location: At Chainage: 1402/1

Sta	arte	d O	n:17/0	07/2008; Ended On: 17.	/07/20	08	G.V	W.T:	5.65	m								
					SI	SPT - Details raphical Representation of SP							2					
									##	10	213	(4	(5)	6(	7(8	190	oue	
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	7	7	10	17	9							M.Dense	ss
					3.00	UDS	Samp	ler In:	talled								M.Dense	UDS
				Greyish Medium Dense Silty Fine Sand	4.50	6	8	8	16	q							M. Dense	SS
G.V	V.T				6,00	6	9	10	19								M.Dense	SS
					7.50	10	13	14	27		1						M.Dense	SS
					9.00	12	13	16	29		J	\					M. Dense	SS
10	.00			Greyish Very Dense	10.50	18	26	29	55				1	\			V.Dense	ss
12	,00			Silty Fine Sand	12.00	21	27	34	61					1			V.Dense	SS

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

Fig. 2.1 Soil Profile at Chainage:1402/1 Location

10.00-12.00	E.G.L-10.00		R.L of Sample below Existing Grou level(m)	nd						
55			SPT of Sample							
SS	SS		Type of Sample							
Silty Sand	Silty Sand		Visual & Engineering Classification of Soil			able 2.1: Laborat				
∞	11		NMC(%)			9				
			LL (%)			Te				
,	,	_	PL (%)	0		[est ]				
l l	,		PI	Clay		Results				
1	,		Consistency, I <sub>C</sub>			ults				
2.65	2.67		Specific Gravity, G			on the Soil Samples				
1			Void Ratio, e							
20	17		Bulk Density, kN/m <sup>3</sup>							
,	1		Free Swell (%)							
	1		Swelling Pressure (kPa)							
V.Dense	M.Dense		Relative Density/ Consistency			es Collected				
0	0		Gravel (%)			cte				
0	0		Coarse (%)	Sie		1 fr				
0	0		Medium (%)	Sieve A		0m				
74	83		Fine (%)	<b>Analysis</b>		Cha				
26	17		Silt (%)	vsis		ina				
0	0		Clay (%)			ge: 1				
ı	14.6		c (kN/m²)	Te	Tria	402/				
-	32.8		c (kN/m²) Test Tost							
1			c (kN/m²)							
1	1		φ (Deg.)							
ı			Unconfined Compression Tests, Cu	(kP	a)					
ı	t		Consolidation Tests, Cc							
SM	SM		IS-Classification							

 $\infty$ 

CHE CONT. AC 1470 NO-CO 1 1 CARSANO.	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1402/1									
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)						
BH-01	6.00	7.88	30.23	45.33						

## 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-1402/1 Location

(As presented in the site plan)

\* Layer-1 (from E.G.L to 10.00m depth below)

Type of Strata Silty Fine Sand
Colour Greyish
Thickness of Layer 10.00m
SPT of the layer 22
Relative Density Medium Dense
Angle of Shearing Resistance, \$\phi\$ 33.60 Deg.

Layer-2 (from 10.00m 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

2.00m

55

Very Dense

41.75 Deg.

The ground water table was encountered at a depth of 5.65m 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 1.50m 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	14	47

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 LS: 1904. The details of the computations are annexed to this report.

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## RECOMMENDATIONS

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

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

## DESIGN OF OPEN FOUNDATION SYSTEM

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

#### 1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1,50

Observed Maximum thickness of Filled up Soil: 0.00 m

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

Minimum Width of Foundation (B): 1.00

#### 1 Soil Data :

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 17

Type of Shear Failure: General

Angle of Shearing Resistance, & 32.10

#### 1 Design Parameters:

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

Effective Overburden pressure at foundation level (q) 7.50 kPa

Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors:

 $N_c = N/A$ 

 $N_q = 24.66$ 

 $N_y = 33.16$ 

## Shape Factors:

 $S_c = N/A$ 

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

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

## Depth Factors :

 $D_c = N/A$ 

 $D_q = 1.00$ 

 $D_{y} = 1.00$ 

## Inclination Factor.

 $I_c = N/A$ 

 $I_{\mathfrak{q}} = \ _{1.00}$ 

 $I_{y} = 1.00$ 

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

 $Q_u = \frac{364.78 \text{ kPa}}{3}$ 

## 2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.):

Qsafe: 145.91 kPa

Limited to an allowable bearing pressure per running meter width;

## 2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 140kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 140kPa and SPT of 17 are computed to be in the order of 47 mm which is within the permissible limits of 50 mmfor individual column footings as ner I S:1904

## **CHAPTER-1**

## INTRODUCTION

## 1.0 Preamble

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

This report includes field and Laboratory test results for the borehole location at Chainage: 1403/1 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: 1403/1

Started On: 16/07/2008; Ended On: 17/07/2008 G.W.T: 4.95m SPT-Details raphical Representation of SP Density/Consistency 10 21 3( 4( 5) 6( 7( 8) 90 ## Depth of Top of Type of Sample Profile Depth of SP1 G.W.T. (m) Engineering Description 30-45 cm Layer(m) 5-30 cm N-Value ofSoil Soil (m) Greyish to Brownish 1.50 6 15 Loose SS Loose Silty Clayey Fine Sand 3.00 UDS Sampler Installed Loose UDS 4.50 4.50 11 19 M Dense SS G.W.T \* Greyish 6.00 9 10 13 23 M Dense SS Medium Dense Silty Fine Sand 7.50 12 15 27 M.Dense SS 8.50 Greyish 9.00 11 14 19 33 Dense SS Dense 10 00 Silty Fine Sand 10.50 20 27 29 56 V.Dense SS Greyish Very Dense

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Chainage: 1403/1 Location

V.Dense

Silty Fine Sand

		nothenthieselD-SI	SM	SM	SM	SM
		Consolidation Tests, Cc		1	i	,
	(кРа)	Unconfined Compression Tests, Cu			1	1
_	x ar	ф (Deg.)	ı	1		,
atio	Box Shear	c (kN/m²)	, ,	,	1	1
Loc	kial st	ф (Deg.)	29.8		i	1
103/1	Triaxial Test	c (F/N/m <sub>z</sub> )		1	ı	
ze:14		Clay (%)	+	0	0	0
inas	ysis	(%) His	10	19	21	27
Cha	Sieve Analysis	Fine (%)	84	81	79	73
шо	eve A	(%) muibəM	0	0	0	0
d fr	Sic	Coarse (%)	0	0	0	0
ecte		Gravel (%)	0	0	0	0
est Results on the Soil Samples Collected from Chainage: 1403/1 Location		Relative Density/ Consistency	Loose	M.Dense	Dense	V.Dense
ldu		Swelling Pressure (kPa)		ı	$\prod$	ı
Saı		Free Swell (%)	'	t	1	i.
Soil		Bulk Density, kN/m3	15	17	119	20
the		Void Ratio, e	1	,	1	1
on		Specific Gravity, G	2.68	2.66	2.66	2.65
sult		Consistency, I <sub>C</sub>	1		1	
Re	Clay	Id		•		
[est		PL (%)	1		1	
Z.		rt (%) nmc(%)	41	= 1	∞	7 -
Table 2.1: Laboratory		Visual & Engineering Classification of Soil	Silty Clayey Sand	Silty Sand	Silty Sand	Silty Sand
Table		Туре оf Sample	SS	SS	SS	SS
		oldms2 to TA2	15	23	33	26
	pu	R.L of Sample below Existing Groun level(m)	E.G.L-4.50	4.50-8.50	8.50-10.00	10.00-12.00

2000	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1403/1								
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)					
BH-01	6.00	7.88	32,59	46.73					

## 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-1403/1 Location

(As presented in the site plan)

\* Layer-1 (from E.G.L to 4.50m 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

4.50m

15

Loose

31.50 Deg.

\* Layer-2 (from 4.50m to 8.50m depth below)

Type of Strata Silty Fine Sand
Colour Greyish
Thickness of Layer 4.00m
SPT of the layer 23
Relative Density Medium Dense

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.90 Deg.

\* Layer-3 (from 8.50m to 10.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish
Thickness of Layer 2.50m
SPT of the layer 33
Relative Density Dense
Angle of Shearing Resistance,  $\phi$  36.825 Deg.

\* Layer-4 (from 10.00m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish
Thickness of Layer 2.00m
SPT of the layer 56
Relative Density Very Dense
Angle of Shearing Resistance,  $\phi$  41.90 Deg.

The ground water table was encountered at a depth of 2.50m 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.
- The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

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

#### DESIGN OF OPEN FOUNDATION SYSTEM

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

#### 1 Geometrical Data :

Type of Footing: Isolated Column
Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

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

Minimum Width of Foundation (B) 1.00 m

#### 1 Soil Data :

Type of Bearing Strata : Silty Sand

Least SPT-value of the Bearing Strata : 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<sup>3</sup>

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w) 0.50

#### Bearing Capacity Factors:

 $N_c = \frac{N}{A}$   $N_q = \frac{22.87}{100}$   $N_{\gamma} = \frac{30.09}{100}$ 

## Shape Factors:

 $S_c = \frac{N}{A}$   $S_q = \frac{1.30}{1.00}$   $S_y = \frac{1.00}{1.00}$ 

## Depth Factors:

 $D_{c} = \frac{1}{N/A}$   $D_{q} = \frac{1}{1.00}$   $D_{r} = \frac{1}{1.00}$ 

#### Inclination Factor.

 $I_c = \frac{1}{N/A}$   $I_q = \frac{1.00}{1.00}$   $I_\gamma = \frac{1.00}{1.00}$ 

## 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 Settlement

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

## **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: 1404/1 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

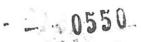
These tests are normally conducted on the soil samples to determine their shear strength characteristics. The test results are presented in table 2.1.

## 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; 1404/1

Started Or		07/2008; Ended On: 17					4.10			
			SPT - Details raphical Representation of SP						25	
Depth of Top of Layer(m) G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value #	10 21 3( 4( 5) 6( 7( 8) 90	Relative Density/Consistency	Type of Sample
		Greyish to Brownish Loose	1.50	6	5	9	14	٩	Loose	SS
G.W.T ↓		Silty Clayey Fine Sand	3.00	UDS	Samp	ler Ins	talled		Loose	UDS
4.50			4.50	8	10	17	27		M.Dense	SS
7.50		Greyish Medium Dense Silty Fine Sand	6.00	7	12	13	25	1	M.Dense	SS
7.30			7.50 9.00	10	16	18	34		Dense Dense	SS
		Greyish Dense Silty Fine Sand	10.50	17	22	25	47		Dense	ss
12.00			12.00	26	29	36	65	\	V.Dense	ss

Bore Hole Terminated at a depth of 12.00m below the existing ground level
Fig. 2.1 Soil Profile at Chainage: 1404/1 Location

	т т	<del></del>			11					
7.50-12.00	4.50-7.50	E.G.L-4.50	R.L of Sample below Existing Grou level(m)	nd						
39	26	14	SPT of Sample							
SS	SS	SS	Type of Sample							
Silty Sand	Silty Sand	Silty Clayey Sand	Visual & Engineering Classification of Soil	Visual & Engineering Classification o						
∞	10	14	NMC(%)		aboratory					
1		,	LL (%)							
ī	,	1	PL (%)		est					
		1	PI	Clay	Res					
	,		Consistency, I <sub>C</sub>		Results on					
2.65	2.66	2.68								
	ı	r	Void Ratio, e  Bulk Density, kN/m <sup>3</sup>							
19	17	15	Bulk Density, kN/m <sup>3</sup>							
	ı		Free Swell (%)							
1	r		Free Swell (%) Swelling Pressure (kPa)							
Dense	M.Dense	Loose	Relative Density/ Consistency							
0	0	0	Gravel (%)		ollected					
0	0	0	Coarse (%)	Sie						
0	0	0	Medium (%)	ve A	from					
78	81	83	Fine (%)	Sieve Analysis	Cha					
22	19	=	Silt (%)	ysis	uina					
0	0	6	Clay (%)		ge: l					
ı		12.4	c (kN/m²)	Tri:	404/					
,	r	30.6	φ (Deg.)							
-	,	ī								
	1		c (kN/m²)  \$\phi\$ (Deg.)  Shear							
1	1	1	Unconfined Compression Tests, Cu	(kPa)						
ı	1	1	Consolidation Tests, Cc							
SM	MS	MS	IS-Classification							

- - 0552

2000	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1404/1								
Location of Bore Hole	Depth of Sample below E.G.L. (m)	рН	Chlorides(ppm)	Sulphates (ppm)					
BH-01 6.00 7.86 60.33 79.37									

## 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-1404/1 Location

(As presented in the site plan)

\* Layer-1 (from E.G.L to 4.50m 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

4.50m

14

Loose

31.20 Deg.

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

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Silty Fine Sand

Greyish

3.00m

26

Medium Dense

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

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

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Silty Fine Sand

Greyish

4.50m

39

Dense

38.475 Deg.

The ground water table was encountered at a depth of 4.10m 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	15	48

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