CHAPTER-3

SUB-SURFACE STRATIFICATION

3.0 Preamble

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

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

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1398/1 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	11	
Relative Density		Loose
Angle of Shearing Resistance, □		30.30 Deg.

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

Type of Strata		Silty Fine Sand
Colour		Greyish
Thickness of Layer		3.00m
SPT of the layer	24	
Relative Density		Medium Dense
Angle of Shearing Resistance, □		34.20 Deg.

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

Type of Strata		Silty Fine Sand
Colour		Greyish
Thickness of Layer		2.50m
SPT of the layer	34	
Relative Density		Dense
Angle of Shearing Resistance, □		37.10 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	53	
Relative Density		Very Dense
Angle of Shearing Resistance, □		41.45 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/m^2)	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.

CHAPTER-5

RECOMMENDATIONS

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

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

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER 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 :	11	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	30.30	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 19.29

N_γ = 23.94

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

Qu = Cu*Nc*Sc*Dc*Ic+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*γ*Nγ*Sγ*Dγ*Ig*w'

Q_u = 340.59 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	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 per I.S:1904

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CHAPTER-1

INTRODUCTION

1.0 Preamble

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

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

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- 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_4 contents.

(f) Swelling Pressure Tests & Free Swelling Index

(g) Bulk Density and Moisture Content

(h) Unconfined Compression Tests on Clay Soils

(i) Box Shear Test in case of sand

(j) Tri-Axial Shear Tests

Unconsolidated undrained.

Consolidated Undrained Test with the Pressure

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

1.1.2.2 Rock Samples

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

1.2 Structure of the Report

- Contents
- Introduction
- Investigation Methodology & Test Results

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

CHAPTER-2

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

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

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

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

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

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

2.3.1.3 Undisturbed Soil Samples

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

2.4 Laboratory Testing:
Soil Samples

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

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

2.4.2 Atterberg Limits

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

2.4.3 Specific Gravity

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

2.4.4 Chemical Tests on Water Sample

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

2.4.5 Swelling Pressure & Free Swell Tests

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

2.4.6 Bulk Density & Natural Moisture Content

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

2.4.7 **Unconfined Compression Tests**

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

2.4.8 **Box Shear Tests**

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

2.4.9 **Triaxial Shear Tests**

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

2.4.10 **Consolidation Tests**

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

Rock Samples

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

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HO/EN/Pre. (Works)/MTC
Location: At Chainage: 1399/1
Started On : 22/07/2008; Ended On : 23/07/2008 G.W.T: 7.60m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 2(3(4(5(6(7(8(90		
				1.50	6	8	9	17		M.Dense	SS
				3.00	UDS Sampler Installed					M.Dense	UDS
			Greyish Medium Dense Silty Fine Sand	4.50	6	9	11	20		M.Dense	SS
				6.00	5	5	8	13		M.Dense	SS
				7.50	9	11	14	25		M.Dense	SS
G.W.T	↓			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

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

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

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Table 2.1: Laboratory Test Results on the Soil Samples Collected from Chainage:1399/1 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-10.50	21	SS	Silty Sand	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	83	17	0	15.1	32.6	-	-	-	-	SM
10.50-12.00	34	SS	Silty Sand	8	-	-	-	-	2.66	-	19	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM

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)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.82	88.61	90.43

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CHAPTER-3

SUB-SURFACE STRATIFICATION

3.0 Preamble

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

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

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1399/1 Location

(As presented in the site plan)

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

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	10.50m
SPT of the layer	21
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.30 Deg.

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

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	34
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.10 Deg.

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/m^2)**	**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

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

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, ϕ:	32.10	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	9.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 24.66

N_γ = 33.16

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

Qu = Cu*Nc*Sc*Dc*Ic+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*γ*Nγ*Sγ*Dγ*Ig*w'

Q_u = 421.16 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 I.S:1904.

CHAPTER-1

INTRODUCTION

1.0 Preamble

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

This report includes field and Laboratory test results for the ***borehole location at Chainage: 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_4 contents.

(f) Swelling Pressure Tests & Free Swelling Index

(g) Bulk Density and Moisture Content

(h) Unconfined Compression Tests on Clay Soils

(i) Box Shear Test in case of sand

(j) Tri-Axial Shear Tests

Unconsolidated undrained.

Consolidated Undrained Test with the Pressure

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

1.1.2.2 Rock Samples

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

1.2 Structure of the Report

- ❖ Contents
- ❖ Introduction
- ❖ Investigation Methodology & Test Results

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

CHAPTER-2

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

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

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

The disturbed soil samples were collected as directed by the engineer-in-charge 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:

<u>Soil Samples</u>

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

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

2.4.2 Atterberg Limits

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

2.4.3 Specific Gravity

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

2.4.4 Chemical Tests on Water Sample

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

2.4.5 Swelling Pressure & Free Swell Tests

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

2.4.6 Bulk Density & Natural Moisture Content

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

2.4.7 Unconfined Compression Tests

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

2.4.8 Box Shear Tests

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

2.4.9 Triaxial Shear Tests

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

2.4.10 Consolidation Tests

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

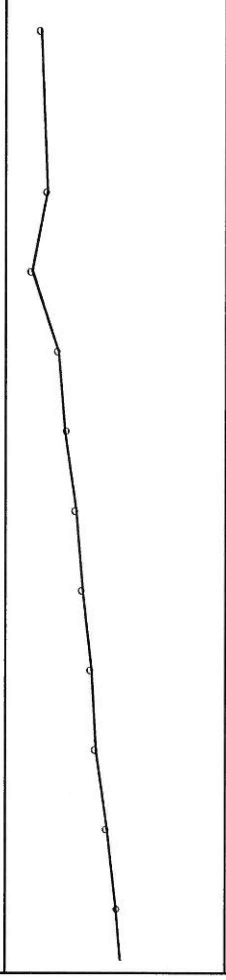
Rock Samples

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

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

Location: At Chainage: 1400/1

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

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP ## 10 2(3(4(5(6(7(8(90	Relative Density/Consistency	Type of Sample
			Greyish Medium Dense Silty Fine Sand	1.50	6	7	9	16		M.Dense	SS
G.W.T	↓			3.00	UDS Collected					M.Dense	SS
				4.50	7	9	10	19		M.Dense	SS
				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
			Greyish Dense Silty Fine Sand	12.00	13	16	18	34		Dense	SS
				13.50	13	17	21	38		Dense	SS
				15.00	15	18	22	40		Dense	SS
				16.50	16	20	25	45		Dense	SS
				18.00	18	23	27	50		Dense	SS
19.00											

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

Location: At Chainage: 1400/1

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

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT (## 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
			Greyish Very Dense Silty Fine Sand	19.50	19	27	29	56		V.Dense	SS
				21.00	21	30	34	64		V.Dense	SS
				22.50	22	32	36	68		V.Dense	SS
				24.00	24	37	42	79		V.Dense	SS
				25.50	25	40	45	85		V.Dense	SS
				27.00	27	40	45	85		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

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Chainage No. 1400/1 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-10.50	19	SS	Silty Sand	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	82	18	0	15.9	32.0	-	-	-	-	SM
10.50-19.00	40	SS	Silty Sand	9	-	-	-	-	2.66	-	19	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM
19.00-30.00	75	SS	Silty Sand	5	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

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)**	**pH**	**Chlorides(ppm)**	**Sulphates (ppm)**
BH-01	4.50	7.85	78.53	67.30

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CHAPTER-3

SUB-SURFACE STRATIFICATION

3.0 Preamble

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

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

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1400/1 Location (As presented in the site plan)

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

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	10.50m
SPT of the layer	19
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.70 Deg.

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

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	8.50m
SPT of the layer	40
Relative Density	Dense
Angle of Shearing Resistance, ϕ	38.75 Deg.

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

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

The ground water table was encountered at a depth of 3.50m within the explored depth of investigation in the fourth 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 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 Pile (mm)	Safe Load Carrying Capacity (kN)	Safe Pull Out carrying Capacity (kN)	Safe Lateral Load carrying Capacity (kN)
1	1000	11000	3043	550

The details of the computations are annexed to this report.

CHAPTER-5

RECOMMENDATIONS

1. 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.
5. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

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

1.0 Type of Installation of Pile — **Bored Cast in Situ**

1.1 Geometrical Data

Assumed Diameter of pile(D):	**1000.0**	mm
Assumed R.L of E.G.L:	0.000	m
Length of pile below E.G.L.(l) :	**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,γ:	17	kN/m^3
Angle of Shearing Resistance,ϕ:	32.7	Deg.
Depth of top of Strata:	0.00	m
Depth of bottom of Strata:	10.50	m
Average Thickness of Strata,I_c:	10.50	m
Effective overburden pressure over the top of strata,σ_{top}:	0.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	73.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	36.75	kN/m^2
Coeff. Of Earth Pressure,k:	1.50	
Skin Resistance of the pile,q_s:	1167.39	kN
(q_s:σ*k*tanϕ*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/m^3
Angle of Shearing Resistance,ϕ:	38.75	Deg.
Depth of top of Strata:	10.50	m
Depth of bottom of Strata:	19.00	m
Average Thickness of Strata,I_c:	8.50	m
Effective overburden pressure over the top of strata,σ_{top}:	73.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	150.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	111.75	kN/m^2
Coeff. Of Earth Pressure,k:	1.50	
Skin Resistance of the pile,q_s:	3592.5	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.3 **Layer-III**

Type of Strata:	Silty Sand	
Average SPT of the strata,N:	60	
Bulk Density of the strata,γ:	20	kN/m^3
Angle of Shearing Resistance,ϕ:	42.5	Deg.
Depth of top of Strata:	19.00	m
Depth of bottom of Strata:	22.00	m
Average Thickness of Strata,I_c:	3.00	m
Effective overburden pressure over the top of strata,σ_{top}:	150.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	180.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	165.00	kN/m^2
Coeff. Of Earth Pressure,k:	2.00	
Skin Resistance of the pile,q_s:	2850.0	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		
Ultimate Skin Resistance,q_s:	**7609.9**	**kN**

1.2.2 Computation of End Bearing Resistance:

Type of Bearing Strata	Silty Sand	
Cross-Sectional Area of pile,Ap:	0.785	m^2
R.L of bottom of pile:	-22.00	
Minimum SPT-value of the Bearing Strata	60	
Angle of Shearing Resistance(ASR)	42.50	Degrees
Bearing Capacity Factor(Nq)	220.00	
Effecitve Over Burden Pressure at the bottom of pile (q)	120.00	kPa
(limited to a maximum value produced by a soil layer of thickness equal to 20 times the diameter of pile from the N.G.L.)		
Ultimate End Bearing Resistance (Qp)	**20734.5**	**kN**
(Qp=Ap*q*Nq)		

1.3.0

Ultimate Load Carrying Capacity (Qu=Qp+q_p)	**28344.4**	**kN**
Safe Load Carrying Capacity (Qsafe =Qu/2.5)	**11337.7**	**kN**
However, limit Q_{safe} to the structural capacity of pile:	**11000.0**	**kN**

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: 1400/2** in the proposed construction area like Major, Minor Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.*

1.1 Scope of Work

1.1.1 Field Work

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

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- ❖ 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_4 contents.

(f) Swelling Pressure Tests & Free Swelling Index

(g) Bulk Density and Moisture Content

(h) Unconfined Compression Tests on Clay Soils

(i) Box Shear Test in case of sand

(j) Tri-Axial Shear Tests

Unconsolidated undrained.

Consolidated Undrained Test with the Pressure

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

1.1.2.2 Rock Samples

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

1.2 Structure of the Report

- ❖ Contents
- ❖ Introduction
- ❖ Investigation Methodology & Test Results

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

CHAPTER-2

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

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

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

The disturbed soil samples were collected as directed by the engineer-in-charge 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:

<u>Soil Samples</u>

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.

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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.

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

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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.

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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.

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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.

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

Rock Samples

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

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

Location: At Chainage: 1400/2

Started On : 20/07/2008; Ended On : 22/07/2008 G.W.T: 2.00m

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 Loose Silty Fine Sand	1.50	6	7	8	15	Loose	SS
G.W.T	↓			3.00	UDS Collected				M.Dense	SS
3.50			Greyish Medium Dense Silty Fine Sand	4.50	7	9	9	18	M.Dense	SS
				6.00	8	9	10	19	M.Dense	SS
				7.50	10	12	17	29	M.Dense	SS
9.00				9.00	10	16	19	35	Dense	SS
			Greyish Dense Silty Fine Sand	10.50	13	16	21	37	Dense	SS
				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 Dense Silty Fine Sand	16.50	19	29	30	59	V.Dense	SS
				18.00	22	30	35	65	V.Dense	SS

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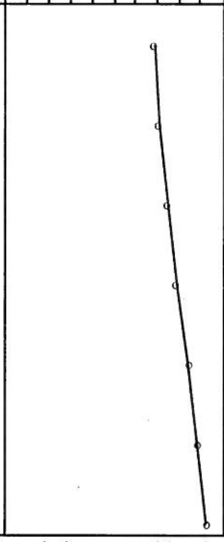
Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC
Location: At Chainage:1400/2
Started On : 20/07/2008; Ended On : 22/07/2008 G.W.T: 2.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SPT	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 20 30 40 50 60 70 80 90		
			Greyish Very Dense Silty Fine Sand	19.50	24	31	36	67		V.Dense	SS
				21.00	24	32	37	69		V.Dense	SS
				22.50	23	34	39	73		V.Dense	SS
				24.00	27	37	40	77		V.Dense	SS
				25.50	28	40	43	83		V.Dense	SS
				27.00	30	43	44	87		V.Dense	SS
30.00				29.50	30	45	46	91		V.Dense	SS



Bore Hole Terminated at a depth of 30.00m below the existing ground level

Fig. 2.1 Soil Profile at Chainage:1400/2 Location

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Table 2.1: Laboratory Test Results on the Soil Samples Collected from Chainage No. 1400/2 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-3.50	15	SS	Silty Sand	12	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	87	13	0	14.8	29.8	-	-	-	-	SM
3.50-9.00	22	SS	Silty Sand	10	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM
9.00-15.00	40	SS	Silty Sand	8	-	-	-	-	2.65	-	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM
15.00-30.00	68	SS	Silty Sand	6	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	74	26	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage No. 1400/2				
Location of Bore Hole	**Depth of Sample below E.G.L. (m)**	**pH**	**Chlorides(ppm)**	**Sulphates (ppm)**
BH-01	4.50	7.87	48.99	70.09

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CHAPTER-3

SUB-SURFACE STRATIFICATION

3.0 Preamble

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

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

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-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	5.50m
SPT of the layer	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 Greyish

Thickness of Layer	6.00m
SPT of the layer	40
Relative Density	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
Angle of Shearing Resistance, □	42.50 Deg.

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.

CHAPTER-4

FOUNDATION SYSTEM

4.0 Preamble

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

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

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

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

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

4.2 Foundation System

4.2.1 Deep Foundation System

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

Hence, the foundation system can be 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 Pile (mm)**	**Safe Load Carrying Capacity (kN)**	**Safe Pull Out carrying Capacity (kN)**	**Safe Lateral Load carrying Capacity (kN)**
1	1000	10000	2140	500

The details of the computations are annexed to this report.

CHAPTER-5

RECOMMENDATIONS

1. 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.
5. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

DESIGN OF PILE FOUNDATION(Refer:BH-01)

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

1.0 Type of Installation of Pile **Bored Cast in Situ**

1.1 Geometrical Data

Assumed Diameter of pile(D):	**1000.0**	mm
Assumed R.L of E.G.L:	0.000	m
Length of pile below E.G.L.(l) :	**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	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	31.5	Deg.
Depth of top of Strata:	0.00	m
Depth of bottom of Strata:	3.50	m
Average Thickness of Strata,I_c:	3.50	m
Effective overburden pressure over the top of strata,σ_{top}:	0.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	17.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	8.75	kN/m^2
Coeff. Of Earth Pressure,k:	1.00	
Skin Resistance of the pile,q_s:	58.96	kN
(q_s:σ*k*tanϕ*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,γ:	17	kN/m^3
Angle of Shearing Resistance,ϕ:	33.6	Deg.
Depth of top of Strata:	3.50	m
Depth of bottom of Strata:	9.00	m
Average Thickness of Strata,I_c:	5.50	m
Effective overburden pressure over the top of strata,σ_{top}:	17.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	56.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	36.75	kN/m^2
Coeff. Of Earth Pressure,k:	1.50	
Skin Resistance of the pile,q_s:	632.8	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.3 **Layer-III**

Type of Strata:	Silty Sand	
Average SPT of the strata,N:	40	
Bulk Density of the strata,γ:	19	kN/m^3
Angle of Shearing Resistance,ϕ:	38.75	Deg.
Depth of top of Strata:	9.00	m
Depth of bottom of Strata:	15.00	m
Average Thickness of Strata,I_c:	6.00	m
Effective overburden pressure over the top of strata,σ_{top}:	56.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	110.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	83.00	kN/m^2
Coeff. Of Earth Pressure,k:	2.00	
Skin Resistance of the pile,q_s:	2511.3	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.4 **Layer-IV**

Type of Strata:	Silty Sand	
Average SPT of the strata,N:	59	
Bulk Density of the strata,γ:	20	kN/m^3
Angle of Shearing Resistance,ϕ:	42.35	Deg.
Depth of top of Strata:	15.00	m
Depth of bottom of Strata:	18.00	m
Average Thickness of Strata,I_c:	3.00	m
Effective overburden pressure over the top of strata,σ_{top}:	110.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	140.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	125.00	kN/m^2
Coeff. Of Earth Pressure,k:	2.00	
Skin Resistance of the pile,q_s:	2147.7	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		
Ultimate Skin Resistance,q_s:	**5350.8**	**kN**

1.2.2 Computation of End Bearing Resistance:

Type of Bearing Strata	Silty Sand	
Cross-Sectional Area of pile,Ap:	0.785	m^2
R.L of bottom of pile:	-18.00	
Minimum SPT-value of the Bearing Strata	65	
Angle of Shearing Resistance(ASR)	42.50	Degrees
Bearing Capacity Factor(Nq)	220.00	
Effecitve Over Burden Pressure at the bottom of pile (q) **(limited to a maximum value produced by a soil layer of thickness equal to 20 times the diameter of pile from the N.G.L.)**	120.00	kPa
Ultimate End Bearing Resistance (Qp)	**20734.5**	**kN**
(Qp=Ap*q*Nq)		

1.3.0

Ultimate Load Carrying Capacity (Qu=Qp+q_p)	**26085.3**	**kN**
Safe Load Carrying Capacity (Qsafe =Qu/2.5)	**10434.1**	**kN**
However, limit Q_{safe} to the structural capacity of pile:	**10000.0**	**kN**

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.

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- ❖ 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_4 contents.

(f) Swelling Pressure Tests & Free Swelling Index

(g) Bulk Density and Moisture Content

(h) Unconfined Compression Tests on Clay Soils

(i) Box Shear Test in case of sand

(j) Tri-Axial Shear Tests

Unconsolidated undrained.

Consolidated Undrained Test with the Pressure

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

1.1.2.2 Rock Samples

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

1.2 Structure of the Report

- ❖ Contents
- ❖ Introduction
- ❖ Investigation Methodology & Test Results

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

CHAPTER-2

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

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

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

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

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

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

2.3.1.3 Undisturbed Soil Samples

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

2.4 Laboratory Testing:

Soil Samples

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

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

2.4.2 Atterberg Limits

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

2.4.3 Specific Gravity

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

2.4.4 Chemical Tests on Water Sample

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

2.4.5 Swelling Pressure & Free Swell Tests

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

2.4.6 Bulk Density & Natural Moisture Content

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

2.4.7 Unconfined Compression Tests

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

2.4.8 Box Shear Tests

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

2.4.9 Triaxial Shear Tests

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

2.4.10 Consolidation Tests

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

Rock Samples

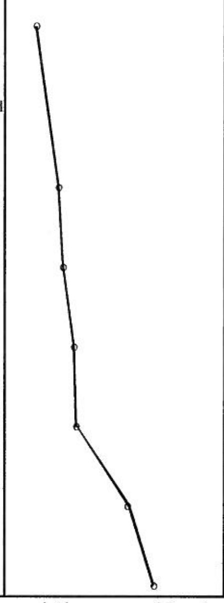
As no rock strata were encountered at the investigation locations, no tests on rock samples could be conducted.

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

Location: At Chainage: 1401/1

Started On : 17/07/2008; Ended On : 18/07/2008 G.W.T: 2.60m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SPT	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 20 30 40 50 60 70 80 90		
				1.50	7	6	9	15		Loose	SS
G.W.T	↓		Greyish to Brownish Loose Silty Clayey Fine Sand	3.00	UDS Sampler Installed					Loose	UDS
4.50				4.50	7	11	14	25		M.Dense	SS
			Greyish Medium Dense Silty Fine Sand	6.00	11	13	14	27		M.Dense	SS
7.50				7.50	13	15	17	32		M.Dense	SS
			Greyish Dense Silty Fine Sand	9.00	13	16	17	33		Dense	SS
10.00											
			Greyish Very Dense Silty Fine Sand	10.50	20	26	30	56		V.Dense	SS
12.00				12.00	26	31	37	68		V.Dense	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

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Chainage:1401/1 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	15	SS	Silty Clayey Sand	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	81	11	8	12.8	29.7	-	-	-	-	SM
4.50-7.50	26	SS	Silty Sand	11	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM
7.50-10.00	32	SS	Silty Sand	9	-	-	-	-	2.66	-	19	-	-	Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM
10.00-12.00	56	SS	Silty Sand	8	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	72	28	0	-	-	-	-	-	-	SM

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Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Chainage:1401/1				
Location of Bore Hole	**Depth of Sample below E.G.L. (m)**	**pH**	**Chlorides(ppm)**	**Sulphates (ppm)**
BH-01	3.00	7.87	33.67	50.92

CHAPTER-3

SUB-SURFACE STRATIFICATION

3.0 Preamble

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

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

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-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)**

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)**

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/m^2)	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

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

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

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER 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, ϕ:	31.50	Deg

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 22.87

N_γ = 30.09

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

Qu = Cu*Nc*Sc*Dc*Ic+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*γ*Nγ*Sγ*Dγ*Ig*w'

Q_u = 410.14 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	164.06	kPa
Limited to an allowable bearing pressure per running meter width:	160.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 160kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 160kPa and SPT of 15 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

CHAPTER-1

INTRODUCTION

1.0 Preamble

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

This report includes field and Laboratory test results for the ***borehole location at Chainage: 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_4 contents.

(f) Swelling Pressure Tests & Free Swelling Index

(g) Bulk Density and Moisture Content

(h) Unconfined Compression Tests on Clay Soils

(i) Box Shear Test in case of sand

(j) Tri-Axial Shear Tests

Unconsolidated undrained.

Consolidated Undrained Test with the Pressure

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

1.1.2.2 Rock Samples

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

1.2 Structure of the Report

- ❖ Contents
- ❖ Introduction
- ❖ Investigation Methodology & Test Results

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

CHAPTER-2

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

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

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

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

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

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

2.3.1.3 Undisturbed Soil Samples

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

2.4 Laboratory Testing:
Soil Samples

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

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

2.4.2 Atterberg Limits

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

2.4.3 Specific Gravity

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

2.4.4 Chemical Tests on Water Sample

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

2.4.5 Swelling Pressure & Free Swell Tests

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

2.4.6 Bulk Density & Natural Moisture Content

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

2.4.7 Unconfined Compression Tests

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

2.4.8 Box Shear Tests

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

2.4.9 Triaxial Shear Tests

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

2.4.10 Consolidation Tests

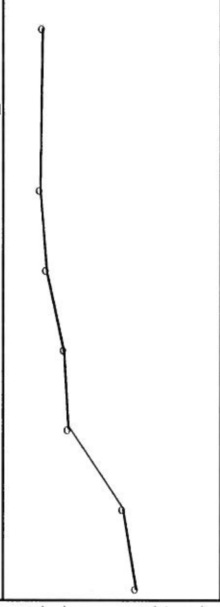
These tests are conducted to determine the compressibility characteristics of the soil. The tests are conducted in a consolidation cell with minimum diameter to thickness ratio as 3. The thickness of soil sample is taken as 20mm to get uniform distribution of pressure on the soil sample. As no fine-grained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

Rock Samples

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

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC
Location: At Chainage: 1402/1
Started On : 17/07/2008; Ended On : 17/07/2008 G.W.T: 5.65m

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	Graphical Representation of SPT (## 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
			Greyish Medium Dense Silty Fine Sand	1.50	7	7	10	17		M.Dense	SS
				3.00	UDS Sampler Installed					M.Dense	UDS
				4.50	6	8	8	16		M.Dense	SS
G.W.T	↓			6.00	6	9	10	19		M.Dense	SS
				7.50	10	13	14	27		M.Dense	SS
				9.00	12	13	16	29		M.Dense	SS
10.00			Greyish Very Dense Silty Fine Sand	10.50	18	26	29	55		V.Dense	SS
12.00				12.00	21	27	34	61		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

0521

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Chainage:1402/1 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-10.00	22	SS	Silty Sand	11	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	83	17	0	14.6	32.8	-	-	-	-	SM
10.00-12.00	55	SS	Silty Sand	8	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	74	26	0	-	-	-	-	-	-	SM

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)**	**pH**	**Chlorides(ppm)**	**Sulphates (ppm)**
BH-01	6.00	7.88	30.23	45.33

CHAPTER-3

SUB-SURFACE STRATIFICATION

3.0 Preamble

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

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

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-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, ϕ	33.60 Deg.

* **Layer-2 (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	55
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	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/m^2)**	**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 I.S: 1904. The details of the computations are annexed to this report.

CHAPTER-5

RECOMMENDATIONS

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

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, ϕ:	32.10	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	7.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 24.66

N_γ = 33.16

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

Qu = Cu*Nc*Sc*Dc*Ic+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*γ*Nγ*Sγ*Dγ*Ig*w'

Q_u = 364.78 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	145.91	kPa
Limited to an allowable bearing pressure per running meter width:	140.00	kPa

2 Settlements

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

CHAPTER-1

INTRODUCTION

1.0 Preamble

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

*This report includes field and Laboratory test results for the **borehole location at Chainage: 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_4 contents.

(f) Swelling Pressure Tests & Free Swelling Index

(g) Bulk Density and Moisture Content

(h) Unconfined Compression Tests on Clay Soils

(i) Box Shear Test in case of sand

(j) Tri-Axial Shear Tests

Unconsolidated undrained.

Consolidated Undrained Test with the Pressure

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

1.1.2.2 Rock Samples

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

1.2 Structure of the Report

- ❖ Contents
- ❖ Introduction
- ❖ Investigation Methodology & Test Results

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

CHAPTER-2

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

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

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

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

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

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

2.3.1.3 Undisturbed Soil Samples

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

2.4 Laboratory Testing:

Soil Samples

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

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

2.4.2 Atterberg Limits

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

2.4.3 Specific Gravity

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

2.4.4 Chemical Tests on Water Sample

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

2.4.5 Swelling Pressure & Free Swell Tests

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

2.4.6 Bulk Density & Natural Moisture Content

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

2.4.7 Unconfined Compression Tests

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

2.4.8 Box Shear Tests

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

2.4.9 Triaxial Shear Tests

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

2.4.10 Consolidation Tests

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

Rock Samples

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

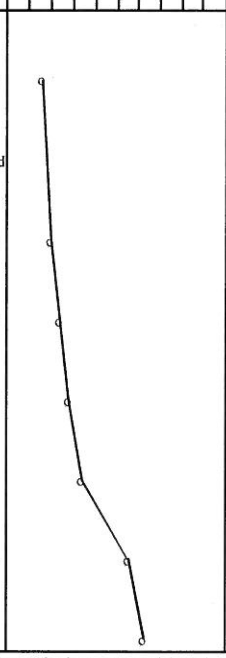
Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC

Location: At Chainage: 1403/1

Started On : 16/07/2008; Ended On : 17/07/2008 G.W.T: 4.95m

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 to Brownish Loose Silty Clayey Fine Sand	1.50	7	6	9	15	Loose	SS
				3.00	UDS Sampler Installed				Loose	UDS
4.50				4.50	6	8	11	19	M.Dense	SS
G.W.T			Greyish Medium Dense Silty Fine Sand	6.00	9	10	13	23	M.Dense	SS
				7.50	8	12	15	27	M.Dense	SS
8.50			Greyish Dense Silty Fine Sand	9.00	11	14	19	33	Dense	SS
10.00			Greyish Very Dense Silty Fine Sand	10.50	20	27	29	56	V.Dense	SS
12.00				12.00	24	26	37	63	V.Dense	SS

Graphical Representation of SPT: ## 10 20 30 40 50 60 70 80 90



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

Fig. 2.1 Soil Profile at Chainage:1403/1 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Chainage:1403/1 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	15	SS	Silty Clayey Sand	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	84	10	6	11.7	29.8	-	-	-	-	SM
4.50-8.50	23	SS	Silty Sand	11	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM
8.50-10.00	33	SS	Silty Sand	8	-	-	-	-	2.66	-	19	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM
10.00-12.00	56	SS	Silty Sand	7	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	73	27	0	-	-	-	-	-	-	SM

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)**	**pH**	**Chlorides(ppm)**	**Sulphates (ppm)**
BH-01	6.00	7.88	32.59	46.73

CHAPTER-3

SUB-SURFACE STRATIFICATION

3.0 Preamble

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

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

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1403/1 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 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
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, ϕ	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, 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/m^2)**	**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

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

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

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER 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, ϕ:	31.50	Deg

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 22.87

N_γ = 30.09

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

Qu = Cu*Nc*Sc*Dc*Ic+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*γ*Nγ*Sγ*Dγ*Ig*w'

Q_u = 410.14 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	164.06	kPa
Limited to an allowable bearing pressure per running meter width:	160.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 160kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 160kPa and SPT of 15 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904

CHAPTER-1

INTRODUCTION

1.0 Preamble

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

*This report includes field and Laboratory test results for the **borehole location at Chainage: 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_4 contents.

(f) Swelling Pressure Tests & Free Swelling Index

(g) Bulk Density and Moisture Content

(h) Unconfined Compression Tests on Clay Soils

(i) Box Shear Test in case of sand

(j) Tri-Axial Shear Tests

Unconsolidated undrained.

Consolidated Undrained Test with the Pressure

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

1.1.2.2 Rock Samples

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

1.2 Structure of the Report

- ❖ Contents
- ❖ Introduction
- ❖ Investigation Methodology & Test Results

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

CHAPTER-2

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

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

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

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

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

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

2.3.1.3 Undisturbed Soil Samples

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

2.4 Laboratory Testing:

Soil Samples

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

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

2.4.2 Atterberg Limits

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

2.4.3 Specific Gravity

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

2.4.4 Chemical Tests on Water Sample

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

2.4.5 Swelling Pressure & Free Swell Tests

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

2.4.6 Bulk Density & Natural Moisture Content

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

2.4.7 **Unconfined Compression Tests**

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

2.4.8 **Box Shear Tests**

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

2.4.9 **Triaxial Shear Tests**

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

2.4.10 **Consolidation Tests**

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

Rock Samples

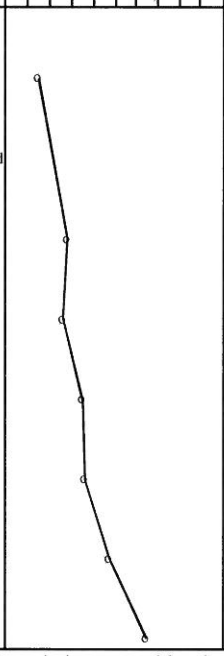
As no rock strata were encountered at the investigation locations, no tests on rock samples could be conducted.

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

Location: At Chainage: 1404/1

Started On : 16/07/2008; Ended On : 17/07/2008 G.W.T: 4.10m

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	Graphical Representation of SPT (## 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
				1.50	6	5	9	14		Loose	SS
			Greyish to Brownish Loose Silty Clayey Fine Sand	3.00	UDS Sampler Installed					Loose	UDS
G.W.T 4.50	↓			4.50	8	10	17	27		M.Dense	SS
			Greyish Medium Dense Silty Fine Sand	6.00	7	12	13	25		M.Dense	SS
7.50				7.50	10	16	18	34		Dense	SS
				9.00	10	15	20	35		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

0551

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Chainage:1404/1 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	14	SS	Silty Clayey Sand	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	83	11	6	12.4	30.6	-	-	-	-	SM
4.50-7.50	26	SS	Silty Sand	10	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM
7.50-12.00	39	SS	Silty Sand	8	-	-	-	-	2.65	-	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

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)**	**pH**	**Chlorides(ppm)**	**Sulphates (ppm)**
BH-01	6.00	7.86	60.33	79.37

CHAPTER-3

SUB-SURFACE STRATIFICATION

3.0 Preamble

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

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

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-1404/1 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	14
Relative Density	Loose
Angle of Shearing Resistance, ϕ	31.20 Deg.

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

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	26
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.80 Deg.

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

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	39
Relative Density	Dense
Angle of Shearing Resistance, ϕ	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/m^2)**	**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.