REPORT

ON

GEOTECHNICAL INVESTIGATIONS

FOR

CONSTRUCTION OF 84 M SPAN 1.5 LANE CLASS A LOADING STEEL TRUSS MOTOR BRIDGE

OVER

KOTIGAD RIVER AT KM 01 OF TIKOCHI-DUCHANU- KIRANU- SIRTOLI MOTOR ROAD IN DISTRICT UTTARKASHI, UTTARAKHAND

SUBMITTED TO:

M/s TONS BUILDERS
DEHRADUN

SUBMITTED BY:

TECHNICAL CONSULTANCY SERVICES
An ISO: 9001-2015 Certified Consultancy Organisation

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ACKNOWLEDGEMENT

We are thankful to M/s Tons Builders for providing us an opportunity to carry out the Geotechnical investigation for construction of a 84 m Span 1.5 Lane Class-A Loading Steel Truss Motor Bridge Kotigad River at Km 01 of Tikochi- Duchanu-Kiranu- Sirtoli Motor Road in District Uttarkashi, Uttarakhand & also for kind cooperation of concerned Engineers during the tests.

For TECHNICAL CONSULTANCY SERVICES,

TECHNICAL CONSULTANCY SERVICES DEHRADUN

(PROJECT COORDINATOR)

CONTENTS

1.0 INTRODUCTION

The work of geotechnical Investigation for proposed construction of 84 m Span 1.5 Lane Class-A Loading Steel Truss Motor Bridge over Kotigad River at Km 01 of Tikochi-Duchanu- Kiranu- Sirtoli Motor Road in District Uttarkashi, Uttarakhand, India has been awarded to M/s Technical Consultancy Services, Dehradun by M/s Tons Builders, Contractor. This report presents the details of geotechnical Investigation carried out and data of results obtained from various field and laboratory tests, their computation, compilation, analysis and suitable recommendations.

2.0 OBJECT OF INVESTIGATIONS

To establish the parameters for the foundation design of the structure, various properties and parameters of the sub-strata at the site are required. These parameters are achieved through geo-technical investigations by drilling boreholes through at the site, carrying field/in-situ tests in the boreholes and collection of samples and conduction of laboratory tests on the samples to assess engineering properties and physical characteristics of the soil and rock strata. The basic details that can be derived from the geotechnical investigations are as follow ---

1. Sub-surface conditions which will reflect the thickness of the different soil strata.
2. Depth of ground water table.
3. Safe bearing capacity of the soil.
4. Depth of foundations.
5. Suitable type of foundations.
6. Requirement, if any, for any treatment needed to enhance the engineering properties of the soil.

3.0 SCOPE OF WORK

The scope of work proposed was:

i) Boring using spiral earth Auger or Core Drilling upto the required depth as per IRC:78 upto the required depth or depth of refusal (5 m inside Rock), whichever is met earlier including collection of soil/rock samples for laboratory testing.

ii) Conducting necessary laboratory tests on soil and rock samples collected as above, recording water table and submission of report based on above tests.

recommending suitable type & depth of foundation & safe bearing capacity of strata in 2 copies.

4.0 ORGANIZATION OF REPORT

The chapter 'introduction' describes the details of the project and various contents of this study. Details of various field and laboratory tests are given in the following two chapters. Findings obtained during these tests are summarized in the next chapter.

'Foundation Analysis' is an important chapter dealing with all design calculations required for the foundation selection and design. Recommendations are finalized in the concluding chapter.

Various table, figures and graphs are given in quite an explanatory mode. A list of Indian Standard Codes, which are referred throughout the study, is also attached at the end of this report.

5.0 FIELD WORK

5.1 Introduction

Drilling with Standard Penetration Tests and extraction of soil and Rock samples/ cores for Laboratory determination of compressive strength and other parameters.

Table – 1 The summary of field investigation results of boreholes

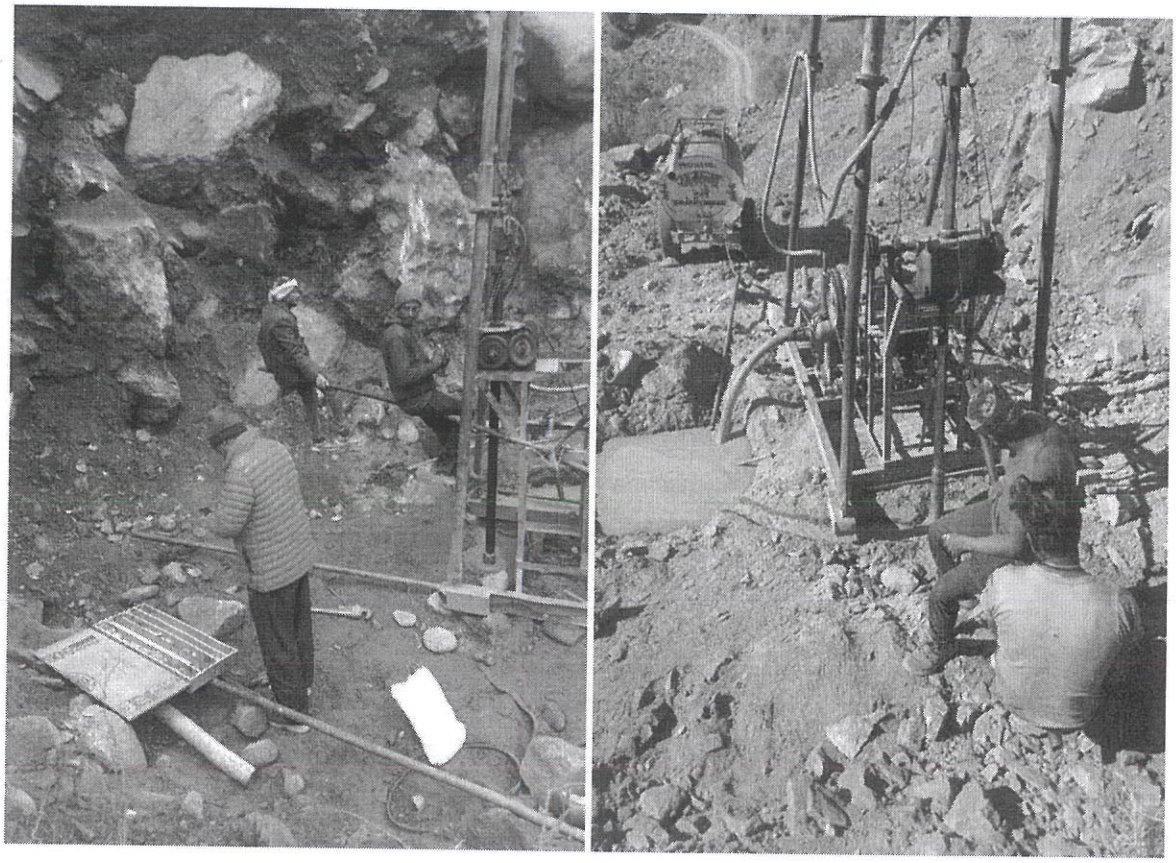
S. No.	Location	RL of Borehole	BH. No.	Water Table (RL)	Terminated depth of Borehole
1	Abutment A-1	1498.00m	BH-1	Not Encountered	15.0m
2	Abutment A-2	1505.10m	BH-2	Not Encountered	10.0m

5.2 Boring

The necessary equipment and team were mobilized to the site for carrying out the required field work. The location of borehole and borehole depths were given by the engineer – in – charge on the basis of field observations and site conditions. The proposed depths of borehole drilling and field tests at regular intervals following the relevant code were carried out in the presence of the representative of site-in-charge. Figure 1 shows the borehole location plan.

The boring/drilling operation has been carried out by deploying rotary drilling rig using Rotary Drilling method below the existing ground surface as per directions of Engineer-in-Charge. The sampling work comprises of collection of disturbed samples (DS) as

obtained from SPT split spoon sampler and undisturbed samples (UDS) in accordance with IS: 2132. Temporary MS casing as required has been placed to support borehole.



BH-1 (A-1) **BH-2 (A-2)**

Figure 1- Field photograph shows the location of borehole and drilling setup

Upon encountering rock strata, core drilling has been carried out using minimum double tube core barrel to extract the recovery of the core. Collection & preservation of core samples has been done as specified in the standard and also recorded core recovery (%) and computed rock quality designation (RQD) (%).

The details of the bore hole / tests conducted at site are given below. The standard penetration tests are planned to carry in soil strata at every 1.5 m intervals. However, the soil layer was observed up to 0.5 depth m from the ground surface which is termed as top soil and beyond this the rock strata was encountered up to a depth of termination, 10 m at BH-2 location. Poorly graded sandy gravels with cobbles and scattered boulders met upto 1.60m depth inside BH-1 followed by sandy gravels in the matrix of compact boulder strata met upto 15.0m explored depth inside BH-1.

Upon encountering the rock strata, the core drilling has been carried out by using double core barrel. The core pieces recovered from drilling have been collected for every 1.5 m and preserved in the core boxes as enclosed in the bore logs sheet. From the core extraction, total core recovery as expressed in (%) has been calculated as the ratio of the

cumulative length of core including non-intact core recovered to the total length of core run.

Rock Quality Designation (RQD) expressed as a percentage of total core run has been calculated as a quantitative index based on core recovery procedure that incorporates only those pieces of core 100mm or more in length.

The borehole records with visual litho logs, sampling details, Core recovery (CR) and Rock quality designation (RQD) values and detailed results of laboratory tests conducted on soil and rock samples are given in table 2.

6.0 GROUND WATER TABLE

Ground water table was not encountered inside drill holes at the time of geotechnical investigation.

7.0 LABORATORY TESTS

Following laboratory tests on selected rock core samples collected from the test locations were conducted: -

S. No.	Name of Test	IS Code No.
1.	Bulk density	IS:2720 Part-II
2.	Specific Gravity	IS:2720 Part-III
3.	Porosity & Void Ratio	By Calculations
4.	Water absorption	IS:2720 Part-II
5.	Unconfined compression test.	IS:9143
6.	Point load strength index	IS:8764

The laboratory tests aim to obtain the following characteristics of different layers in overburden/ soil strata:

a) Grain size analysis, hydrometer analysis, liquid limit, plastic limit, specific gravity tests, consolidation, shear tests etc. were conducted for obtaining properties of the soil samples.

b) Chemical analysis of soil and water samples to determine pH, sulphate and chloride content to decide any precautionary measures for protecting the concrete and reinforcement.

The laboratory tests results for all the boreholes were given in Annexure.

Laboratory tests were conducted as per the procedures given in relevant IS codes. **Sieve analysis was carried out ignoring particle size > 22.4mm.**

CHEMICAL ANALYSIS OF SOIL SAMPLES

Soil samples were collected from the boreholes and analysed chemically for contents of pH, Sulphates and chlorides. The results are tabulated below:

Table 2

Summary of laboratory chemical test results of Soil Samples

pH	Chlorides (%)	Sulphate (%)	Carbonate (%)	Bi Carbonate (%)
7.78- 8.43	0.0070- 0.0113	0.0043- 0.0066	18- 26	13- 26

8.0 DISCUSSIONS OF TEST RESULTS

8.1 Borehole

The classification of subsoil strata met at this site was done according to IS: 1498-1970. The test results can be summarized as below-

BH-1 (A-1) Location:

The subsoil strata from 0.0 to 1.60 m depth consist overburden of poorly graded sandy gravels with cobbles and boulders strata followed by sandy gravels in the matrix of compact boulder strata upto the depth explored.

BH-2 (A-2) Location:

The subsoil strata consist of highly to moderately weathered/ intensely fractured rock strata up to 2.20m depth further followed by partly fractured hard rock strata upto the depth explored.

Depth, m		Soil Classification	Range of N value	Soil properties
From	To			
Borehole-1 (A1) 0.00	1.60	Overburden silty-sandy gravels with cobbles & Boulders	>100	C= 0 Phi= 30- 32°
1.70	15.0	sandy gravels in the matrix of compact boulder strata*	Refusal	Core Rec=28-42% C= 0, phi =34- 36^0
Borehole-2 (A2) 0.0	2.20	Overburden with Highly weathered/ fractured Rock	76- >100	Core Rec=16-26% RQD=0
2.30	10.0	Partly fractured hard rock*	Refusal	Core Rec=62-86% RQD=31- 49
WATER TABLE: Water Table was not met upto depth explored.				

Table no. 3 Borehole Wise Details of Subsoil Strata

The layer wise properties of the subsurface strata encountered at this site are given in following table no. 3.

Depth, m		Unit Weight, gm/cc	Field Parameters		Laboratory Parameters
From	To		Core Rec	RQD	
Borehole-1 (A1) 0.00	1.60	..	8- 12%	Nil	C= 0 Phi= 30- 32°
1.70	15.0	2.64- 2.68	28-42%	0	C= 0, phi =34- 36°
Borehole-2 (A2) 0.0	2.20	..	16- 26%	Nil	PLS= 2.2kg/ cm^2
2.30	10.0	2.62- 2.66	62- 86%	31- 49%	qc=300- 400kg/cm^2

Table No.4 Layer wise Properties of Subsoil Strata

The Detailed description of sub-surface strata encountered along with various laboratory test results are presented in the above table 2. The bore logs are enclosed at the end of this report. The subsurface profile depicting the distribution of the various lithological layers along the total core recovery and RQD values and other laboratory test parameters are given in detail in the bore logs.

8.2 Proposed depth & type of foundations:

Depending upon the visual examination of soil & field strata, field and laboratory test results and the type of structures proposed at this site, the safe bearing capacity of sub-soil strata Raft footing/open foundation have been analyzed. The details of the proposed foundations are presented in the following paragraph:

Open foundations and raft foundations bearing on the underlying compact rock formation are suitable foundation schemes. We recommend a minimum foundation level as 1490.00m for L.H.S. Abutment A-1 and 1503.00m for R.H.S. Abutment A-2 (Please refer GAD).

The founding levels of various structures should be decided based on the ground levels and the rock characteristics. It should be ensured that the foundations are seated on the natural undisturbed rock/ Strata. Any loose pockets, soils, disturbed materials etc., encountered at founding levels should be removed and replaced by lean concrete.

9.0 COMPUTATION OF SAFE BEARING CAPACITY

Computation of Safe Bearing Capacity at BH-1 Location: Detailed calculation is given as below and recommended values are given below:

9.01 Computation of Safe Bearing Capacity at BH-1 and BH-2 Locations:

Detailed calculation is given as below and recommended values are given below:

1. CALCULATION OF MAXIMUM LEVEL OF SCOUR:

CALCULATION OF SILT FACTOR as per IRC 78-2014			
TABLE A (SAMPLE 1 from BH-1)			
Sieve Designation	**Sieve Opening (mm)**	**Weight of Soil retained (gm)**	**Per cent retained**
5.60mm	5.60	125.00	15.63
4.00mm.	4.00	275.00	34.38
2.80mm.	2.80	142.00	17.75
1.00mm.	1.00	111.00	13.88
425 micron	0.43	26.00	3.25
180 micron	0.18	31.00	3.88
75 micron	0.75	65.00	8.13
Pan -		25.00	3.13
Total:		**800.00**	

TABLE B			
Sieve No.	**Avrage size (mm.)**	**Percentage of weight retained**	**Column (2 x column (3)**
5.60 to 4.00mm	4.80	34.38	165.00
4.00 to 2.80mm.	3.40	17.75	60.35
2.80 to1.00 mm.	1.90	13.88	26.36
1.00 to 425 micron	0.71	3.25	2.31
425 to 180 micron	0.30	3.88	1.17
180 to 75 micron	0.13	8.13	1.03
75 micron and below	0.04	3.13	0.12
Total:			**256.35**

Weighted mean diameter dm =	256.35				
	100				
=	2.56				
Silt Factor =	As per notificaion no. 40 of IRC-05:2015				
=	9.00				
Discharge cumecs		739.34			
Design Dischage in Cumec		961.14			
Linear waterway				148.81	
But Linear waterway provided				46.90	
Discharge through linear waterway				**20.49**	
Scour Depth					
$d_{sm} = 1.34(D_b^2/K_{sf})^{1/3}$	**1.34**	**46.66**		**3.60**	**4.82**
Wher Df=Design discharge for foundation per metr with at effactve linear waterway.					
Ksf= Silt factor for a representative sample of bed level obtained upto the level of anticipated deepest scour.					
Maximum Depth of Scour for Design of Foundation from HFL					
Flood without Seismic Combination					
For Abutments	a) with approach retained or lowest bed level whichever is deeper 1.27 d_{sm}			6.13	
Take 6.13m from HFL of stream or 1.38m from LBL.					

A. CALCULATION OF SAFE BEARING CAPACITY FOR ABUTMENT A-1:

TYPCIAL BEARING CAPACITY COMPUTATIONS FOR FOOTINGS AT 2.0m DEPTH FROM MSL	11.0mx16m Size 2.0m Depth	Unit
REFERENCE BORE HOLE: BH-1		
1.1 Geometrical Data :		
Shape of the Foundation	Rectangle	
Shape considered for bearing capacity design	Rectangle	
Size of Footing (B)	10.00	m
Breadth to Length Ratio of Foundation (B/L)	1.60	
Depth of Foundation below protected bed Level (D_f):	2.00	m
Inclination of Vertical Load with the Vertical (a)	0.00	Deg.
Design SPT Value	100	
1.2 Soil Data :(Refer BH-01)		
Type of Bearing Strata :	Sandy gravel	
phi=	34°	
Type of Shear Failure:	Mixed	
phi'=	29.83	
Undrained Shear Strength (Cu)=	0.00	t/m^2
1.3 Design Parameters:		
Bulk Density of Soil above the foundation depth (g_{bulk})	2.12	t/m^3
Effective Overburden pressure at foundation level (q)	4.24	t/m^2
True Bearing Capacity Factors:		
N'_c =	29.81	
N'_q =	18.13	
N'_γ =	22.00	
Water Table Correction Factor W'=	0.50	
Shape Factors:		
S_c =	1.13	
S_q =	1.13	
S_g =	0.75	
Depth Factors :		
D_c =	1.07	
D_q =	1.03	
D_g =	1.03	
Inclination Factor:		
I_c =	1.00	
I_q =	1.00	
I_g =	1.00	
Specific Gravity G=	2.66	
Dry Density Yd=	2.08	
Void Ratio e=(G*Yw/Yd)-1	0.28	

Since<0.55, general shear failure, considering mixed on safer side

1.4 Ultimate Bearing Capacity (Qu) :		
Qu=F*Cu*Nc*Sc*Dc*I'c+q(N'q-1)SqDqIq+0.5ByN'ySyDyIyW'	172.00	t/m²
1.5 Safe Bearing Capacity (Qsafe) :		
Factor of Safety (F.S.) :	2.50	
Qsafe :	68.80	t/m²
Limit Q_{safe} from settlement consideration	**50.00**	t/m³
2 Computation of Settlement: (as per IS:8009-Part-I)		
2.2 Computation of immediate Settlement (S_i) as per Clause 9.1.4		
Design N Value	100	
Settlement for Unit Pressure (fig.9 of IS:8009)	4.8	mm
Settlement for Unit Pressure after Water Table Correction	9.6	mm
Allowed Pressure (Settlement)	50.0	mm
Net Allowed Pressure	52.1	t/m²
Recommended Safe Bearing Pressure	**50.0**	**t/m²**

2. CALCULATION OF SAFE BEARING CAPACITY FOR ABUTMENT A-2:

SAFE BEARING CAPACITY BASED ON RMR VALUES

Abutment A-2, B.H. No.-2:	**Rating**
Strength of Intact Rock materials (MPa) compressive strength (320kg/cm²)	4
Rock Quality Designation (RQD) ..... 36 %	8
Spacing of Discontinuities	10
Condition of discontinuities	-
Ground water condition	10
Total RMR value:	**32**

Rock mass strength using from RMR values using the formula:

qns = qc. $e^{\{ (RMR-100) / (18.75) \}}$ = 320.0 X $e^{32 - 100 / 18.75}$ =8.5135 Kg/cm² or 85.135 t/m², say 80.0t/m².

B. DETAILS CALCULATION OF SAFE BEARING CAPACITY BASED ON COMPRESSIVE STRENGTH OR INTACT ROCK SPECIMEN USING THE PROCEDURE GIVEN IN IS 12070-1987:

qs : Safe gross bearing pressure

qc : Average lower bound uniaxial compressive strength of Rock cores

Nj : Empirical coefficient.

The safe Bearing capacity estimated from the following equation as given in IS: 12070-1987 using the formula:

qs = qc. Nj

qs= 320.0 X 0.10 = 31.0 Kg/cm²

Safe bearing capacity (S.B.C) :- 32.0 kg/cm²= 320.0 t/m².

C. SAFE BEARING CAPACITY BASED ON CLASSIFICATION & RMR AS PER IS 12070-1987

BEARING CAPACITY ANALYSIS FOR FOUNDATIONS SEATING ON ROCK FOR RHS ABUTMENT (BH-2)

Location : 84 m Span 1.5 Lane Class-A Loading Steel Truss Motor Bridge over Kotigad River at Km 01 of Tikochi- Duchanu- Kiranu- Sirtoli Motor Road in District Uttarkashi - **RHS Abutment**

BEARING CAPACITY ANALYSIS FOR OPEN FOUNDATIONS BEARING ON ROCK HAS BEEN DONE BY TWO DIFFERENT METHODS AS GIVEN BELOW:

1) Presumptive Values of safe bearing capacity
2) Based on RMR value

Foundation Lvl.: 1503.0 m Inside firm Rock

Below Founding Level : Rock Core Recovery: 70 % RQD value 36 %

$$q_{net\ safe} = q_s * c_{sub} * c_c * c_s$$

where:

$q_{net\ safe}$ =	safe net bearing capacity	c_s =	correction for orientation of joints
q_s =	safe bearing capacity	c_c =	correction for solution cavities (in limestone)
c_{sub} =	correction for saturation / submerged condition		

Material	$q_{net\ safe}$, T/m^2
Massive crystalline bedrock including granite, diorite, gneiss, trap rock	1000
Foliated rocks such as schist or slate in sound condition	400
Sedimentary rock, including hard shales and sandstones	250
Soft or broken bed rock (excluding shale) and soft limestone	100
Soft shale	30

Presumptive Value of safe bearing capacity for design: q_s = 400 T/m^2

Correction for saturation/submergence:	c_{sub}=	0.80
Correction for orientation of joints	c_c =	0.70
Correction for solution cavities	c_c =	1.00

$q_{net\ safe}$= 224.0 T/m^2

Class of rock	I	II	III	IV	V
Description of rock	Very Good	Good	Fair	Poor	Very Poor

RMR	100-81	80-61	60-41	40-21	20-0
$q_{net\ safe}$ (T/m^2)	600-448	440-288	280-141	135-48	45-30

RMR value for design =	32	Class of Rock:	IV	Rock Description:	Poor

$q_{net\ safe}$ =	98.4	T/m^2

Recommended value of Net Safe Bearing Pressure for Design: 98.4 T/m^2

10.0 RECOMMENDATIONS

10.01 Strata consists of:

BH-1 (A-1) Location:

The subsoil strata from 0.0 to 1.60 m depth consist overburden of poorly graded sandy gravels with cobbles and boulders strata followed by sandy gravels in the matrix of compact boulder strata upto the depth explored.

BH-2 (A-2) Location:

The subsoil strata consist of highly to moderately weathered/ intensely fractured rock strata up to 2.20m depth further followed by partly fractured hard rock strata upto the depth explored.

10.02 Recommended net safe Bearing Capacity can be adopted corresponding to various parameters for proposed bridge location as given in table below:

Table no. 5: Recommended Value of Net SBC/API

Foundation Level in m	BH. No.	Recommended Net Allowable Bearing Pressure, T/m^2	Likely Foundation Bearing Material
1490.00	Borehole Location-1 Abutment A-1	50.0	Compact Boulder strata
1503.00	Borehole Location-2 Abutment A-2	80.0	Fractured Rock

Box excavation will be carried out for construction of foundation to maintain minimum depth of foundation as shown in drawings.

10.2 Water table was not met inside BH-1 & BH-2 at the time of geotechnical investigation, which was carried out in the month of December, 2024, but necessary correction applied in bearing capacity calculations due to probable flooding around foundations during rainy season/ floods.

10.3 If any filled up strata is found at the time of excavation of foundations upto a greater depth, depth of foundation should be increased accordingly. For the purpose, it is suggested to get the excavation pits inspected from a competent Geotechnical Engineer.

10.4 The above-recommended value of Safe Bearing Capacity of Soil has been arrived at on the basis of the soil strata observed during the field exploration. However, during the actual construction if a soil stratum met with is found to be different a competent Geo technical engineer should be consulted.

10.5 If the bearing capacity corresponding to any other size or depth is required the matter may be referred back to us.

10.6 This report is meant only for technical purposes, and is not to be referred for legal purposes.

For Technical Consultancy Services,

(Project Coordinator)

ANNEXURE

LIST OF REFERRED IS CODES

Field Investigation

1. IS: 1948-1970 Classification and Identification of soils for general engineering purposes (first revision) Amendment 2
2. IS: 1892-1979 Code of practice for sub surface investigation for foundation
3. IS: 2131-1981 Method of standard penetration tests for soils
4. IS: 13365- (Part-I) – 1968 "Quantitative Classification Systems of Rockmass-Guidelines- Part-1 Rock Mass Rating (RMR) for predicting Engineering Properties"
5. IS: 12070- 1987- Code of practice for Design and construction of Shallow Foundations on Rocks

Foundation construction

1. IS: 1904-1986 Code of practice for design and construction of foundation in soils: General requirements (Third revision)
2. IS: 13365- (Part-I) – 1968 "Quantitative Classification Systems of Rockmass-Guidelines- Part-1 Rock Mass Rating (RMR) for predicting Engineering Properties"
3. IS: 12070- 1987- Code of practice for Design and construction of Shallow Foundations on Rocks

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