REPORT ON

SUB SOIL INVESTIGATION AND RECOMMENDATION FOR THE FOUNDATION OF PROPOSED BRIDGE ACROSS RIVER VASISTA GODARI DISTRICT – ANDHRA PRADESH

[BORE HOLE NO.: 1]

1 INTRODUCTION

M/S BSCPL – BEKEM RE [JV], Hyderabad & South Central Railway Secunderabad Division, Vijayawada requested the Civil Engineering Department of V.R.Siddhartha Engineering College, Vijayawada to conduct necessary soil testing on soil samples collected by **M/S Rakir Engineering [Dindi]** and provide the soil parameters & recommend suitable foundation and bearing capacity of soil for the proposed **Bridge across Vasista River in Godavari District, Andhra Pradesh**

The following are the responsibilities of **M/S Rakir Engineering [Dindi], Andhra Pradesh**

- Soil boring of 150 mm diameter upto 65 metres depth in one location as specified by the client.
- Collection of undisturbed and disturbed soil samples from the bore
- Conducting Standard Penetration Test (SPT) at regular intervals within the bore.
- Testing of undisturbed and disturbed soil samples collected from the bore in the laboratory.
- Recommendation of suitable bearing capacity and type of foundation for the proposed structure.

M/S Sree Devi Engineering Enterprises**, Vijayawada** did the soil boring, sample collection and field testing on behalf of **M/S Rakir Engineering [Dindi],** and soil testing and recommendations were provided by V R Siddhartha Engineering College, Vijayawada

This report contains the results of field and laboratory tests. Recommendations on bearing capacity of soil and type & depth for foundation for the proposed **Bridge** are also included.

2 THE STRUCTURE AND LOCATION

The proposed structure is a Major Bridge across river for the railways. The proposed bridge across Vasista River, Godavari District, Andhra Pradesh

3 FIELD SOIL INVESTIGATION PROCEDURES

The following methods were adopted for sub-soil investigations as per IS: 1892-1979. One soil investigation bores of 150 mm diameter upto a depth of 65 metres were proposed and drilled within the proposed structure location. Boring was done using combination of shell and auger methods with casing pipe to depending upon the type of strata met with in the bore hole location using hand boring machine. Bore holes of 150 mm diameter with casing pipe were drilled to facilitate collection of Undisturbed and Disturbed soil samples and to conduct Standard Penetration Tests.

Standard Penetration Tests (SPT) were conducted at 1.0 to 2.0 meter intervals within each bore. These tests were conducted as per IS:2131-1981. Number of disturbed but representative soil samples were collected from the auger cuttings sand bailers for identification and for conducting laboratory tests. Undisturbed soil samples (in Clayey soil) were also collected at 2.0 metre intervals from the boreholes. The bore hole No. 1 of was advanced upto a depth of **65metres** below the existing ground level. A Strata is considered to be hard, when the standard penetration test value, N i.e. the number of blows required for 300 mm penetration of the SPT spoon beyond a seating penetration of 150 mm in the strata is more than 100 (Clause 3.3.3 of IS:3132-1981). If the penetration of the spoon is less than 300 mm more than 50 blows, the N value is written as N>100. The depth of water table at the end of boring is observed. All the results obtained from the field operations are shown in the log of bore (Figure: 1)

4 LABORATORY TESTS

Indices tests such as natural moisture content, liquid limit, plastic limit and unit weight were conducted on DS/UDS soil samples as per Indian Standard to identify and establish the consistency of these soils. Sieve analysis tests were also conducted on sandy/gravelly soil for knowing the particle size distribution and classification of soil.

Unconfined compressive strength tests and direct shear tests were conducted on UDS soil sample to know the shear strength of soil. The results are given in Table 1 to 2.

5 SUB SOIL PROFILES

The Sub soil profile at the bore hole locations, based on the identification of soil samples and the results of tests (both field and laboratory) are indicated in Figure 1. The idealized design soil parameters are given in Table 1.

5.1 Bore Hole Number: 1. R L = +5.00 m, boat Water Level= 4.00 m

Depth Below Ground Level	Soil Type and Classification	Recorded SPT "N" Value
1.00 – 5.00	Water Depth in the river	-
5.00 – 7.00	Yellowish brown silty fine to medium sand, SM-SP	19, 21
7.00 – 9.00	Yellowish brown fine to medium sand, SP	19, 23
9.00 – 10.00	Yellowish brown coarse to medium sand, SP	24
10.00 – 15.00	Yellowish brown coarse to medium sand, SP	4, 3
15.00 – 17.00	Blackish brown plastic silty clay [CH]	5, 6
17.00 – 18.00	Blackish brown plastic silty clay [CH]	4
18.00 – 20.00	Blackish brown plastic silty clay [CH]	11, 9
20.00 – 22.00	Blackish brown plastic silty clay [CH]	13, 50
22.00 – 24.00	Yellowish brown plastic sandy silty clay + pebbles	27, 30
24.00 – 25.00	Yellowish brown plastic sandy silty clay + pebbles	26
25.00 – 30.00	Yellowish brown plastic sandy silty clay + pebbles	29,32,28,31,27
30.00 – 32.00	Yellowish brown plastic sandy silty clay + pebbles	27, 30
32.00 – 35.00	Yellowish brown plastic sandy silty clay + pebbles	30, 32

35.00 – 38.00	Yellowish brown plastic sandy silty clay, MH-CH	34,33,35
38.00 – 40.00	Yellowish brown plastic sandy silty clay, MH-CH	37, 38
40.00 – 44.00	Yellowish brown plastic sandy silty clay, MH-CH	40, 42
44.00 – 46.00	Yellowish brown plastic sandy silty clay, MH-CH	46
46.00 – 50.00	Yellowish brown sandy silty clay + lime pebbles	49, 51
50.00 – 54.00	Yellowish brown sandy silty clay + lime pebbles	56, 50
54.00 – 58.00	Yellowish brown sandy silty clay + lime pebbles	62, 66
58.00 – 65.00	Yellowish brown sandy silty clay + lime pebbles	71,68,72, 75

SILT FACTOR:

The silt factor, f as per Lacy's equation can be calculated from the sieve analysis of soil samples using weighted mean grain size.

Lacy's Silt factor, f will be **1.76 √ Dm**

whereDm = weighted mean grain size

The design calculations are as follows:

Bed Material – silty fine to medium sand [SM-SP] from 5.00 m to 15.00 m

SizeRange [1]	Average Size [2]	Percent weight retained [3]	[2] x [3]
6.00 – 4.75 mm	5.375 mm	0	0
4.75 mm – 2.00mm	3.375 mm	0	0
2.00mm – 0.425 mm	1.213 mm	80	97.04
0.425 mm– 0.075 mm	0.250 mm	15	3.75
Below 0.075 mm	0.075 mm	05	0.375
Sum Total			101.165
Weighted mean grain size, d in mm [101.165/100]			1.01165
Silt factor, f = 1.76 √d = 1.76 x √1.01165			1.77

A silt factor, f = 1.75 is proposed for the Silty Sand

6 SELECTION OF FOUNDATION AND BEARING CAPACITY OF SOIL

Since the proposed structure is a Major Bridge across a River Vasista and the top soil is silty sand/ sand upto 15.0 metres and then soft silty clay upto 22 m followed by stiff sandy silty clay with pebbles**. Deep foundation in the form of Open Well Foundation/ Pile foundation is ideal**

The size and depth of foundation can be decided based on loading and soil characteristics. The depth of foundation should satisfy the following requirements.

It should rests on sound strata of adequate bearing capacity and safe from settlement considerations also.

It should have adequate embedded length so as to resist the overturning moments due to horizontal forces and scour.

The soil properties are given in Table 1-4 were utilized to arrive the safe load carrying capacity of selected raft foundation. Based on shallow foundation, the safe bearing capacity (excluding over burden) of soil at different depth and location is given in Table 1.

The allowable bearing capacity of soil is calculated as per IS 6403 specification considering the shear failure and settlement failure criterion using the following equations.

$qu = C\ NcSc\ Dc + \gamma\ D\ NqSqDq\ Rw2 + 0.5\ \gamma\ B\ N\gamma S\gamma D\gamma Rw2$ ---- (1)

$qa = 35\ (\ N-3\ )\ [(B+0.3)/2B]^2 Rw\ Rd$ for settlement of 25 mm for sand (2)

$Qa = 1.25\ N$ for clayey soil (3)

Deep Foundation in the form of Bored cast in situ pile foundation is also suitable. The length and size & its load carrying capacity can be obtained from the soil properties given in Table 1

In case of pile foundation, the load carrying capacity of the pile can be calculated using the static formula given by IS: 2911 (Part 1 /Sec 2) - 2010 considering both friction and bearing resistance. The allowable load is normally obtained by using an overall

factor of safety of 2.5. The load carrying of pile can also be obtained from the SPT, N values.

For the correlation of cohesion and unconfined compressive strength, static cone resistance from N values, IS: 2911 (Part 1 /Sec 2) - 2010 is followed.

Unconfined compressive strength = qc = N

Cohesion, c = qc/2

Static cone resistance = 2N

Pile foundation in the form of Bored cast in-situ piles with casing is preferable in this location.

The ultimate load carrying capacity of single pile can be obtained from Static Formula as given in IS: 2911 (Part 1 /Sec 2) - 2010 for bored piles considering Skin Friction and bearing resistance.

For Piles in Cohesive Soil[Clay]

$Qu = Ap .Nc .Cp + \alpha . C . As$ ----- (1)

Ap = Cross sectional area of the pile toe

Nc = Bearing capacity factor usually taken as 9 for deep foundation

Cp = Average cohesion at pile tip

α = reduction factor [usually 0.3 to 0.7 depends on the strength of clay]

C = Average cohesion through out the length of pile

For Piles in Cohesionless GranularSoil [Sand]

$Qu = Ap .Pd .Nq + \sum K. Pdi .\tan \delta Asi$

Ap = Cross sectional area of the pile toe

Pd = effective overburden pressure at pile toe – limited to 15D to 20 D

Nq = bearing capacity factor depends upon the angle of internal friction,ϕ

K = coefficient of earth pressure, between 1 and 1.5

Pdi = effective overburden pressure for the layer concerned

δ = angle of wall friction between the soil and pile – usually taken as $2/3\phi$ to ϕ

Asi = surface area of pile stem for the layer concerned

Open Well foundation is ideal at this location.

The allowable bearing capacity of soil is calculated as per IS 6403 specification considering the shear failure and settlement failure criterion.

The allowable bearing capacity will be as per IS: 3955-1967 for well foundation in sandy soil which will be as follows,

$Q = 5.4\ N^2\ B + 16\ (100+N^2)\ D$

For well foundation, the bearing capacity of soil at the foundation level will be very high. The values given in Table 1 are for the shallow foundation.

Suitable depth of well foundation may be provided based on scour and other design requirements. It is suggested the well should be in strong layer ie about 25 m to 30 m below the bed level in stiff sandy silty clay + pebbles

Dr N R Krishnamurthy

8 RECOMMENDATIONS **CE 010319/1**

Based on the field and laboratory test results, the following recommendations are made for the Major Bridge across River Vasista in Godavari District, Andhra Pradesh [Bore Hole No.: 1]

- **The soil profile is given in Figure 1.**
- **It consists of silty sand/ sand upto 15 m followed by soft clay upto 22 metres and then stiff sandy silty clay + pebbles**
- **The bearing capacity of soil at different depths is given in Table 1 for the shallow foundation.**

- **A silt factor, f = 1.75 is proposed for the bed material iesilty sand**
- **Deep foundation in the form of Open Well foundation and Pile foundation is ideal at this location.**
- **Bored pile foundation is proposed.**
- **Suitable size and length can be selected from the loading.**
- **For well foundation, the wells may be placed in stiff sandy silty clay + pebbles layer.**
- **The allowable bearing pressure of well foundation in sand will be as per IS: 3955-1967& IRC 78**

Dr N R Krishnamurthy
Professor **Professor & Head** **Dean / Principal**

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2 THE STRUCTURE AND LOCATION

The proposed structure is a Major Bridge across river for the railways. The proposed bridge across Vasista River, Godavari District, Andhra Pradesh

3 FIELD SOIL INVESTIGATION PROCEDURES

The following methods were adopted for sub-soil investigations as per IS: 1892-1979. Three soil investigation bores of 150 mm diameter upto a depth of 65 metres were proposed and drilled within the proposed structure location. Boring was done using combination of shell and auger methods with casing pipe to depending

upon the type of strata met with in the bore hole location using hand boring machine. Bore holes of 150 mm diameter with casing pipe were drilled to facilitate collection of Undisturbed and Disturbed soil samples and to conduct Standard Penetration Tests.

Standard Penetration Tests (SPT) were conducted at 1.0 to 2.0 meter intervals within each bore. These tests were conducted as per IS:2131-1981. Number of disturbed but representative soil samples were collected from the auger cuttings sand bailers for identification and for conducting laboratory tests. Undisturbed soil samples (in Clayey soil) were also collected at 2.0 metre intervals from the boreholes. The bore holes were advanced upto a depth of **65 - 68metres** below the existing ground level. A Strata is considered to be hard, when the standard penetration test value, N i.e. the number of blows required for 300 mm penetration of the SPT spoon beyond a seating penetration of 150 mm in the strata is more than 100 (Clause 3.3.3 of IS:3132-1981). If the penetration of the spoon is less than 300 mm more than 50 blows, the N value is written as N>100. The depth of water table at the end of boring is observed. All the results obtained from the field operations are shown in the log of bore (Figure: 1-3)

4 **LABORATORY TESTS**

Indices tests such as natural moisture content, liquid limit, plastic limit and unit weight were conducted on DS/UDS soil samples as per Indian Standard to identify and establish the consistency of these soils. Sieve analysis tests were also conducted on sandy/gravelly soil for knowing the particle size distribution and classification of soil.

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5 SUB SOIL PROFILES

The Sub soil profile at the bore hole locations, based on the identification of soil samples and the results of tests (both field and laboratory) are indicated in Figure 1-3. The idealized design soil parameters are given in Table 1, 3 & 5.

5.1 Bore Hole Number: 1. R L = +5.00 m, boat Water Level= 4.00 m

Depth Below Ground Level	Soil Type and Classification	Recorded SPT "N" Value
1.00 – 5.00	Water Depth in the river	-
5.00 – 7.00	Yellowish brown silty fine to medium sand, SM-SP	19, 21
7.00 – 9.00	Yellowish brown fine to medium sand, SP	19, 23
9.00 – 10.00	Yellowish brown coarse to medium sand, SP	24
10.00 – 15.00	Yellowish brown coarse to medium sand, SP	4, 3
15.00 – 17.00	Blackish brown plastic silty clay [CH]	5, 6
17.00 – 18.00	Blackish brown plastic silty clay [CH]	4
18.00 – 20.00	Blackish brown plastic silty clay [CH]	11, 9
20.00 – 22.00	Blackish brown plastic silty clay [CH]	13, 50
22.00 – 24.00	Yellowish brown plastic sandy silty clay + pebbles	27, 30
24.00 – 25.00	Yellowish brown plastic sandy silty clay + pebbles	26
25.00 – 30.00	Yellowish brown plastic sandy silty clay + pebbles	29,32,28,31,27
30.00 – 32.00	Yellowish brown plastic sandy silty clay + pebbles	27, 30
32.00 – 35.00	Yellowish brown plastic sandy silty clay + pebbles	30, 32
35.00 – 38.00	Yellowish brown plastic sandy silty clay, MH-CH	34,33,35
38.00 – 40.00	Yellowish brown plastic sandy silty clay, MH-CH	37, 38
40.00 – 44.00	Yellowish brown plastic sandy silty clay, MH-CH	40, 42
44.00 – 46.00	Yellowish brown plastic sandy silty clay, MH-CH	46
46.00 – 50.00	Yellowish brown sandy silty clay + lime pebbles	49, 51
50.00 – 54.00	Yellowish brown sandy silty clay + lime pebbles	56, 50
54.00 – 58.00	Yellowish brown sandy silty clay + lime pebbles	62, 66
58.00 – 65.00	Yellowish brown sandy silty clay + lime pebbles	71,68,72, 75

The compressibility index of clay layer from 15 to 18 m, Cc = 0.50
The compressibility index of clay layer from 18 to 22 m, Cc = 0.45
The soil from 22 m onwards will be sandy silty clay + pebbles and **over consolidated.**
The compressibility index of stiff clay layer from 22 to 35 m, Cc = 0.10
The preconsolidation pressure of this layer will be 1.0 kg/cm^2
The compressibility index of stiff clay layer from 35 to 50 m, Cc = 0.06
The preconsolidation pressure of this layer will be 1.2 kg/cm^2
The compressibility index of stiff clay layer below 50m, Cc = 0.04
[It is highly over consolidated]
The preconsolidation pressure of this layer will be 1.5 kg/cm^2

SILT FACTOR:

The silt factor, f as per Lacy's equation can be calculated from the sieve analysis of soil samples using weighted mean grain size.

Lacy's Silt factor, f will be **1.76 √ Dm**

whereDm = weighted mean grain size

The design calculations are as follows:

Bed Material – silty fine to medium sand [SM-SP] from 5.00 m to 15.00 m

SizeRange [1]	Average Size [2]	Percent weight retained [3]	[2] x [3]
6.00 – 4.75 mm	5.375 mm	0	0
4.75 mm – 2.00mm	3.375 mm	0	0
2.00mm – 0.425 mm	1.213 mm	80	97.04
0.425 mm– 0.075 mm	0.250 mm	15	3.75
Below 0.075 mm	0.075 mm	05	0.375
Sum Total			101.165
Weighted mean grain size, d in mm [101.165/100]			1.01165
Silt factor, f = 1.76 √d = 1.76 x √1.01165			1.77

A silt factor, f = 1.75 is proposed for the Silty Sand

5.2 Bore Hole Number: 2. R L = +6.00 m, boat Water Level= 5.00 m

Depth Below Ground Level	Soil Type and Classification	Recorded SPT "N" Value

1.00 – 6.00	Water Depth in the river	-
6.00 – 9.00	Brownish silty fine to medium sand [SM-SP]	17, 20, 23
9.00 – 12.00	Yellowish brown fine to medium sand [SP]	27, 27, 30
12.00 – 17.00	Yellowish brown fine to medium sand [SP]	29, 30, 31, 32
17.00 – 18.00	Blackish brown plastic silty clay [CH]	5
18.00 – 19.00	Blackish brown plastic silty clay [CH]	7
19.00 – 20.00	Blackish brown plastic silty clay [CH]	9
20.00 – 21.00	Yellowish brown plastic silty clay [MH-CH]	25
21.00 – 28.00	Yellow brown sandy clay / clayey sand, SC-CH/MH-CH	21,25,26,24,22
28.00 – 34.00	Yellow brown sandy clay / clayey sand, SC-CH/MH-CH	25,29,27,29
34.00 – 38.00	Yellow brown sandy clay / clayey sand, SC-CH/MH-CH	31, 33
38.00 – 46.00	Yellow brown sandy clay / clayey sand, SC-CH/MH-CH	37,38,40,38
46.00 – 50.00	Yellow brown sandy clay / clayey sand, SC-CH/MH-CH	41, 46
50.00 – 52.00	Yellowish brown silty fine to medium sand [SM-SP]	52
52.00 – 54.00	Yellowish brown plastic sandy silty clay, MH-CH	46
54.00 – 62.00	Yellowish brown fine to medium sand [SP]	53, 58, 63, 65
62.00 – 66.00	Yellowish brown silty fine to medium sand [SM-SP]	68, 73

The compressibility index of clay layer from 17 to 18 m, Cc = 0.50
The compressibility index of clay layer from 18 to 20 m, Cc = 0.48
The soil from 20 m onwards will be sandy silty clay + pebbles and **over consolidated.**
The compressibility index of stiff clay layer from 20 to 35 m, Cc = 0.10
The preconsolidation pressure of this layer will be 1.0 kg/cm^2
The compressibility index of stiff clay layer from 35 to 50 m, Cc = 0.06
The preconsolidation pressure of this layer will be 1.2 to 1.5 kg/cm^2
SILT FACTOR:

Bed Material – silty fine to medium sand [SM-SP] from 6.00 m to9.00 m

SizeRange [1]	Average Size [2]	Percent weight retained [3]	[2] x [3]
6.00 – 4.75 mm	5.375 mm	0	0
4.75 mm – 2.00mm	3.375 mm	0	0

2.00mm – 0.425 mm	1.213 mm	75	90.975
0.425 mm– 0.075 mm	0.250 mm	20	5.0
Below 0.075 mm	0.075 mm	05	0.375
Sum Total			96.35
Weighted mean grain size, d in mm [96.35/100]			0.9635
Silt factor, f = 1.76 √d = 1.76 x √0.9635			1.73

A silt factor, f = 1.75 is proposed for the Silty Sand

5.3 Bore Hole Number: 3. R L = +9.00 m, boat Water Level= 8.00 m

Depth Below Ground Level	Soil Type and Classification	Recorded SPT "N" Value
1.00 – 9.00	Water Depth in the river	-
9.00 – 10.00	Brownish silty fine to medium sand [SM-SP]	13
10.00 – 11.00	Yellowish brown silty medium to fine sand [SM-SP]	17
11.00 – 15.00	Blackish brown plastic silty clay [CH]	4
15.00 – 19.00	Blackish brown plastic silty clay [CH]	5, 6
19.00 – 21.00	Blackish brown plastic silty clay [CH]	9, 10
21.00 – 23.00	Yellowish brown sandy clay + pebbles [MI-CI]	13, 15
23.00 – 25.00	Yellowish brown plastic sandy silty clay [MH-CH]	23, 24
25.00 – 26.00	Yellow brown sandy clay / clayey sand + pebbles	25
26.00 – 28.00	Yellow brown sandy clay / clayey sand, SC-CH/MH-CH	21, 22
28.00 – 29.00	Yellow brown sandy silty clay [MH-CH]	22
29.00 – 32.00	Yellow brown sandy silty clay [MH-CH]	25, 28
32.00 – 38.00	Yellow brown sandy clay / clayey sand, SC-CH/MH-CH	25,21,23
38.00 – 44.00	Yellow brown sandy clay / clayey sand, SC-CH/MH-CH	27, 29, 31
44.00 – 50.00	Yellow brown sandy clay / clayey sand, SC-CH/MH-CH	38,42,44
50.00 – 56.00	Yellow brown sandy clay / clayey sand, SC-CH/MH-CH	47, 51, 54
56.00 – 60.00	Yellowish brown silty medium to fine sand [SM-SP]	58, 65
60.00 – 64.00	Yellowish grey brown sandy silty clay [MH-CH]	68, 74

64.00 – 68.00	Yellowish brown silty medium to fine sand, SM-SP	76, 80

The compressibility index of clay layer from 11 to 19 m, Cc = 0.50

The compressibility index of clay layer from 19 to 21 m, Cc = 0.45

The preconsolidation pressure of this layer will be 0.10 kg/cm^2

The soil from 21 m onwards will be sandy silty clay + pebbles and **over consolidated.**

The compressibility index of stiff clay layer from 21 to 44 m, Cc = 0.15

The preconsolidation pressure of this layer will be 1.0 kg/cm^2

The compressibility index of stiff clay layer from 44 to 56 m, Cc = 0.07

The preconsolidation pressure of this layer will be 1.2 to 1.5 kg/cm^2

SILT FACTOR:

Bed Material – silty medium to fine sand [SM-SP] from 9.00 m to11.00 m

SizeRange [1]	Average Size [2]	Percent weight retained [3]	[2] x [3]
6.00 – 4.75 mm	5.375 mm	0	0
4.75 mm – 2.00mm	3.375 mm	0	0
2.00mm – 0.425 mm	1.213 mm	23	27.899
0.425 mm– 0.075 mm	0.250 mm	62	15.50
Below 0.075 mm	0.075 mm	15	1.125
Sum Total			44.524
Weighted mean grain size, d in mm [44.524/100]			0.44524
Silt factor, f = 1.76 √d = 1.76 x √0.44524			1.174

A silt factor, f = 1.18 is proposed for the Silty Sand

6 SELECTION OF FOUNDATION AND BEARING CAPACITY OF SOIL

Since the proposed structure is a Major Bridge across a River Vasista and the top soil is silty sand/ sand upto 11 to 18metres and then soft silty clay upto 20 to 22 m

followed by stiff sandy silty clay with pebbles**. Deep foundation in the form of Open Well Foundation/ Pile foundation is ideal**

The size and depth of foundation can be decided based on loading and soil characteristics. The depth of foundation should satisfy the following requirements.

It should rests on sound strata of adequate bearing capacity and safe from settlement considerations also.

It should have adequate embedded length so as to resist the overturning moments due to horizontal forces and scour.

The soil properties are given in Table 1-6 were utilized to arrive the safe load carrying capacity of selected raft foundation. Based on shallow foundation, the safe bearing capacity (excluding over burden) of soil at different depth and location is given in Table 1, 3 and 5.

The allowable bearing capacity of soil is calculated as per IS 6403 specification considering the shear failure and settlement failure criterion using the following equations.

$qu = C\ NcSc\ Dc + \gamma\ D\ NqSqDq\ Rw2 + 0.5\ \gamma\ B\ N\gamma S\gamma D\gamma Rw2$ ---- (1)

$qa = 35\ (N-3)\ [(B+0.3)/2B]^2 Rw\ Rd$ for settlement of 25 mm for sand (2)

$Qa = 1.25\ N$ for clayey soil (3)

Deep Foundation in the form of Bored cast in situ pile foundation is also suitable. The length and size & its load carrying capacity can be obtained from the soil properties given in Table 1

In case of pile foundation, the load carrying capacity of the pile can be calculated using the static formula given by IS: 2911 (Part 1 /Sec 2) - 2010 considering both friction and bearing resistance. The allowable load is normally obtained by using an overall factor of safety of 2.5. The load carrying of pile can also be obtained from the SPT, N values.

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Unconfined compressive strength = qc = N

Cohesion, c = qc/2

Static cone resistance = 2N

Pile foundation in the form of Bored cast in-situ piles with casing is preferable in this location.

The ultimate load carrying capacity of single pile can be obtained from Static Formula as given in IS: 2911 (Part 1 /Sec 2) - 2010 for bored piles considering Skin Friction and bearing resistance.

For Piles in Cohesive Soil[Clay]

$Qu = Ap .Nc .Cp + \alpha . C . As$ ----- (1)

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For Piles in Cohesionless GranularSoil [Sand]

$Qu = Ap .Pd .Nq + \sum K. Pdi .\tan \delta Asi$

Ap = Cross sectional area of the pile toe

Pd = effective overburden pressure at pile toe – limited to 15D to 20 D

Nq = bearing capacity factor depends upon the angle of internal friction,ϕ

K = coefficient of earth pressure, between 1 and 1.5

Pdi = effective overburden pressure for the layer concerned

δ = angle of wall friction between the soil and pile – usually taken as $2/3\phi$ to ϕ

Asi = surface area of pile stem for the layer concerned

Open Well foundation is ideal at this location.

The allowable bearing capacity of soil is calculated as per IS 6403 specification considering the shear failure and settlement failure criterion.

The allowable bearing capacity will be as per IS: 3955-1967 for well foundation in sandy soil which will be as follows,

$Q = 5.4\ N^2\ B + 16\ (100+N^2)\ D$

For well foundation, the bearing capacity of soil at the foundation level will be very high. The values given in Table 1 are for the shallow foundation.

Suitable depth of well foundation may be provided based on scour and other design requirements.

The depth of well foundation shall be decided with respect to the following consideration;

a) **Scour**
b) **Stability [Lateral stability]**
c) **Should be placed in Strong layer**

It is suggested the well should be in strong layer ie about 35 m to 40 m below the bed level in stiff sandy silty clay + pebbles

The overall size and shape of the well foundation should be sufficient to transmit the loads to the soil.

The steining thickness should be sufficient to transmit the load and also provide necessary weight for sinking [Sinking effort] and adequate strength against forces acting on the steining, both during sinking of the wells and service.

For this bridge multiple dredge holes are suggested. The best section will be Double "D" well shape.

Since the top soil is silty sand of medium dense in nature, the top sandy soil is not going to liquefy. Moreover, for the deep foundation in the form of well foundation, liquefaction analysis is not needed for the sandy soil at the top.

Bearing capacity [vertical stability] and settlement of well foundation is not a concern because the well is placed in strong layer always.

For Well Foundation lateral stability analysis should be done.

Since the soil at the foundation level is highly Over Consolidated, the compression index will be very low and there will be preconsolidation pressure [Past pressure] and hence, the settlements will be small and will be with in permissible limits

Dr N R Krishnamurthy

8 RECOMMENDATIONS **CE 010319/1**

Based on the field and laboratory test results, the following recommendations are made for the Major Bridge across River Vasista in Godavari District, Andhra Pradesh

- **The soil profile is given in Figure 1 to 3.**
- **It consists of silty sand/ sand upto 15 - 17 m followed by soft clay upto 20 - 22metres and then stiff sandy silty clay + pebbles**

- **The bearing capacity of soil at different depths is given in Table 1, 3 and 5 for the shallow foundation.**
- **A silt factor, f = 1.75 is proposed for the bed material iesilty sand**
- **Deep foundation in the form of Open Well foundation and Pile foundation is ideal at this location.**
- **Bored pile foundation is proposed.**
- **Suitable size and length can be selected from the loading.**
- **For well foundation, the wells may be placed in stiff sandy silty clay + pebbles layer.**
- **The allowable bearing pressure of well foundation in sand will be as per IS: 3955-1967& IRC 78**
- **Since the top soil is silty sand of medium dense in nature, the top sandy soil is not going to liquefy. Moreover, for the deep foundation in the form of well foundation, liquefaction analysis is not needed for the sandy soil at the top.**
- **Bearing capacity [vertical stability] and settlement of well foundation is not a concern because the well is placed in strong layer always.**
- **For Well Foundation lateral stability analysis should be done.**
- **Since the soil at the foundation level is highly Over Consolidated, the compression index will be very low and there will be preconsolidation pressure [Past pressure] and hence, the settlements will be small and will be with in permissible limits**

Consolidation Properties of the soil

For Bore Hole No.: 1

The compressibility index of clay layer from 15 to 18 m, Cc = 0.50

The compressibility index of clay layer from 18 to 22 m, Cc = 0.45

The preconsolidation pressure of this layer will be 0.10 kg/cm^2

The soil from 22 m onwards will be sandy silty clay + pebbles and **over consolidated.**

The compressibility index of stiff clay layer from 22 to 35 m, Cc = 0.10

The preconsolidation pressure of this layer will be 1.0 kg/cm^2

The compressibility index of stiff clay layer from 35 to 50 m, Cc = 0.06

The preconsolidation pressure of this layer will be 1.2 kg/cm^2

The compressibility index of stiff clay layer below 50m, Cc = 0.04
[It is highly over consolidated]
The preconsolidation pressure of this layer will be 1.5 kg/cm^2

For Bore Hole No.: 2
The compressibility index of clay layer from 17 to 18 m, Cc = 0.50

The compressibility index of clay layer from 18 to 20 m, Cc = 0.48

The soil from 20 m onwards will be sandy silty clay + pebbles and **over consolidated.**

The compressibility index of stiff clay layer from 20 to 35 m, Cc = 0.10

The preconsolidation pressure of this layer will be 1.0 kg/cm^2

The compressibility index of stiff clay layer from 35 to 50 m, Cc = 0.06

The preconsolidation pressure of this layer will be 1.2 to 1.5 kg/cm^2

For Bore Hole No.: 3
The compressibility index of clay layer from 11 to 19 m, Cc = 0.50

The compressibility index of clay layer from 19 to 21 m, Cc = 0.45

The preconsolidation pressure of this layer will be 0.10 kg/cm^2

The soil from 21 m onwards will be sandy silty clay + pebbles and **over consolidated.**

The compressibility index of stiff clay layer from 21 to 44 m, Cc = 0.15

The preconsolidation pressure of this layer will be 1.0 kg/cm^2

The compressibility index of stiff clay layer from 44 to 56 m, Cc = 0.07

The preconsolidation pressure of this layer will be 1.2 to 1.5 kg/cm^2

Dr N R Krishnamurthy
Professor **Professor & Head** **Dean / Principal**