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Analysis of Liquefaction for design of Bridge Abutment in the Valley of River

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Abstract -Present studies are based on the enhancing the knowledge of the geotechnical work. For sub-surface exploration boring has done through wash boring on the riverbed. Sand and Silt has been observed during sub-surface exploration and condition of failure of liquefaction in that area for design of bridge abutments. Safe bearing capacity also measured after obtained corrected STP number and give factor of safety for purpose design structure. A series of laboratory tests were also conducted in the Dehradun laboratory for further calculation of safe bearing capacity and the summarized results showing that the possibility of liquefaction can occur in few depths.

***Key Words*:**Standard Penetration Test, Road Network, Liquefaction

1. INTRODUCTION

Rural Development process are going day by day in the developing countries like India and it required to well-connected road in those area which are very far away from the city to supply daily need items and more. There are so many difficulties face by the engineer during construction of highway like faulty area and discontinuity of road by the availability of river. That time civil engineer requires to use technical knowledge in this type of problem. Faulty area like less strength of subgrade or soil needs soil stabilization, while discontinuity of road due to river requires to provide bridge for improvement of Road Network. Before start construction of bridge there required lot of test to check whether the site location is suitable for carrying the load of capacity of bridge or not. There required to check the bearing capacity of riverbed and more to avoid failure of structure. Generally, the cohesionless soil like sand is available near the river valley and that has increased the chances of liquefaction failure in those area. In present studies the bore hole made up by the wash boring in the site and standard penetration test conducted in different depth of bore hole to calculate the number of blows. SPT number is used to calculate safe bearing capacity and liquefaction failure criteria of river valley.

In present practice the subsurface investigation has been conducted in the site and laboratory test also conducted to evaluate strength of riverbed in terms of safe bearing capacity and liquefaction for construction of super structure like bridge. The abutment of bridge will be construct below the riverbed, so the evaluation of strength of riverbed has been done up to 15 m.

2. METHODOLOGY

Present studies are based on the sub-surface investigation and laboratory experiments. Furthermore, the methodology of scope of present work summarized follows:

1. **Sub-surface investigation:** Site exploration of riverbed of present work has been done by the Wash Boring as per IS 1892: 1979 guidelines. In this process water is forced under the pressure through inner tube and inner tube fitted with a cutting sharp edge tool, which cut the sub surface and water pressure exhale the soil particles through tube to the outside. The whole setup is performed inside the casing pipe during site exploration. The disturbed and undisturbed sample also collected from different depth of bore hole.
2. **Standard Penetration Test:** Standard Penetration Test is suitable for cohesionless soil like sand or silty sand, and the procedure of test was followed as per IS 2131 1981. Split spoon sampler connected to a rod and a free fall of 750 mm was given to the 63.5 kg hammer to sink the split spoon sampler into the stratum. The number of blows were recorded for 450mm penetration of split spoon sampler. While the number of blows for last 300 mm penetration were recorded for further calculation. Overburden and dilatancy correction factor given to noted number of blows and final corrected SPT numbers were used to determine the safe bearing capacity and liquefaction analysis of soil strata.

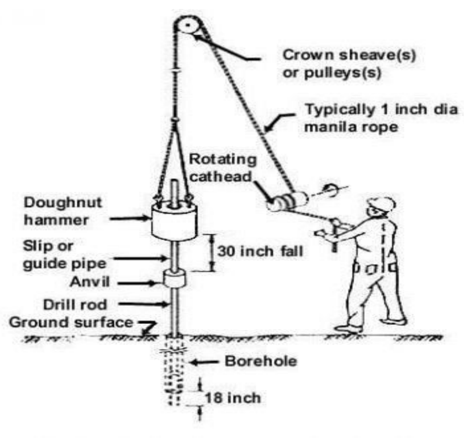

Fig.1: Field Set up of Standard Penetration Test

i. Overburden correction Factor: **$N_c = C_N N$**
Where C_N = correction factor for the overburden pressure.

ii. Dilatancy correction factor: **$N_R = 15 + 0.5\ (N_c - 15)$**
Where N_C =the Overburden correction Factor, If N_C lessis than or equal to 15, then $N_c = N_R$

3. Net Bearing Capacity of Soil: Standard penetration test is used to obtain corrected Standard Penetration Resistance for further calculation of bearing capacity. The corrected Standard Penetration Resistance vs angle of internal friction relationship graph is given in the IS 6403 1983. The angle of internal friction is used to calculate Nc, Nq and Nγ. Ultimate and Net Bearing Capacity as per IS 6403 1983 for cohesionless soil is given as:

Ultimate Bearing Capacity:

qu = {C $N_c$sc dc ic + q $N_q$sqdqiq Rw1 + 0.5 γ $N_γ$sydyiy Rw2}

Where, B = Width of foundation (m)
C = Effective cohesion, t/m2
Df = Depth of foundation (m)
γ = In-situ density (t/m3)
Nc, Nq, Nγ = Bearing capacity factors
sc, sq, sγ = Shape factors
dc, dq, dγ = Depth factors
ic, iq, iγ = Inclination factors
Rw1, Rw2 = G.W.T. correction factors

Net Bearing Capacity of Soil:
qnet = {C Nc sc dc ic + Df (Nq - 1) sqdqiq Rw1 + 0.5 γ B Ny sydyiy Rw2}

Net Safe Bearing Capacity of Soil:
qnet safe = qnet/Factor of Saftey

4. Estimation of Liquefaction:

a. Evaluation of Cyclic Stress Ratio (CSR): Seed and Idriss (1971) formulated the following equation for calculation of CSR:

$$CSR = 0.65\left(\frac{\text{amax}}{\text{g}}\right)\left(\frac{\sigma}{\sigma'}\right)\text{rd}$$

Where,
amax= peak horizontal acceleration at ground surface generated by the earthquake
g = acceleration of gravity,
σ= total vertical overburden stresses
σ’= effective vertical overburden stresses
rd = stress reduction coefficient

For noncritical projects, the following equationsmay be used to estimate average values of rd:

rd = 1.0 - 0.00765 z for z < 9.15 m
rd = 1.174 - 0.0267 z for 9.15 m < z < 23 m
rd = 0.744 - 0.008 z for 23 < z < 30 m
rd = 0.50 For z > 30 m

Furthermore, Idriss& Boulanger modified above relationship for the earthquake magnitude 7.5. Accordingly, the value of CSR is given as:

$$CSR = 0.65\left(\frac{\sigma \times \text{amax}}{\sigma'}\right)\left(\frac{\text{rd}}{\text{MSF} \times K\sigma}\right)$$

A new parameter rd, which could be adequately expressed as a function of depth and earthquake magnitude (M) was introduced and may be explain from following relations:

$$Ln\,(rd) = \alpha(z) + \beta(z)M$$

$$\alpha = -1.012 - 1.126\,Sin\left(\frac{z}{11.73} + 5.133\right)$$

$$\beta = 0.106 + 0.118\,Sin\left(\frac{z}{11.28} + 5.142\right)$$

Above equations are approximated for depth z ≤ 34 m, However the following expression may be used for depth z > 34m:

$$rd = 0.12\exp(0.22M)$$

Determination of MSF and Kσ

$$MSF = 6.9exp\left(-\frac{M}{4}\right) - 0.058$$

$$C\sigma = \frac{1}{18.9} - 2.55\sqrt{N}$$

$$k\sigma = 1 - C\sigma \times ln\left(\frac{\sigma'}{Pa}\right)$$

where,
M = Magnitude of Moment
Z= Depth in Meter

b. Evaluation of Cyclic Resistance Ratio (CRR): Idriss and Boulanger methodformulated the following equation for calculation of CRR:

$$CRR = exp\left\{\left(\frac{N1}{14.1}\right) + \left(\frac{N1}{126}\right)^2 - \left(\frac{N1}{23.6}\right)^3 + \left(\frac{N1}{25.4}\right)^4 - 2.8\right\}$$

Where,

$$\Delta N = exp\left\{1.63 + \frac{9.7}{FC} - \left(\frac{15.7}{FC}\right)^2\right\}$$

$$N1 = N + \Delta N$$

5. **Laboratory Experiments:**
   a) **Particle Size Distribution:**The Standard Procedure of test followed as per IS: 2720 (PartIV) – 1985.
   b) **Atterberg Limit:**Liquid Limit and Plastic Limit of Soil and Stone dust wascalculated as per IS: 2720(Part V) – 1985
   c) **Standard Proctor Test:** Maximum Dry Density and Optimum Moisture Content of soil and Stone dust was determined by as per IS:2720 (Part VII) – 1980.

3. RESULTS & DISCUSSION

1. Laboratory Experiments results and Bore Hole Data: A series of lab test results and field data observation tabulated below:

Table: 1 Bore Hole data & Lab Results

Soil Profile			Geotechnical Investigation Work					BH. No. 1		
Dia. of Bore Hole 150 mm			Method of Boring: Wash Boring					Water Table 7.50 m		
			Standard Proctor Test		Grain Size Analysis			Atterberg Limits		
SPT NO.	Depth (m)	N-Value	OMC (%)	MDD (Kn/m2)	Gravel %	Sand %	Silt & clay %	Liquid %	Plastic %	Plasticity Index %
1	1.5 1.95	11	13.2	15.21	0	88.5	11.5	NP	NP	NP
2	3 3.45	14	14.1	15.31	0	92	8	NP	NP	NP
3	4.5 4.95	9	13.8	15.11	0	92.76	7.24	NP	NP	NP
4	6 6.45	11	13.2	14.98	0	97.41	2.59	NP	NP	NP
5	7.5 7.95	11	12.8	15.21	0	96.45	3.55	NP	NP	NP
6	9 9.45	7	15.2	15.32	0	96.36	3.64	NP	NP	NP
7	10.5 10.95	32	14.2	15.21	0	95.88	4.12	NP	NP	NP
8	12 12.45	42	15.2	15.32	0	92.25	7.69	NP	NP	NP
9	13.5 13.95	47	16.1	15.22	0	87.56	12.3	NP	NP	NP
10	15 15.45	52	16.2	15.42	0	88.28	11.16	NP	NP	NP

2. Safe Bearing Capacity: Safe Bearing Capacity of soil at different depth of bore hole as per IS 6403 1983 tabulated below:

Table: 2Safe Bearing Capacity of soil as different depth

S. No.	Depth in meter	Corr. SPT No	ϕ	Nc	Nq	Ny	Safe Bearing Capacity in ton/m2
1	1.5	16	32	36.53	24.36	32.65	27.68
2	3	18	33	39.72	27.34	37.77	31.96
3	4.5	10	30	30.14	18.4	22.4	19.13
4	6	11	30	30.14	18.4	22.4	19.13
5	7.5	13	31	33.33	21.38	27.52	11.70
6	9	11	30	30.14	18.4	22.4	13.84
7	10.5	21	33	39.72	27.34	37.77	15.98
8	12	24	35	46.12	33.3	48.03	9.56
9	13.5	25	35	46.12	33.3	48.03	9.56
10	15	26	35	46.12	33.3	48.03	11.70

3. Liquefaction Analysis: The ratio of Cyclic Stress Ration (CSR) to the Cyclic Resistance Ratio (CRR) gives the factor of safety of liquefaction. If the value of Factor of Safety is less than 1 that means more chance to failure of structure due to liquefaction. Hence more methods require to avoid failure of structure. The summarized results of present studies are as following:

Table: 3Evaluation of Cyclic Stress Ratio (CSR)

Depth in meter	α	β	rd	MSF	kσ	CSR
1.5	-0.05116	0.0061	0.9979	1.00014	1.171	0.13287
3	-0.13388	0.0154	0.9920	1.00014	1.098	0.14082
4.5	-0.23094	0.0262	0.9852	1.00014	1.036	0.14830
6	-0.34075	0.0384	0.9775	1.00014	1.010	0.15095
7.5	-0.46152	0.0518	0.9690	1.00014	0.987	0.15301
9	-0.59128	0.0662	0.9599	1.00014	0.982	0.17118
10.5	-0.72792	0.0813	0.9501	1.00014	0.965	0.18895
12	-0.86919	0.0968	0.9399	1.00014	0.952	0.20434
13.5	-1.01279	0.1125	0.9294	1.00014	0.941	0.21759
15	-1.15639	0.1281	0.9186	1.00014	0.930	0.22956

Table: 4Evaluation of Cyclic Resistance Ratio (CRR)

Depth in meter	Finer Content (%)	ΔN	CRR	Factor Safety CRR/ CSR	Status of Failure
1.5	14	1.0652	0.174524	1.313	No
3	15	1.1811	0.196293	1.393	No
4.5	17	1.3476	0.127655	0.860	Yes
6	25	1.6236	0.137146	0.908	Yes
7.5	26	1.6384	0.153103	1.000	Yes
9	28	1.6620	0.137439	0.802	Yes
10.5	29	1.6713	0.243764	1.290	No
12	34	1.7020	0.307634	1.505	No
13.5	26	1.6384	0.334742	1.538	No
15	42	1.7212	0.372518	1.622	No

4. CONCLUSION:

Present studies are based on the field data and laboratory data and these data is used to evaluating the safe bearing capacity and estimation of liquefaction of for design of bridge abutment. The estimation of these parameters gives an idea about the sub surface geotechnical properties of soil. The soil was sand and silty sand type, while the laboratory test shows that the soil was cohesionless soil having no cohesion. The estimation of liquefaction data shows that the failure may occur due to liquefaction, hence we suggest that more factor of safety use for design of bridge abutment.

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