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Soil Investigation And Bearing Capacity Calculation for A Bridge At Dukheri Under DFCC

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***Abstract*—The aim of this research is to conduct Standard Penetration Test and to obtain Bore Logs at Dukheri in Ambala a district of Haryana. Once Standard Penetration Test is performed Bearing Capacity would be computed from the results of Standard Penetration Test being performed. Then a Suitable Foundation was proposed for the Bridge following that a dynamic Pile Load Test was performed to calculate the Load carrying Capacity of the Bridge. The bearing capacity of foundation soil is important for foundation design because it can carry heavy loads from the superstructure. The primary goal of the Soil investigation is to determine the bearing capacity of foundation soil for the design of bridge foundation. In order to investigate the subsurface conditions at the proposed bridge, boreholes were advanced at each abutment location using a mechanical shell and auger, where caving of the borehole occurred, 150 mm diameter casing was used to keep the borehole stable as per IS specifications.This research includes the details of Methodology of Investigation, collection of samples and their results for suitable recommendations for the properties essential to the design of foundations and recommendations about foundations for Bridge at Dukheri under Dedicated Freight Corridor Corporation of India.**

Keywords—Soil Investigation,Bearing Capacity, Standard Peneteration Test, Foundation, Bridge.

I. INTRODUCTION

A Bridge is a structure build to span a valley, road, river, body of water, or any other physical obstacle. Designs of Bridges will vary depending upon the function of the bridge and nature of the area where the bridge is to be constructed. Plain region poses unique problem for bridge construction. In a restricted Plain area itself climatic conditions, geological features and hydrological parameters vary considerably. Keeping in view the bridge site and various constraints, type of bridge and method of construction are to be selected carefully for safe, economical and successful completion of bridge construction.

Theprojectsection(Pilkahi-Sahnewal)ispartofeasternDFCandcoversthreestates starting from Pilkhani in Uttar Pradesh, passing through Haryana and finally terminating atSahnewal near Ludhiana city in Punjab covering districts of Saharanpur, Yamunanagar,Ambala,FatehgarhSahib,Patialaand Ludhiana. The Indian Railways chainage of 187.500 to the north of Pilkhani station is the point at whichthis section of corridor commences. The Pilkahi-Sahnewal section ends at Sahnewal, as it isnot possible to connect it with Ludhiana railway station because of challenges to be faceddue to the enormous growth of Ludhiana town. Further, because of space constraint atDhandarikalan and nearby airport, the corridor is now being terminated at the Sahnewalstation.

The aim of this research is to conduct Standard Penetration Test and to obtain Bore Logs at Dukheri in Ambala a district of Haryana. Once Standard Penetration Test is performed Bearing Capacity would be computed from the results of Standard Penetration Test being performed. Then a Suitable Foundation was proposed for the Bridge following that a dynamic Pile Load Test was performed to calculate the Load carrying Capacity of the Bridge. The bearing capacity of foundation soil is important for foundation design because it can carry heavy loads from the superstructure. The primary goal of the Soil investigation is to determine the bearing capacity of foundation soil for the design of bridge foundation. In order to investigate the subsurface conditions at the proposed IOCL bridge, boreholes were advanced at each abutment location using a mechanical shell and auger, where caving of the borehole occurred, 150 mm diameter casing was used to keep the borehole stable as per IS specifications.

The objective of Research is to interpret the engineering properties of the sub-surface stratum for the purpose of design of the structures. Fieldwork including Drilling of bore holes and sample collection was carried out. Standard tests were conducted on selected soil samples to determine the design parameters, confirming to relevant IS specifications. This research includes the details of Methodology of Investigation, collection of samples and their results for suitable recommendations for the properties essential to the design of foundations and recommendations about foundations for Bridge at Dukheri under Dedicatted Freight Corridor Corporation of India..

II. GEOLOGICAL INFORMATION OF THE REGION

A. Location

The site is referred to as SAHNEWAL – PILKHANI SECTION (from Km 360.200 to Km 187.500) in the State of Punjab and Haryana.

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B. Climate

Project stretch is located on the Indo-Gangetic alluvial plains. Climate corresponds to semiarid with high variation between summer and winter temperatures. Average annual rainfall is in a range of 20 – 40 cm. Summer temperatures can be as high as 47°C, and winter temperatures as low as 0°C. The weather is generally dry, but is very humid from mid-May to the end of August. Rainfall is primarily from the south-west due to monsoon weather, and is concentrated in the period July to mid-September.

C. Topography, Geography and General Geology

The project site is part of Indo-gangetic Plain. It is the world's most extensive tract of uninterrupted alluvium. These deep, river-deposited sediments give rise to fertile soils.

The Indo-Gangetic Plain, with an area of about 270,000 square miles (700,000 square kilometres), varies in width by several hundred miles. It is the world's most extensive tract of uninterrupted alluvium. These deep, river-deposited sediments give rise to fertile soils. In addition, they are rich in groundwater for well irrigation. The flat terrain also makes the area ideal for canal irrigation.

The greater part of the Indo-Gangetic Plain is drained by the Ganges River, which rises in the southern Himalayas and flows in a generally south to southeast direction to the Bay of Bengal. Its principal tributary, the Yamuna, or Jumna, flows past New Delhi, the capital of India, to join the Ganges near Allahabad. North of Goalundo Ghat in Bangladesh, the Ganges is joined by the Brahmaputra.

The soils along the alignment belong to the " Indo Gangetic Alluvium " and are river deposits. The Pleistocene and Recent Deposits of the Indo-Gangetic Basin are composed of gravels, sands, silts and clays with remains of animal and plants. The older alluvium is rather dark coloured (locally called "Bhanger") and is generally, rich in concentrations or nodules of impure calcium carbonate (kankars). The kankars are of all shapes and sizes, varying from small sand sized grains to big grains and big lumps. The age of the "Bhanger" allu|vium is Middle to Upper Pleistocene.

The newer alluvium (locally called khaddar) is light coloured and poor in concretions. It contains lenticular beds of sand and gravel as well as peat beds. It is merged by insensible gradations into the Recent or deltaic alluvia and its age is Upper Pleistocene to Recent.

III. METHODOLOGY

To determine the in situ soil strength Standard penetration test (SPT) at various depths are carried out in each borehole. The observed SPT-N Values and corrected SPT N values are presented.

SOIL SHEAR PARAMETERS

To arrive the soil strength parameters, following approach is adopted to arrive from field SPT N values.

Angle of Internal Friction

a) SPT N-Angle of Internal Friction

Based on N value as per IS 6403:1981, angle of internal friction can be assessed for cohesion less soils.

Relative Density (Dr) - Angle of Internal Friction

Using above relative density, angle of internal friction (Ø) is calculated using the Meyerhof, correlation

Ø = 25 + 0.15 Dr(%) for granular soil with more than 5% fine sand and silt.

2) Cohesion

Based on the N value, the following relation given in Foundation Design Manual by N.V. Nayak is used to derive cohesion values based on SPT N.

Cohesion values obtained from the by testing of UDS sample testing also considered. However, the cohesion value is limited to 300 kN/sqm for bearing capacity calculations. From the above two, conservative value of cohesion value is considered in design.

3) Deformation Modulus (Es)

a) Cohesion-less soils

Deformation Modulus E for sands has been obtained from correlations with SPT 'N' as provided in Foundation analysis and Design by JE Bowles. Following stiffness correlations are adopted based on in-situ density / consistency of soil and its grain size composition.

E= 250 (N+15) kPa

b) Cohesive soils

The soils present in this stretch are over consolidated clays, hence only immediate settlements are considered for the settlement estimations. For short term, immediate settlements, Elastic modulus value has been obtained from the correlations given with respect to cohesion value as per Foundation Analysis and Design by J E Bowles,

Normally consolidated clays
, Es = (200 to 500) Cu
Normally consolidated insensitive and lightly over-consolidated clays,
Es = (750 to 1200) Cu
Heavily over-consolidated clays,
Es = (1500 to 2000) Cu

Where, C is cohesion value. However, the Es value limited to 500 Cu for the settlement estimations and the maximum value limited to 50000kPa. From the above, conservative value for deformation Modulus is considered in design.

4) Modulus of volume compressibility (mv).

Modulus of volume compressibility for clays is the inverse of Deformation modulus

$$E_S = \frac{1}{m_v}$$

Modulus of volume compressibility for clays is as provided in Pile Design and Construction Practice by M. Tomlinson as per the following relation based on SPT N and laboratory consistency limits.

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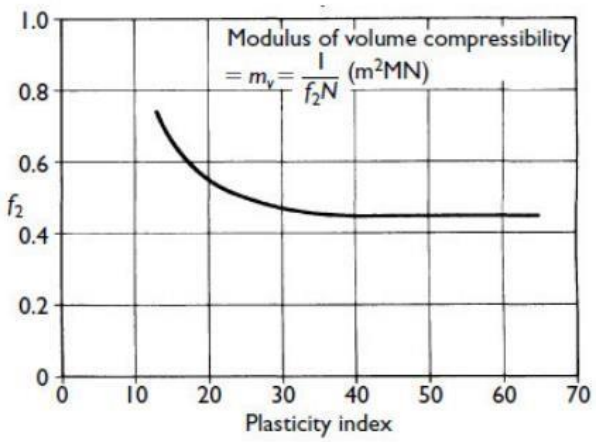

Relation between SPT N Value , Plasticity Index and mv

5) BEARING CAPACITY CALCULATIONS

Bearing capacity and soil investigation.

- All civil engineering structures whether they are buildings, dams, bridges etc. are built on soils. A foundation is required to transmit the load of the structure on a large area of soil. The foundation of the structure should be so designed that the soil below does not fail in shear nor there is the excessive settlement of the structure. The conventional method of foundation design is based on the concept of bearing capacity.

- Soil when stressed due to loading, tend to deform. The resistance to deformation of the soil depends upon factors like water content, bulk density, angle of internal friction and the manner in which load is applied on the soil. The maximum load per unit area which the soil or rock can carry without yielding or displacement is termed as the bearing capacity of soils.

- Soil properties like shear strength, density, permeability etc., affect the bearing capacity of soil. Dense sand will have more bearing capacity than loose sand as unit weight of dense sand is more than loose sand.

- If the bearing capacity of soil at shallow depth is sufficient to safely take the load of the structure, a shallow foundation is provided. Isolated footing, combined footing or strip footing are the option for the shallow foundation. Deep foundations are provided when soil immediately below the structure does not have the adequate bearing capacity. Pile, piers or well are the options for deep foundations. Mat or raft foundations are useful for soil which is subjected to differential settlement or where there is a wide variation in loading between adjacent columns.

Types of bearing capacity of soil.

Ultimate bearing capacity:-

The ultimate bearing capacity of soil is the maximum vertical pressure that can be applied to the ground surface, at which point a shear failure mechanism develops in the supporting soil.

In essence, this means the maximum amount of load the soil can take before it fails, or gives way completely. We don't use this figure on its own in the foundation design process, as it's also important to consider how soil will settle under pressure, which could affect its ability to support a structure.

Allowable bearing capacity :-

The allowable bearing capacity of soil is the amount of load the soil can take without experiencing shear failure or exceeding the allowable amount of settlement. This is the figure that is used in the design of foundations.

The allowable bearing capacity is always lower than the ultimate bearing pressure because it takes into account the settlement of soil, not just the load required to cause shear failure.

Standard Penetration Tests (SPT) :-

Standard Penetration Tests were conducted at 3.0 m interval as per the procedure in IS: 2131 – 1981. For conducting the test, the bottom of the borehole was properly cleaned and split spoon sampler was properly seated in position in the borehole. The split spoon sampler resting on the bottom of borehole was allowed to sink under its own weight; then the sampler was seated 15 cm with the blows of the hammer of 63.5 Kg weight falling through 75 cm. Thereafter, the split spoon sampler was further driven by 30 cm. The number of blows required to affect each 15 cm of penetration was recorded. The first 15 cm of drive is considered to be seating drive. The total blows of penetration for the second and third 15 cm of penetration is termed the penetration resistance N. The 'N' values are indicative of the compactness / relative density of cohesion less soils and consistency of cohesive soils. In case the blow count of SPT in soil (including the number of blows for seating) exceeds 100, the corresponding penetration was recorded and this particular test at that depth stopped. If the total penetration is more than the seating penetration of 15 cm, then breakup of blow count for 15 cm seating penetration and for remaining portion of penetration is also be given.

Disturbed Sampling (Soil) in boreholes:-

In all boreholes, disturbed soil samples was taken at every 1.5 m interval and at significant change of stratum (or as per specified). Soil from cutting edge of undisturbed samplers and from split spoon sampler used for standard penetration tests was taken as disturbed samples. These samples were placed without delay in adequately sealed polythene bags.

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Figure.: Disturbed Soil Sample from SPT

Undisturbed Sampling (Soil) in Boreholes:-
Undisturbed sampling was done in accordance with IS: 2132 – 1986. Undisturbed soil
samples (UDS) was obtained at every 3.0 m interval as per approved methodology and sampling schedule.
Undisturbed samples were collected using 100mm dia. and 450 mm long MS tubes provided with sampler head with ball check arrangement. Collection of undisturbed samples in very hard cohesive soils / dense granular soils / gravels / cobbles / pebbles / boulders, refusal strata is practically not possible and such collected samples will not truly represent the undisturbed conditions.

Figure:. Sample collected with casing

Figure : SPT being conducted at Site.

Figure: SPT being conducted at Site.

BOREHOLES

The Boreholes in soil were progressed by shell & auger boring method as per IS: 1892 –1979 and approved methodology. Boring was advanced at selected / specified borehole locations. The following steps were adopted during boring operations;

1) Boring rig with power winch was assembled at site and was shifted and erected at the borehole location.
2) Taking out the top soil up to approximately 500 mm.
3) The auger was joined at the end of hollow drill rod, which is rotated manually.
4) After reaching the drill rods attached with the auger attained its full depth another piece (extension rod) was attached and continued the drilling up to the level of water table.
5) Below the water table shell was used instead of auger, casing pipe was lowered as per requirement.
6) Casing was used as per the prevailing soil conditions, to stabilize the borehole.
7) Required field tests i. e, Standard Penetration Tests and collection of undisturbed / disturbed samples was conducted as per requirements at specified depths / levels, the same has been discussed in detail in this document.

This process was continued till the achievement of full depth of bore hole as per requirement.

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IV. RESULT AND DISCUSSION

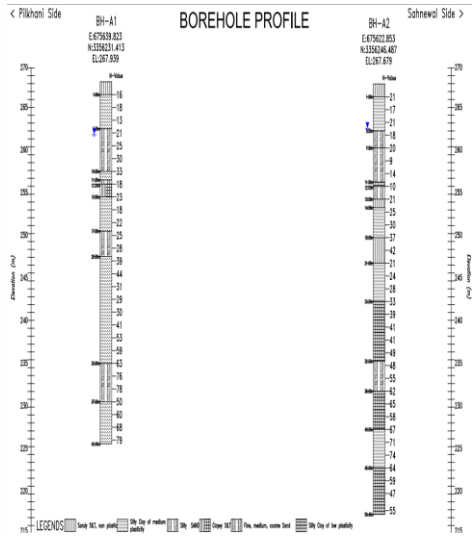

Figure :- BORE HOLE PROFILE FOR ABUTMENT A 1 & A 2 .

Bore Hole Profile data was collected from 2 sides namely Abutment A 1 and Abutment A2.Bore was done up to a depth of 55 meters at Maximum.

Table 1 :- FIELD TEST REPORT FOR ABUTMENT A 1

FIELD TEST RESULTS										
ELEVATION IN METERS	DEPTH IN METERS BELOW REFERENCE	NATURE OF SAMPLING	SAMPLE REFERENCE NUMBER	LEVEL OF WATER TABLE	DEPTH IN METERS	NO. OF BLOWS	PENETRATION(CM)	N VALUE (RECORDED)	N VALUE (CORRECTED)	DESCRIPTION OF SOIL
267.939	1	DS	1		0.00-1.00					BROWNISH GREY SANDY SILT NON PLASTIC(ML) 1.50M
	2	SPT	1		1.50-1.95	16	30	16	16	STIFF TO VERT STIFF BROWNISH GREY SILTY CLAY OF MEDIUM PLASTICITY(CI) 5.50M
	3	UDS	1		2.50-2.80					
	4	SPT	2		3.00-3.45	18	30	18	18	
262.439	5.5	SPT	3		4.50-4.95	13	30	13	13	
	6	UDS	2		5.50-5.80		30			MEDIUM DENSE TO DENSE BROWNISH GREY SILTY SAND (SM) 10.50M
	7	SPT	4		6.00-6.45	21	30	21	18	
	8	SPT	5		7.50-7.95	25	30	25	19	
	9	UDS/DS	3		8.50-8.80	SLIPPED				
257.439	10.5	SPT	6		9.00-9.45	30	30	30	21	
256.439	11.5	SPT	7	6.20m	10.50-10.95	33	30	33	33	HARD BROWNISH GREY SILTY CLAY OF MEDIUM PLASTICITY (CI) 11.50M
255.939	12	UDS	4		11.50-11.80					BROWNISH GREY SILTY SAND (SM) 12.00M
254.439	13.5	SPT	8		12.00-12.45	18	30	18	18	VERY STIFF BROWNISH GREY SANDY SILT OF LOW PLASTICITY WITH NOMINAL CLAY (ML-CL) 13.50
	14	SPT	9		13.50-13.95	23	30	23	23	VERY STIFF BROWNISH GREY SANDY SILTY CLAY OF MEDIUM PLASTICITY (CI) 17.50M
	15	UDS	5		14.50-14.80					
	16	SPT	10		15.00-15.45	18	30	18	18	
250.439	17.5	SPT	11		16.50-16.95	22	30	22	22	
	18	UDS/DS	6		17.50-17.80	HARD TO PENETRATE				MEDIUM DENSE GREY SILTY SAND (SM) 20.50M
	19	SPT	12		18.00-18.45	25	30	25	17	
	20.5	SPT	13		19.50-19.95	28	30	28	17	

In this Table we will get the Elevation in Meters, Depth in meters below reference point , Nature of Sampling , Level of Water Table here was 6.20 Meters. Then further in this table we have Number of Blows corresponding to the Depth in Meters and Peneteration. SPT N values and Corrected N values are also mentioned and at last Description of Soil is also recorded which varies from Brown grey Sandy Silt to Medium Dense Grey Silty Sand.

Table 1 (a) :- FIELD TEST REPORT FOR ABUTMENT A 1

	21	UDS/DS	7		20.50-12.80	HARD TO PENETRATE			
	22	SPT	14		21.00-21.45	39	30	39	39
	23	SPT	15		22.50-22.95	44	30	44	44
	24	UDS/DS	8		24.00-24.45	HARD TO PENETRATE			
	25	SPT	16		25.50-25.95	31	30	31	31
	26	SPT	17		26.60-26.80	29	30	29	29
	27	UDS/DS	9		27.00-27.45	HARD TO PENETRATE			
	28	SPT	18		28.50-28.95	30	30	30	30
	29	SPT	19		29.50-29.80	41	30	41	41
	30	UDS/DS	10		30.00-30.45	HARD TO PENETRATE			
	31	SPT	20		31.50-31.95	53	30	53	53
	32	SPT	21	6.20m	32.50-32.80	59	30	59	59
234.03	33	UDS/DS	11		33.00-33.45	HARD TO PENETRATE			
	34	SPT	22		34.50-34.95	63	30	63	25
	35	SPT	23		35.50-35.80	76	30	76	28
	36	UDS/DS	12		36.00-36.45	HARD TO PENETRATE			
230.439	37.5	SPT	24		37.50-37.95	78	30	78	28
	38	SPT	25		38.50-38.80	50	30	50	50
	39	UDS/DS	13		39.00-9.45	HARD TO PENETRATE			
	40	SPT	26		40.50-40.95	60	30	60	60
	41	SPT	27		41.50-41.80	68	30	68	68
	42	UDS/DS	14		42.00-42.45	HARD TO PENETRATE			
	43	SPT	28			79	30	79	79

HARD BROWNISH GREY SILTY CLAY OF MEDIUM PLASTICITY (CI)

HARD BROWNISH GREY SILTY CLAY OF MEDIUM PLASTICITY (CI) 33M

VERY DENSE GREY SILTY SAND (SM) 37.50M

HARD BROWNISH GREY SILTY CLAY OF MEDIUM PLASTICITY (CI) 42.45M

NOTE: 1. CLASSIFICATION OF SOIL AS PER IS :1498

2. ABBREVATION USED :- DS - DISTURBED SAMPLE. SPT - STANDARD PENETRATION TEST . UDS- UNDISTURBED SAMPLE . UC- UNCONFINED COMPRESSION TEST. UU-UNCONSOLIDATED UNDRAINED TEST . DST-DIRECT SHEAR TEST .

In this Table we will get the Elevation in Meters, Depth in meters below reference point , Nature of Sampling , Level of Water Table here was 6.20 Meters. Then further in this table we have Number of Blows corresponding to the Depth in Meters and Peneteration. SPT N values and Corrected N values are also mentioned and at last Description of Soil is also recorded which varies from Brown grey Sandy Silt to Hard Brownish Grey Silty Clay.

V. CONCLUSION

From conducting Standard Peneteration Test and obtained Bore Hole Log its is very evident that Safe Bearing Capacity is achieved at very deep depths hence settlement corresponding to the required Bearing pressure of 10t/m^2 is being achieved at deep depths hence we will go for Deep Foundations. Safe settlement is also being achieved after the SPT being conducted for the depth of Upto 40 mtrs it is clear that Pile foundation must be followed in order to sustain the load of 30t/mtr^2 and to bear the speed of 100kmph to 120kmph safely without any mishappening. A closed set of Friction Piles is recommended for the structure. As the Safe settlement is achieved in deep depths so it is evident that depth of Piles must be kept in Between 20 mtrs/25 mtrs. Advisable Diameter of Pile was 1200mm so as to transfer the load from above structure to soil beneath.

REFERENCES

[1] J. David Rogers (2006) Subsurface Exploration Using the Standard Penetration Test and the Cone Penetrometer Test. *Environmental & Engineering Geoscience* 12 (2): 161–179Alencar, A; Galindo, R.; Olalla Maranon, C. (2021) Assessment of the Bearing Capacity of Bridge Foundation on Rock Masses. *Applied Sciences. 2021*, 11, 12068. Wathiq Aljabban (2013) Estimation Of Standard Penetration Test (SPT) Of Hilla City-Iraq By Using GPS Coordination.*Jordan Journal Of Civil Engineering* 7(2):133-145

[2] Wathiq Aljabban (2013) Estimation Of Standard Penetration Test (SPT) Of Hilla City-Iraq By Using GPS Coordination.*Jordan Journal Of Civil Engineering* 7(2):133-145.Wazoh, H. N and Mallo, S. J (2014) Standard Penetration Test in Engineering Geological Site Investigations.*The International Journal Of Engineering And*

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Vol. 12 Issue 02, February-2023

Science (IJES)|| Volume || 3 || Issue || 7 || Pages || PP-40-48 || 2014 ||ISSN (e): 2319 – 1813ISSN (p): 2319 – 1805

[3] Wazoh, H. N and Mallo, S. J (2014) Standard Penetration Test in Engineering Geological Site Investigations.*The International Journal Of Engineering And Science (IJES)*|| Volume || 3 || Issue || 7 || Pages || PP-40-48 || 2014 ||ISSN (e): 2319 – 1813ISSN (p): 2319 – 1805. Biswas Uprety, Mihir Lal (2021) Standard Penetration Test in Geotechnical Engineering Site Investigations.***Journal of Emerging Technologies and Innovative Research.*** Volume 8, Issue 4

[4] Debojit Sarker , Md. Zoynul Abedin (2015) Applicability of Standard Penetration Test in Bangladesh andGraphical Representation of SPT-N Value. *International Journal of Science and Engineering Investigations* vol. 4, issue 41.

[5] John, T. and Thomas, S. (2017) Bearing Capacity prediction for shallow foundation by in-situ and experimental investigation. *International Journal of Scientific & Engineering. Research, Vol. 8*, Issue 4, ISSN 2229-5518.

[6] Roy, S. and Bhalla, SK. (2017) Role of Geotechnical Properties of Soil on Civil Engineering Structures. *Resources and Environment 2017*, 7(4): 103-109.

[7] António Viana da Fonseca , Cristiana Ferreira, Catarina Ramos and Fausto Molina-Gómez (2019) The geotechnical test site in the greater Lisbon area for liquefaction characterisation and sample quality control of cohesionless soils. *AIMS Geosciences*, 5(2): 325–343.Aziz HY and Jialian Ma. (2021) Design and Analysis of bridge foundation with different codes. *Journal of Civil Engineering and Construction Technology, Vol. 2(5)*, pp. 101118, May 2011.

[8] Han Xia, Jiangtao Zhang, Jun Cai, Huangsong Pan and Xuesen She (2020) Study on the Bearing Capacity and Engineering Performance of Aeolian Sand. Hindawi *Advances in Materials Science and Engineering, Vol. 2020*, Article ID 3426280, 11, 12068.

[9] Biswas Uprety, Mihir Lal (2021) Standard Penetration Test in Geotechnical Engineering Site Investigations.***Journal of Emerging Technologies and Innovative Research.*** Volume 8, Issue 4. John, T. and Thomas, S. (2017) Bearing Capacity prediction for shallow foundation by in-situ and experimental investigation. *International Journal of Scientific & Engineering. Research, Vol. 8*, Issue 4, ISSN 2229-5518.

[10] Aziz HY and Jialian Ma. (2021) Design and Analysis of bridge foundation with different codes. *Journal of Civil Engineering and Construction Technology, Vol. 2(5)*, pp. 101118.

[11] IRC-78, Standard specifications and code of practice for road bridges, 2014.

[12] Codes of practice for the design of sub-structures and foundations of bridges, 2003.

[13] IS 6403-1981 Code of Practice for determination of bearing capacity of shallow foundation. Foundation Analysis and Design by J.E. Bowles, Fifth Edition (1997).

[14] Foundation design Manual for practicing by Narayan Nayak.