Integrated Methodology of Geoengineering Investigation for Determination of Subsurface Lithology and Suggest Founding Levels of the Civil Structures at Road Over Bridge Locations - A Case Study in Vizianagaram District, Andhra Pradesh

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Abstract-The paper presents an application of the geoelectrical method in organic soils occurring in the area of a designed investment. To gather the information outlined above, it is necessary to conduct subsurface investigations. This information is often obtained from direct mechanical boring and some other geotechnical methods. In order to evaluate the competence of subsurface layers, determine optimum depth to competent layers, and provide preliminary recommendations for foundation design, an engineering geophysical investigation involving the 2D Resistivity Imaging (RI) technique was carried out at the Gosthani River in Vizianagaram district, Andhra Pradesh state. Electrical resistivity is a physical parameter that may reflect the variability of the geological medium with regard to lithology if the range of conductivity of water filling the pore space is narrow. Auger drilling method is followed to collect undisturbed soil samples and taken to soil mechanics laboratory. Geo-Engineering techniques were helped us to find out several engineering properties of soils like safe bearing capacity, type of soil and maximum dry density.

Key Words: Geo-Engineering techniques, Auger drilling, Electrical resistivity and Gosthani River.

INTRODUCTION:

Geo-Engineering is concerned with the engineering behavior of earth materials. Geo-Engineering includes investigating existing subsurface conditions and materials; determining their physical/mechanical and chemical properties that are relevant to the project considered, assessing risks posed by site conditions; designing earthworks and structure foundations; and monitoring site conditions, earthwork and foundation construction. The selection of appropriate research methods is particularly important in the recognition of areas with a complex geological structure. In such areas, the application of a multidisciplinary approach using geophysical methods is recommended by Ercoli et al. (2012) and Zini et al. (2015). The application of traditional geotechnical and geological-engineering research methods (boreholes, dynamic and static probing, etc.) supplying point data, coupled with geophysical methods (ground-penetrating radar, electrical resistivity imaging) allowing for a quasicontinuous record of physical changes in the soil medium, enables obtaining complementary results for the correct recognition of the soil-water conditions (Kowalczyk and Mieszkowski, 2011; Pierwoła et al., 2011; Maślakowski et al., 2014a; Kowalczyk et al., 2017). The investigations presented in this paper have been conducted in the Gosthani River, which has adapted seasonal water flow for its course. The depressions were successively filled with organic sediments, becoming much shallower and currently represent peat plains. Geoelectrical methods are used in the studies of peatlands (Slater and Reeve, 2002; Kowalczyk and Mieszkowski, 2011; Comas et al., 2015; Walter et al., 2016) and at present more frequently for recognizing the extent of organic soils in the foundations of designed investments (Maślakowski et al., 2014a; Pasierb and Nawrocki, 2015). Electrical resistivity imaging (ERI) is often used in the recognition of complex geological conditions in investigations of the foundations of roads and motorways (Ganerød et al., 2006; Maślakowski et al., 2014a; Ngan-Tillard et al., 2010; Osinowo et al., 2011; Wisén et al., 2008; Kowalczyk et al., 2017). Foundations built for above-ground structures include shallow and deep foundations. Retaining structures include earth-filled dams and retaining walls. Earthworks include embankments, tunnels, dikes, levees, channels, reservoirs, deposition of hazardous waste and sanitary landfills. The engineering properties of soils are affected by four main factors: the predominant size of the mineral particles, the type of mineral particles, the grain size distribution, and the relative quantities of mineral, water and air present in the soil matrix. Fine particles (fines) are defined as particles less than 0.075 mm in diameter.

Location:

The study area is the High level Road Over Bridge (ROB) over Gosthani river as well over the GT Rail track near Bheemasingi village in Vizianagaram district of Andhra Pradesh on the high way between Vizianagaram and Srungavarapukota towns starting at 10.000km RD and ending at 11.450km RD has shown in Fig.1. Present ROB is across river Gosthani only and after the bridge crossing the road traverses across the above said railway track within 200m distance where manned rail gate is present to control the traffic. As the traffic of the GT railway track is heavy and the road traffic is also increased very much due industrialization in the surrounding areas, road traffic getting jammed and the road users facing difficulties. Keeping in view of the of inconvenience face by the road passengers, it is proposed to construct Road Over Bride(ROB) over the railway track also has shown in Fig.2.

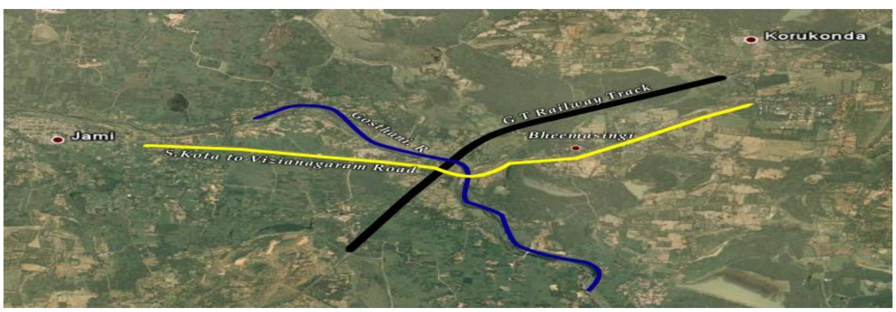

Fig.1. Location map of the study area

Fig.2: Proposed road over bridge alignment

Instead of continuation of the existing ROB across Gosthani river over the railway line also a new alignment is proposed due to insufficient place between the railway track and present bridge to maintain sufficient slope, a new ROB is proposed. The proposed new alignment covers both the rail track and river course and is shown below. The new alignment is about 1.450km that traverse across a small hill mound on the left bank, Gosthani river and Railway track at Km831/3 in between Alamanda – Korukonda.

Physiography:

Rock hill mounds, rock outcrops, gravelly soils are observed on the left bank surroundings of the Gosthani river. A longitudinal cross section is taken along the proposed ROB alignment for alength of 1.450km in which the maximum elevation is +32. m MSL over the left bank rock outcrop and minimum is + 21. in the river bed. Gosthani river takes right angle turn at this proposed ROB site. Left portion of the river bed consists of sand deposit and the right portion covered with silty sand. The right bank and beyond the top soils consists of alluvial soils and the topography is plain but in between bunds are made for railway track. Surface observations indicate rock formations are expected at shallow depth on the left bank and thick alluvial formations are expected in the river course as well for the entire right bank reach.

Geology:

Reconnaissance study of surface and subsurface geology is essential in and around the study area particularly along the proposed ROB alignment to have an idea about the sequence of the deposited soils and basement rock. Rock out crops present on the left bank and also along the proposed alignment belongs to Quartzite with east-west strike and with variable dip of 65^0 to 75^0 due south. No outcrops are observed in the river bed as well on the right bank till the end point of the ROB. Near Jami village which is about 2.0km on the west side and Korukonda village about 1.0 km towards east charnockite rock outcrops and hill mounds are observed. Bore holes drilled along the alignment also indicate the presence of charnockite rock at deeper depth. Surface and subsurface geological observations reveals the presence of quartzite and charnockite basement rock.

An alluvial soil consists of clay, sand, sandy clay formations are observed in the river course as well on the right bank side for about 1.0km from the railway line alignment and the formation thickness varies between 10m and 20m. Irrigated crops on the right bank are fed by the bore holes drilled in that region.

Geophysical Investigations:

Geophysical surveys make use of differences in the physical properties like electrical conductivity and elastic moduli, density and magnetic susceptibility of geological formations in the area to investigate the subsurface. These methods may be employed to get preliminary information on stratigraphy or complement a reduced boring programme by correlation of stratigraphy between widely spaced boreholes. Of the four methods of geophysical surveys, namely seismic, electrical, and magnetic and gravity surveys, only seismic refraction and electrical resistivity surveys are widely used. Magnetic methods are occasionally used for detecting buried channels, dykes, ridges, and intrusions in the subsurface rocks. Resistivity method consists of simple equipment, battery power supply and easy to handle in the field with out disturbing any public or land use. This method has been applied in various Civil Engineering problems posed by the State and Central Govt. Organizations.

Water Table:

Water plays an important role from the foundation point of view. Water level noted in the bore holes during soil investigation (July, 2009) indicate the variability between 0.50m and 6.80m. However, the site of investigation is a river influenced area; water table will be at shallow depth for some or other. Hence, water table influence on the structures should be considered while designing the structural foundations.

Field Drilling Operations:

Bore hole drilling operations have been carried out at 9 locations along the proposed ROB with auger and rotary drilling methods. The drilling machine used for the purpose is a rotary type. The operations are carried out as per the IS Code 1982 (1962). The purpose of the drilling is to collect un-disturbed soil samples and conduct Standard Penetration Test (SPT) to determine the engineering properties of sub-surface layers in field. The drilling in the overburden soils was executed by 150-mm diameter bit. Tests conducted and the lithology observed during the drilling is shown in the Table 1.

Table 1:Bore well locations Chainage with respect to the Running Distance (RD)

Bore Hole No.	**Running Distance (Km.)**	**Depth of the drilling**	**R.L (M)**
1	10	8	25.25
2	10.24	10	29.206
3	10.39	19	22.603
4	10.43	16.5	21.793
5	10.47	19	20.74
6	10.52	28.5	24.036
7	10.777	27	28.33
8	10.875	20	28.069
9	11	30	28.436

Standard Penetration Test (SPT):

Standard Penetration Tests were conducted in the bore holes at every change of strata in accordance with I.S. 2131 (1981). A standard split spoon sampler of 50.8 mm dia with cutting shoe and driving head attachment was driven at the bottom of the clear bore hole by a 63.5 kg monkey falling freely from a height of 75 cms. The first 15 cms of the drive was neglected and the strokes required to drive the next 30 cms were recorded as standard penetration resistance (N value). The results of the standard penetration test (SPT) are given in the bore hole log data with corresponding depths. The Standard Penetration Test values and the safe bearing capacity arrived from the 'N' values as per the IS-6403-1971 are listed in the following Table-2

Table 2 - Allowable bearing capacity values arrived from the SPT values ('N' value) at Bore holes –1 and 9

Bore Hole No.1- 10.00km			Bore Hole No.- 10.240km		
Depth(m)	'N' Value	Bearing Capacity (t/m^2)	Depth(m)	'N' Value	Bearing Capacity (t/m^2)
2.0-2.45	13	7	2.0-2.45	30	15
4.0-4.45	26	13	4.0-4.45	37	19
6.0-6.45	29	15	6.0-6.05	>100	>50
			8.0-8.02	>100	>100

BORE LOG: Soil Investigation at the proposed ROB at Railway Km 831/3, Bheemasingi, Vizianagaram Dt.

Bore Hole No. 1
Location : Chainage- 10.000km
Dates of Execution : 28-07-09 to 28-07-09
R.L: +26.236m

Method of Drilling : Rotary
Diameter of the Bore : 150 mm
Bore terminated at : 8.00m bgl
Groundwater table : 6.80m bgl

SAMPLES		S. P. T.			STRATA DIMENSIONS			STRATA DISCRIPTION
Depth (m)	Type	Depth (m)	'N' Value	SBC t/m^2	Litho-log	Depth (m)	Thick-ness (m)	
0.50						0.0-0.5	0.50	Filled soil
1.00	DS				../../			
1.50	UDS-1	1.0-1.45			....			
2.00					../../			
2.50	SPT-1	2.0-2.45	13	7	....			
3.00					../../			
3.50	DS				....		6.50	Sand with gravel
4.00					../../			
4.50	SPT-2	4.0-4.45	26	13	....			
5.00					../../			
5.50	DS				....			
6.00					../../			
6.50	SPT-3	6.0-6.45	29	15	....			
7.00					../..	0.5-7.0		
7.50	Rock Core samples obtained by Nx size diamond drilling bit 7.00 to 8.00m C.R- 56%,RQD- Nil				/ / /	7.0-8.0	1.00	Hard rock with fractures
8.00								

Calculation of Bearing Capacity:

Terzaghi's square footing equation has been used for calculating the safe bearing capacity (SBC) as per IS: code 6403-1971. Soil Investigation at ROB, Bheemasingi, Vizianagaram Dt has shown in Table 3.

Table 3: U.D. Soil sample Analysis for the required physical parameters

S.No	Parameters	B.H.No.1- 10.00km	B.H.No.2- 10.420km
1	Depth (m)	1.5-1.95	1.5-1.95
2	Grain size analysis		
	Gravel (%)	12	19
	Sand (%)	59	51
	Fines (%)	29	30
3	Atterberg limits		
	Liquid limit (%)	NP	NP
	Plastic limit (%)	NP	NP
	Plasticity index	NP	NP
4	N.M.C (%)	9.2	7.6
5	Bulk density (g/cc)	2.04	2.05
6	IS Classification	GC	GC
7	Specific gravity	2.65	2.68
8	Free swell- %	2	2
9	Shear parameters		
	Cohesion (kg/cm^2) -C	0.08	0.10
	Angle of internal friction (Φ) in degrees	28	25
10	Safe Bearing Capacity (t/m^2)- safety factor-3	22.2	17.5

Rock samples Analysis – Unconfined compressive Strength:

The rock core samples collected at various depths from the bore holes through Nx size core drilling are tested in the laboratory to determine the unconfined compressive strength of the rock. The rock cores are sized in the ratio 2:1 of length and diameter has been selected and unconfined compressive strength of the rock is determined in the laboratory as per the IS: 1121-1971. The results are shown in the table – 4.

Physical observation of the rock core samples indicate that the hard rock formation identified can be classified as hard rock with minor fractures/hair line cracks. The rock sample belongs to Charnockite and Quartzite.

Table 4- Crushing strength of the Rock samples

Bore hole No.	Depth of the sample (M)	Unconfined compressive Strength (tons/m^2)	Safe Bearing Capacity (tons/m^2) Safety factor-8	Type of rock
BH-1(10.000km)	Btn. 7.00m and 8.00m	1860	220	Quartzite
BH-2(10.420km)	Btn. 8.00m and 10.00m	2256	282	Quartzite
BH-3(10.540km)	Btn.17.00m and 19.00m	2130	266	Charnockite
BH-4(10.580km)	Btn. 15.00m and 16.50m	3560	445	Charnockite
BH-5(10.680km)	Btn. 17.00m and 19.00m	3800	475	Charnockite
BH-6(10.720km)	Btn. 27.50m and 28.50m	4850	606	Charnockite
BH-7(10.777km)	Btn.25.00m and 27.00m	2840	355	Charnockite
BH-8(10.875km)	Btn. 18.00m and 20.00m	3250	406	Charnockite
BH-9(11.200km)	29.00 and 30.00m	No sizable samples		Charnockite

CONCLUSIONS:

The bore hole samples and bore log analysis shows that the sub-surface formations can be broadly divided into

i) Deposited soils due to fluvial action – Alluvial soils
ii) Rock formations under differential weathering.

- Based on the visual observation and some physical properties of the samples collected from the bore holes up to a depth of 30m, the sub-surface formations can be broadly designated as a) clay. b) silty clay/clayey sand/sandy clay/gravelly clay, c) sand d) soft disintegrated rock (SDR), e) hard disintegrated rock and f) hard rock with fractures.
- The top layer is the alluvial soil consist of clay, sand, silt and mixer of these in different proportions. the thickness of the layer varies between 5.00m and 20.0 meters. SBC arrived from the UD samples shows that the values vary between 5 t/m^2 and 30 t/m^2 and the average SBC value is around 12 t/m^2.
- Second layer is soft disintegrated rock and the layer thickness varies between 3.0m and 12.0m and the 'N' value vary between 25 and >100 and its SBC range between 150 t/m^2 and >50 t/m^2. the average SBC value can be taken as 30 t/m^2
- Third layer is Hard disintegrated rock may be a part of the hard rock with high intensity fracturing and is in between SDR and HR. 'N' value in this layer is >100 blows for penetration of 1cm to 5cms. SBC of the layer may be in the range of 50 to 100 t/m^2.
- Nx size rock core samples are obtained in the Hard rock/ hard rock with minor fractures layer up to 2m from its surface level. Core recovery varies between 50% and 70% and RQD varies 0% and 30%. SBC of the rock samples varies between 220 t/m^2 and 606 t/m^2.

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