Electrical Resistivity Method in Engineering and Environmental Studies: A Case Study of Gbagada Area, Lagos State, Nigeria.

Oyedele, K.F and Ojo, A.O
Dept of physics (Geophysics Programme)
University of Lagos, Lagos Nigeria.
kayodeunilag@yahoo.com

Abstract
Foundation problems are caused by a combination of soil conditions, the weather and inadequate foundation maintenance. This paper presents the results of electrical resistivity method in delineating subsurface soil conditions at Gbagada area, Lagos state Nigeria. Three main soil types were mapped: namely sand, clayeysand and clay. The depth to sand bodies range from 1.18 to 18.09 m while the depth to clay bodies range from 3.43 to over 25.14m. On the other hand the depth to clayeysand bodies range from 1.88 to over 23.64m. It is concluded that the depth to clay layers in most parts of the study area is near the surface. [New York Science Journal. 2009;2(3):13-20]. (ISSN: 1554-0200).

Keywords: Electrical resistivity, sediment, lithology and stratigraphy.

1 Introduction

Since soil condition is one of the sources of foundation problems the need to know the strength, the fitness and the overall subsurface stratigraphy in an area prior to construction works cannot be overemphasized. Other sources of foundation problems include the weather and inadequate foundation maintenance.

Symptoms of foundation problems include cracks in bricks and sheetrock, windows that won't open, doors that won't close, cracks in the foundation, cracks in tile floors and many more. Sometimes some of these symptoms can simply be cosmetically repaired. Complete underpinning of the foundation may not be necessary. It takes an expert to properly diagnose true foundation problems. Just because you have some or all of these symptoms, does not mean that you need foundation repair. However, if adequate precautionary measures are taken into consideration before the commencement of construction exercise some of these problems if not total would have been taken care of.

In many coastal areas of the world, the near surface soil is of expansive clay. Expansive clay behaves differently than sandy soil. Sandy soil does not expand when it gets wet. The water fills the air spaces between the grains of sand. Because of this, the soil volume does not change and there is little movement of structures supported by the soil when the soil moisture conditions alternate between wet and dry. Meanwhile expansive clay soil expands when it absorbs water. Water becomes bound to the clay particles. As the soil goes through wet and dry periods, the soil expands and contracts. Structures sitting on top of the soil rise and fall with the soil. If this happened uniformly across the structure, damage to the foundation and finishes from soil movement would be limited. Unfortunately, uniform shrinking and swelling doesn't usually happen. The result is "differential" foundation movement, which causes cracking and distress in the foundation and finishes.

Although there may be a number of layers and types of expansive clay or other soil under a particular structure, the shrinkage and swelling process is usually limited to soil that is near enough to the ground surface to be affected by climatic conditions. Many Engineers refer to these upper soil layers as the "active zone". While the depth of the 'active zone" depends on both site and soil conditions. This depth ranges between 2 and 5 meters below ground surface.

To this end, electrical resistivity survey method was employed to classify the soil conditions at Gbagada area of Lagos State, Nigeria with a view to provide information on the subsurface stratigraphic variations with respect to depths. This method is the most widely used geophysical techniques, very efficient and cost effective (Neil and Ahmed, 2006, Susan, 2004, Hinze, 1990, Fitterman et al, 2001, Kontar amd ozorovich, 2006 and Oyedele, 2008).

2 Geologic setting

The study area is situated in Lagos (fig1). The surface geology is made up of the Benin formation (Miocene to Recent) and the recent littoral alluvial deposits. The Benin formation consists of thick bodies of yellowish (ferruginous) and white sands (Jones and Hockey, 1964). Multi-layer lithology have been classified by Longe et al, 1987, into three types namely admixtures of sand and clay, coarse sand and clay. The thickness varies from 8 to 35m.

3 Data acquisition and processing

The field data were acquired using Terrameter SAS1000 system. About twenty-four vertical electrical sounding (VES) using Schlumberger electrode array system were conducted. Only results for fourteen VES stations were presented. As a control measure to geographical data, one borehole was drilled to aid lithological delineation.

The acquired data is processed using WinGlink software programme. This is a powerful software package that was designed to read and store data acquired by different geographical surveys carried out in an area of interest, as well as other auxiliary information. By this technique, erroneous interpretations arising from manual techniques are eliminated. The processed data were presented in the form of 1-D resisitvty models, inferred sediments and contoured maps.

4 Results and discussion

Resistivity Curves

Figure 2 shows representative samples of 1-D models resisitivity field curves obtained from the study area. Visual inspection of the field model curves shows a typical 3 to 5-layered case. The detailed stratigraphic sequence of the area is presented in Table1.

Inferred sediments

The geoelectric section alongside with the drilled borehole was used to delineate the stratigraphic succession in the study area (table1).

Beneath VES 1, the lithology consists of topsoil, medium sand, clay and coarse sand. Here the depths to sand layers range from 1.18 to over 5.57m while the average depth to clay layer is 5.57m. Beneath VES, 2 the lithology consists of topsoil, medium sand and coarse sand. The average depth to sand layer is greater than 18.09m. There is no clay layer in this zone as the current terminated in the third layer.

Beneath VES 3, the stratigrphy is made up of top soil, medium sand, clayey sand and coarse sand. The depths to sand layers range from 1.61 to over 17.04m while the depth to clayey sand is 17.604m. Beneath VES 4, the sediment is made up of topsoil, medium sand clayey sand and coarse sand. The depths to sand bodies range from 3.05 to over 21.95m. On the other hand, the depth to clayey sand layer is about 21.95m.

Beneath VES 5, the sediments consist of topsoil, medium sand, clay and coarse sand.
The depths to sand bodies range from 3.74m to over 10.55m, while the depth to clay layer is 10.55m. .The sediments beneath VES 6 consist of topsoil, medium sand, clay and coarse sand. The depths to sand bodies range from 1.62 to over 6.15m while the depth to clay layer is 6.15m. The stratigraphhy beneath VES 7 is made up of the topsoil, medium sand, clay and coarse sand. Here the depth to sand layers varies from 2.8m to over 11.03m while the depth to clay layer is 11.03. The lithology beneath VES 8 consists of topsoil, clayey sand, medium sand, clay and coarse sand. The depths to clay bodies range from11.0m to 39.09m while the depths to sand layers vary from 3.77 to 39.09m.

The stratigraphy beneath VES 9 is made up of topsoil, clay, medium sand, clay and coarse sand. The depths to clay layers vary from 7.05 to over 25.14m. The sediments beneath VES 10 consist of topsoil, clay, medium sand and clay. The depth to clay layers range from 4.69 to over 10.26m.

Beneath VES11, the sediments consist of topsoil, medium sand, clay and coarse sand and clayey sand. The depths to sand layers vary from 1.33 to 11.97m while the depth to clay layer is 3.43m. The lithology

beneath VES12 consists of topsoil, medium sand, clayey sand, and coarse sand. The depths to sand body ranges from 1.87m to over 18.49m while the depth to clayey sand layer is 18.49m.
The sediments Beneath VES13, consist of topsoil, medium sand, clayey sand and clay .The depth to clay layer is over 23.64m while the depth to sand body is 2.1m. On the other hand, the lithology beneath VES14 is made up of topsoil, medium sand, clay coarse sand, and clay. The depths to clay layer range from 3.91 to over 16.22m while the depths to sand body vary form 1.54 to 16.22. On the whole the thicknesses of the sand layers vary from 0.80 to 28.09m while the thicknesses of the clay layers vary from 3.43 to 25.14m.

Contoured maps
The data in table 1 were used as input into the WinGLink software Programme to produce series of maps (Figs 3 and 4).
Figures 4a and 4b show the isopach maps of sand bodies between 0 to 15m and 0 to 20m respectively. In figure 3a, the thicknesses of the sand bodies beneath VES 3,4,6,7,8,11,12,13 and 14 range from 1.18 to 3m. The thickness of the sand layers beneath VES 1,5, 9 and 10 vary from 3 to 6m, while the thickness of the sand body beneath VES 2 vary from 9 to 12. Figure 3c shows the isopach map of depths to freshwater layer which vary from 2 to over 22m. On the other hand, figures 4a to 4d show the isoresisitivity depth-slice maps at 5m, 10m, 20m and 30m respectively. On the whole, the resistivity values at these depths vary from 50 to 1000 ohm-m.

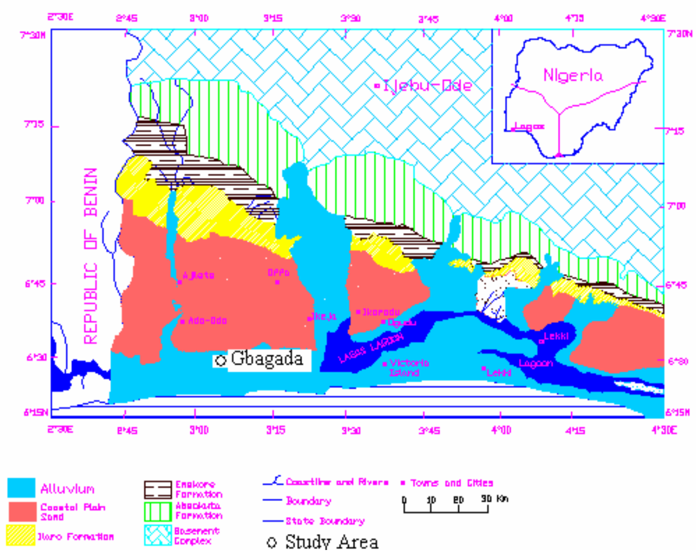


Fig 1: Geological map of Lagos showing the study area

Ves 1 ves2

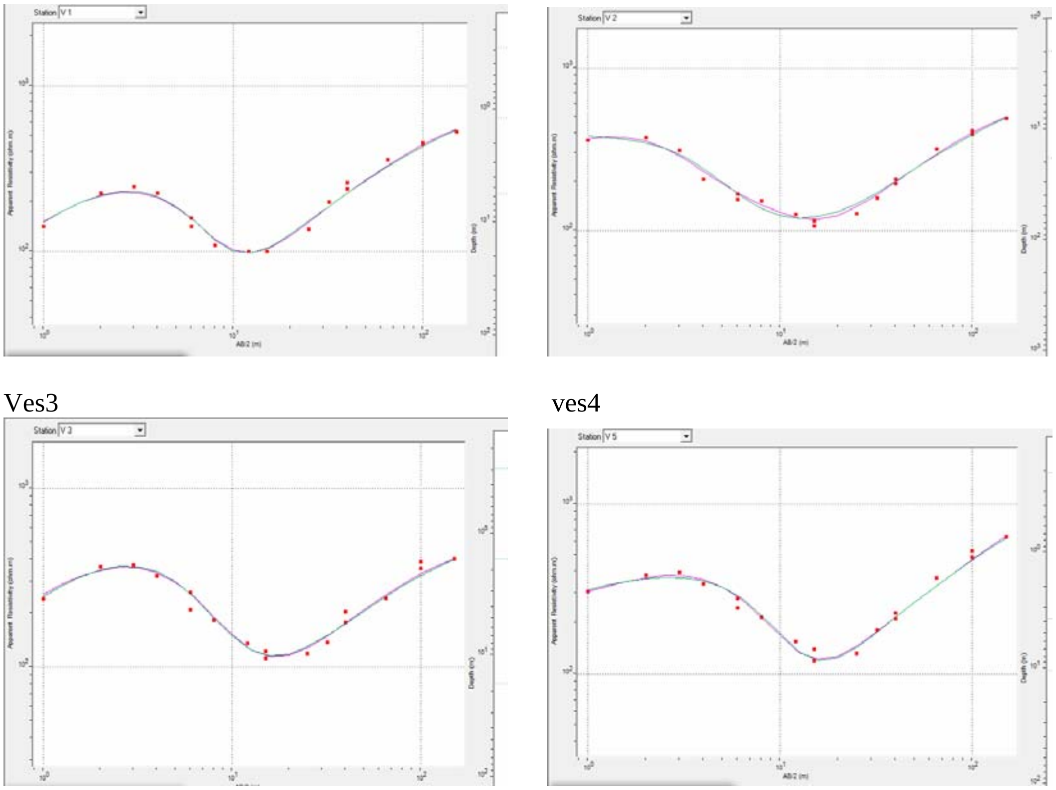
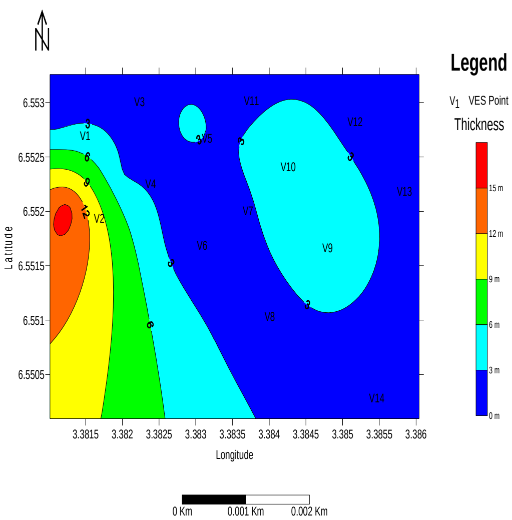
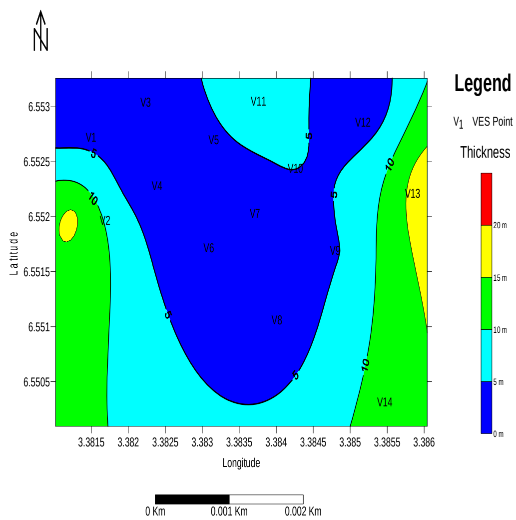


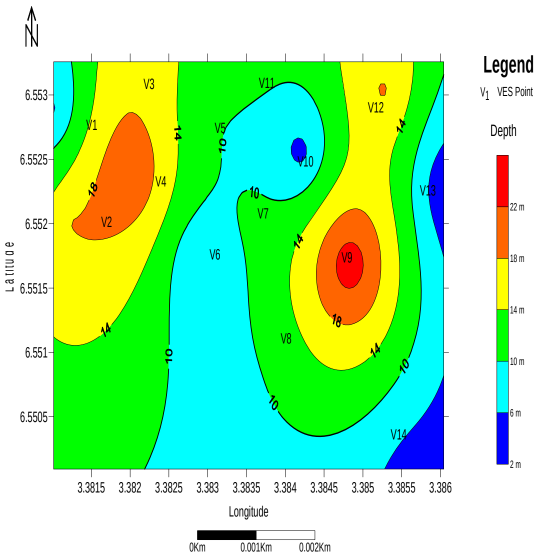
Fig 2: Representative of 1-D model resistivity curves



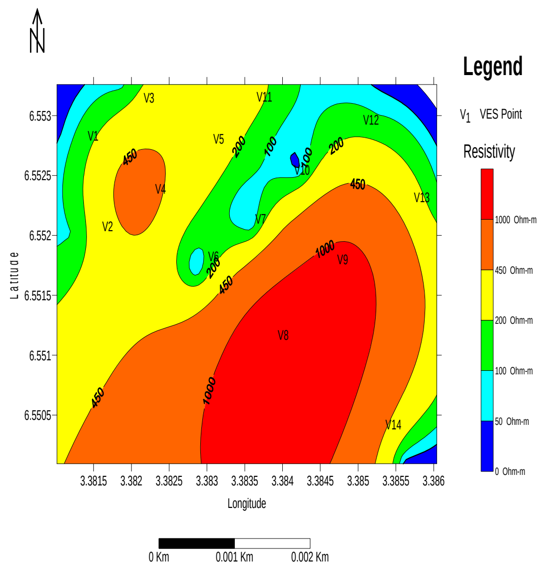
(a) : Sand Isopach Map between 0-15m



(b) : Thickness of sand layer between 0 – 20 m

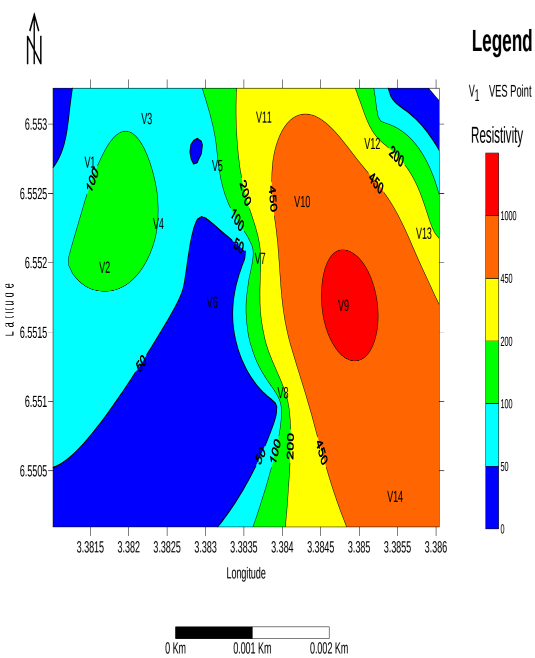


(c): Depth to Freshwater aquifer layer

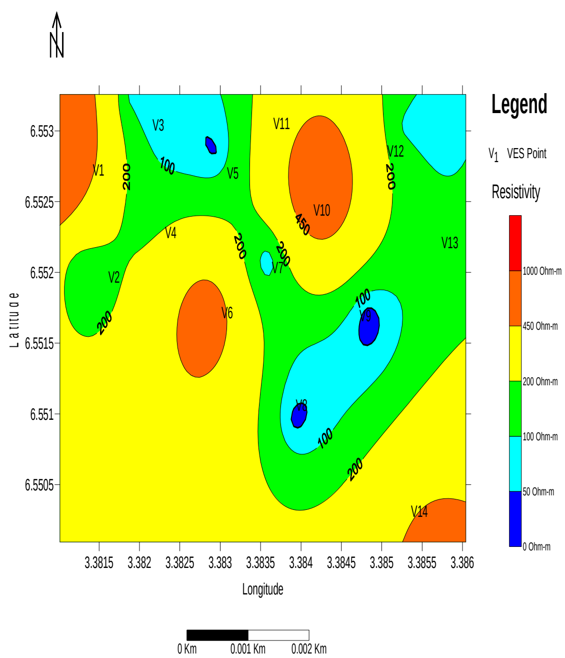


(d): Isoresistivity Depth-slice Map at 3 m

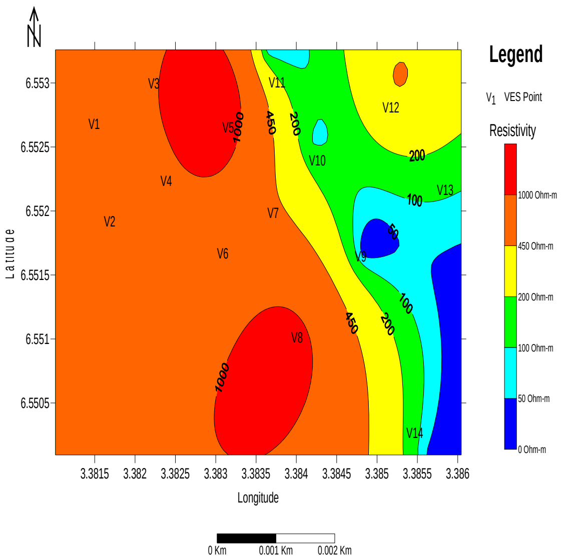
Fig 3: Contoured maps for sand bodies and depth to freshwater layers.



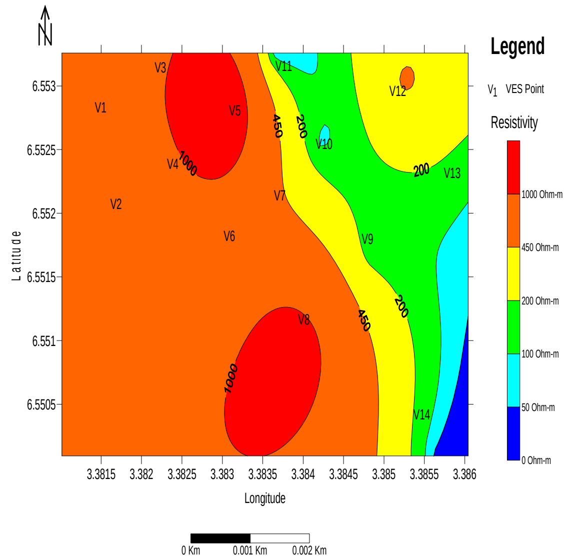
(a) : Isoresistivity Depth-slice Map at 5 m



(b): Isoresistivity Depth-slice Map at 10 m



(c): Isoresistivity Depth-slice Map at 20 m



(d): Isoresistivity Depth-slice Map at 30 m

Fig 4: Isoresistivity Depth-slice Map at 5m, 10m, 20m and 30m respectively.

Table 1: Measured parameters/Inferred sediments

VES Station	Layer	Resistivity (Ohm-m)	Thickness (m)	Depth (m)	Lithology
1	1	55.39	0.28	0.28	Topsoil
	2	742.85	0.9	1.18	Medium Sand
	3	32.98	4.39	**5.57**	**Clay**
	4	934.95	-	-	Coarse Sand
2	1	388.14	1.94	1.94	Topsoil
	2	102.08	16.15	18.09	Medium Sand
	3	911.54	-	-	Coarse Sand
3	1	101.52	0.29	0.29	Topsoil
	2	763.42	1.32	1.61	Medium Sand
	3	87.65	15.43	17.04	**clayey sand**
	4	653.12	-	-	Coarse Sand
4	1	386.35	0.48	0.48	Topsoil
	2	666.95	2.57	3.05	Medium Sand
	3	155.25	18.9	21.95	**clayey sand**
	4	586.5	-	-	Coarse Sand
5	1	158.46	0.2	0.2	Topsoil
	2	420.55	3.54	3.74	Medium Sand

	3	43.73	6.81	10.55	**Clay**
	4	1812.75	-	-	Coarse Sand
6	1	105.39	0.27	0.27	Topsoil
	2	471.89	1.35	1.62	Medium Sand
	3	42.56	4.53	6.15	**clay**
	4	625.98	-	-	Coarse Sand
7	1	138.93	0.66	0.66	Topsoil
	2	464.08	2.17	2.83	Medium Sand
	3	54.8	8.2	11.03	**clay**
	4	534.96	-	-	Coarse Sand
8	1	313.92	1.33	1.33	Topsoil
	2	57.88	0.55	1.88	**clayey sand**
	3	1975.68	1.89	3.77	Medium Sand
	4	34.44	7.23	11	**clay**
	5	1294.98	28.09	39.09	Coarse Sand
	6	16.71	-	-	**clay**
9	1	121.34	1.19	1.19	Topsoil
	2	27.4	1.16	2.35	**clay**
	3	1368.12	4.7	7.05	Medium Sand
	4	22.93	18.09	25.14	**clay**
	5	143.38	-	-	Coarse Sand
10	1	116.64	2.19	2.19	Topsoil
	2	42.81	2.5	4.69	**clay**
	3	757.34	5.57	10.26	Medium Sand
	4	89.66	-	-	**Clay**
11	1	89.08	0.53	0.53	Topsoil
	2	140.3	0.8	1.33	Medium Sand
	3	43.22	2.1	3.43	**clay**
	4	269.74	8.54	11.97	Coarse Sand
	5	67.62	-	-	**clayey sand**
12	1	206.37	0.9	0.9	Topsoil
	2	862.39	0.97	1.87	Medium Sand
	3	89.61	16.62	18.49	**clayey sand**
	4	485.41	-	-	Coarse Sand
13	1	44.01	0.41	0.41	Topsoil
	2	391.8	1.69	2.1	Medium Sand
	3	121.26	21.54	23.64	**clayey sand**
	4	73.52	-	-	**clay**

14	1	90.81	0.62	0.62	Topsoil
	2	183.78	0.92	1.54	Medium Sand
	3	30.24	2.37	3.91	**clay**
	4	549.79	12.31	16.22	Coarse Sand
	5	47	-	-	**clay**

5 Conclusion

The soil conditions at Gbagada area, Lagos State , Nigeria using Electrical resistivity survey technique revealed that the sediments consists of topsoil, medium sand, clay, clayey sand and coarse sand. Based on the results of the investigations, it is concluded that major parts of the area consist of clay and clayey sands at shallow depths and these might pose a serious threat to the survival of engineering structures in this type of environment if adequate care is not considered.

Correspondence:
Oyedele, K.F and Ojo, A.O
Dept of physics (Geophysics Programme)
University of Lagos, Lagos Nigeria
kayodeunilag@yahoo.com

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