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The Role of Geotechnical Site Investigations on the Lekki Toll Road Infrastructure Project in Lagos, Nigeria

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Abstract: A spell of increased prosperous economic activities and increase in population within the Eti-Osa - Ibeju-Lekki Environs will result in increased traffic volumes which will in-turn stress the existing trunk highway leading to the government's decision to upgrade the existing Lekki – Epe highway Infrastructure. With its natural history, infrastructure construction in urban context, particularly the construction of the Lekki Toll Road which entails widening of an existing highway, can require significant phasing and sequencing of temporary works in order to deliver the permanent solution with the constrained environment.

The first 20km of the expressway up to Ajah Community is characterized by very heavy traffic with significant encroachment of the RoW by numerous small businesses. Most, if not all of these businesses, may be occupying the Row without legal ownership of the land. However, upgrade of the existing Lekki – Epe expressway infrastructure involves the provision of additional traffic lanes to facilitate increase traffic flow and relieve congestion. Invariably, the highway cuts across significant development where acquisition of additional land would require major public consultation. These spatial constrain generally resulted in the requirement for new traffic lanes, pedestrian bridges and traffic circles to be constructed within the government gazetted and published right of way (Row).

In a typical fast developing environment, the implementation of the life cycle of a project of this nature entails collaboration efforts between Lagos State Government (LASG), Lekki Concession Company Ltd (LCC), and Hitech Construction Company Ltd (Hitech). For the implementation of the associated works for the project, pedestrian bridges, roads, traffic cycles and toll plazas would be constructed and the need for geotechnical investigation works is necessary prior to the commencement of construction.

Key Words: Geotechnical Investigations, Lekki Toll Road, CPT, SPT, Lagoonal Sand Deposits

1 Introduction

With its natural history, infrastructure construction in urban context, particularly the construction of the Lekki Toll Road which entails widening of an existing highway, can require significant phasing and sequencing of temporary works in order to deliver the permanent solution with the constrained environment. The constraint encountered in the case study area includes:

- Continuance of existing traffic flow from both directions (Eastbound & Westbound Traffic)
- Dominance of existing utilities and services such as telecommunications infrastructure, Electricity power overhead and underground cables and water pipelines.
- Unsuitable ground conditions in the area allocated for Toll Plaza
- The amalgamation of existing road alignment and geometric requirement during construction of new highway.

A range of geotechnical solutions are available to alleviate and conquer the above listed constraints. Whilst looking at the above listed constraints, we have to consider a range of possible geotechnical solution ensured to be the most technically and economically viable to proffer solution to the ground condition of the additional lanes according to the new road design.

Methods of Investigation

According to Frankiepile (2005), geotechnical site investigation and the assessment of soil characteristics are the important part in the process of foundation design. The first stage of the process begins with the determination of the type of tests to be carried out in the proposed area and they are as follows:

- Field Investigation and In-situ Testing
    - Auger Trial Holes
    - Rotary Percussion Drilling
    - Cone Penetration Testing(CPT)
    - Standard Penetration Testing (SPT)
- Laboratory Testing
    - Triaxial Compression Test

- Grading/Sieve Analysis
- Ph
- California Bearing Ratio (CBR)
- Atterberg Limits / Moisture Density Relationship

The objectives of a geotechnical investigation may embrace any combination of the following (BS 1377:1990):

- To access the general suitability of the site for the proposed engineering works
- To enable an adequate and economical design to be prepared
- To foresee and provide against difficulties that may arise during construction owing to ground and other local conditions.
- To advise on the availability and suitability of local materials for construction purposes.

Taking the above objectives into consideration, the planning of a geotechnical investigation will be influenced by the following main factors:

- The nature of the proposed engineering development
- The Geology and Geomorphology of the site
- Access to and the remoteness of the site
- The site topography, vegetation and drainage
- The nature of adjacent developments
- Knowledge of previous geotechnical investigations or foundation installations carried out in the area.
- Evidence of problem soil condition (soft clays, dolomites, expansive or collapsible soils).

The cost of an adequate investigation is very low in comparison to the total cost of the project. The consequences of not providing sufficient, accurate and reliable geotechnical information, however, can have a significant effect on a project and can lead to delays and extras during construction with associated costly claims. However, conditions vary from site to site. Consequently, a variety of techniques has been developed to enable both the geotechnical engineer and specialist contractor to select the appropriate investigation procedures.

According to Mair and Wood (1987), in-situ testing is becoming increasingly important in geotechnical engineering as it has been established that only laboratory testing alone may not be reliable and more sophisticated laboratory testing can be time consuming and expensive.

Toll Plaza 1: Admiralty Toll Plaza

Figure 1 Proposed Land Area for Admiralty Toll Plaza

Admiralty Toll Plaza is situated in Maroko. It is bordered to the north by the Tarzan Boat Park, to the west by Oniru Police Station, to the south and east by vacant plots. The geotechnical Investigation for the proposed Toll Plaza was aimed at supplying information on the site in terms of:

- Specific geology of the site.
- Depth to bedrock and/or other competent founding horizons.
- Potential geotechnical restraining factors.
- Foundation recommendations for the proposed structures.
- Presence of groundwater.

Site Works & Method of Investigation

The field investigation was carried out in August 2007 and comprised of 5 boreholes as indicated in Table 1.

Table 1 Comprised of 5 boreholes

SITE	BOREHOLE NUMBER
Toll Plaza 1	TP1-1B
	TP1-2B
	TP1-4B
	TP1-2
	TP1-5

The boreholes were drilled to a depth of approximately 20m and during the boring operations, soil samples were taken regularly at depths of intervals of 0.75m and whenever change of soil type was observed. All the soil samples recovered in the boreholes were examined, identified and classified roughly in the field and all data were carefully recorded in the borehole logs. Standard Penetration Tests (SPTs) were carried out in each of the boreholes. SPT was performed mainly at depths where cohesion less (granular) soils was encountered in the borehole. The test was to aid in the evaluation of the in-situ relative densities of the sandy strata since it would not be possible to obtain undisturbed samples in such type of subsoil. Bowles (1997) explained that in performing the Standard Penetration Test (SPT), a 50mm diameter split tube sampler is driven 450mm into the cohesion less soil with a hammer failing freely a distance of 750mm. The number of blows required to drive the last 300mm of the 450mm split spoon is the value of the penetration which is termed the penetration resistance **(N-Value)** and it provides an indication of the relative density of the stratum tested.
The boreholes were logged according to current stands and procedures (Brink and Bruin, 2001). The profiles including a graphical representation of the SPT are included in the borehole log.

Results of the Investigation for Toll Plaza 1

It can be seen that at Toll Plaza 1 the profile comprises a relatively thin layer of fill underlain by loose to medium dense lagoon sands to a depth of at least 20m. Only in one borehole, TP1-4B did the sand became dense at a depth of18.5m. The sand is occasionally slightly silty and organic matter can often be found in the upper layers of the sand. The water table was high at this site with water being encountered at depths of between 0.5m and 2.4m below ground level. Variations in the water level were noted to correspond with times of heavy rainfall. As shown in Table 2.

Table 2 Thickness of layers (m) - lagoonal sands

Borehole Number	THICKNESS OF LAYERS - LAGOONAL SANDS						
	Fill	Very Loose	Very Loose to Loose	Loose	Medium Dense	Dense	Water Table Below GL (m)
TP1-1B	0-4.5	4.5-9.0 ss, og		9.0-11.5ss 15.0-19.0	11.5-15.0ss 19.0-20.0		2.3
TP1-2B	0-1.0		6.5-9.5 11.0-12.5	1.0-3.0 9.5-11.0 15.0-18.0ss	3.0-6.5 12.5-15.0ss 18.0-20.0ss		1.6-2.4
TP1-4B	0-1.5	7.5-9.5		1.5-7.5ss,og 9.5-11.0	11.0-18.5ss,og	18.5-20.0	1.0-1.3
TP1–2	0-1.0			1.0-3.0ss,og 6.0-9.0 og 9.0-11.25	3.0-6.0		1.1-1.6
TP1–5	0-0.5			6.0-10.5 ss,og	0.5-6.0 og 10.5-12.0ss,og 12.0-15.5		0.5

Og is Organic Matter Present, Ss is Silty Sand and Cl is Clayey Sand (Geotechnical Investigation Report, LCC (2008).

Figure 2 Admiralty Toll Plaza – Completed

Toll Plaza 2: Conservation Toll Plaza

Results of the Investigation for Toll Plaza 2

At Toll Plaza 2, a thin layer, 1.0m thick, of fill/topsoil is present across most of the site. This is underlain by lagoonal sand which is occasionally slightly silty. The sand is generally medium dense to dense but in Borehole TP2-2 the sand was loose from the surface to a depth of 3.5m and in TP2-3 loose sand was present from 4.5m to 6.0m and again from 13.5m to 18.0m. The water table was high at this site with water being encountered at surface to a depth of 1.3m. Variations in the water level were noted to correspond with times of heavy rain, as shown in Table 3.

Table 3 Thickness of layers - LAGOONAL SANDS

Borehole Number	THICKNESS OF LAYERS (m) - LAGOONAL SANDS				
	Fill	Loose	Medium Dense	Dense	Water Table Below GL (m)
TP2-1	0-1.0		1.0-7.5 13.5-18.0 19.5-21.5	7.7-13.5 18.0-19.5	0.3
TP2-2		0.0-3.5	3.5-5.0 6.5-7.5 9.5-12.0 13.5-19.5	5.0-6.5ss 7.5-9.5 12.0-13.5ss 19.5-20.5	1.3
TP2-3	0-1.0	4.5-6.0 13.5-18.0	1.0-4.5 6.0-13.5 18.0-21.0	21.0-22.0	0.0-1.0

Og is Organic Matter Present, Ss is Silty Sand and Cl is Clayey Sand (Geotechnical Investigation Report, LCC (2008).

Figure 3 Conservation Toll Plaza - Completed

Results of the Investigation for Bridge 2

One borehole was drilled at this site. Soil samples from the borehole indicate very loose to very dense lagoonal sand present from surface to a depth of 21.0m. The consistency improves with depth. The sand is occasionally silty and occasionally has some organic matter. The water table is at a depth of 1.0m, as shown in Table 4.

Table 4 Thickness of layers - LAGOONAL SANDS

Borehole Number	THICKNESS OF LAYERS (m) - LAGOONAL SANDS					
	Fill	Very Loose Very Loose to Loose	Loose	Medium Dense	Dense	Very Dense
BRIDGE	BH 1	0.0-5.5og 5.5-6.5ss	6.5-7.0 og 7.0-12.0	16.5-18.0si	12.0-15.0 15.0-15.5ss 15.5-16.5	18.0-21.0

Source: Geotechnical Investigation Report, LCC (2009).

Evaluation of Geotechnical Investigations Results

- **Founding Conditions**
  Considering the consistency of the sands present from surface to depth, and the expected loading from the proposed structures, conventional foundations are not an option for the site. At surface the sand, for all sites, is generally loose to medium dense and the allowable bearing capacity, therefore, varies from approximately 50kPa to approximately 200kPa. The bearing capacity of the lagoonal sand is not adequate for the structures envisaged. Therefore a piled option was considered for the structures coming to this vicinity.

- **Groundwater**
  The water table is very high at all four of the sites and this affects the founding options available for the structures.

- **Excavatability**
  The loose to dense sand, present relatively close to the surface will be easily excavated and can be classified as ‘’soft’’ excavation. Some lenses or zones of slightly more competent material may be excavated but normal excavation

methods should be adequate. However, the presence of groundwater will require that any excavation will need to be laterally supported and de-watered.

All the laboratory tests for this Project were carried out in accordance with British Standard Institute Code of Practice, BS 1377 of 1990; “Method of Tests of Soil for Civil Engineering Purposes”.

Recommendations

After the careful evaluation of the geotechnical investigation results based on the subsoil condition and their physical properties resulting from the result of both the laboratory and in-situ tests, it was recommended that all the structures be placed on piled foundations. Augered cast in-situ piles are considered suitable. Since no significant hard layers or boulder layers were evident in the boreholes, then there is no foreseen problem with auger drilling to the required depth.
However, temporary casing was used due to high water table and poor consistency of the soil present.

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Authors introduction

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Registered Professional Engineering Geologist with the Council of Nigerian Mining Engineers and Geoscientists (COMEG) and Project Manager experienced in the sector of Geotechnical Engineering in Nigeria, West Africa. He received his B.Sc.(2001) and PGdip(2006) degrees in Geology from the University of Port Harcourt, Choba, Nigeria; and his M.Sc.(2012) degree in Project Management from the University of Liverpool, Liverpool, U.K

Christian Azuka Olele supervised several Sub-Structure Projects that has to do with Geotechnics on the Lekki Toll Road Infrastructure Project (Pedestrian Bridges,

Falomo Ramp Bridge and Toll Booths & Plazas), Precast & Sheet Piles for Osborne Jetty Terminal, Ikoyi, Lagos.

He is Interested in dealing with engineering geology and geotechnical engineering of Projects in Nigeria and African countries. Currently he is heading the construction management team of EdgeGold Concept Services Limited, Lagos

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