THE ASSOCIATION FOR CONSULTING ENGINEERING IN NIGERIA (ACEN)

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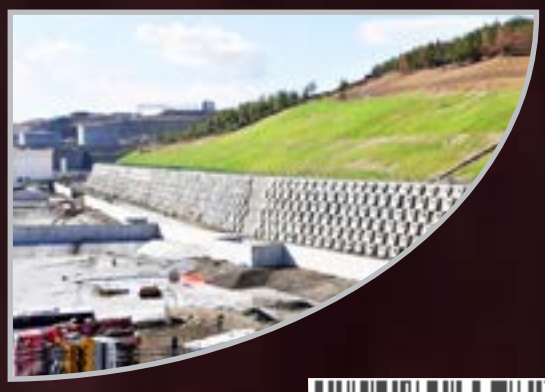
INSIDE

GEOTECHNICAL ENGINEERING SERVICES



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CONTENTS

FROM THE EDITORIAL SUITE

It is our pleasure to inform our teeming readers that we have received great encouragement from them based on their feedback on the quality of the contents of the various editions of ***"The Consulting Engineer"*** magazine. This feedback is a morale booster and we thank the readers who have expressed their opinions.

Engr. Ajibade Oke, *FNSE*

This edition comes with the running theme "Geotechnical Engineering Services". We assure you it is going to serve as a delightful source of knowledge filled with excitement in various aspects of geotechnical engineering. Most importantly, readers will appreciate the importance of studies of the strata under the earth's surface and their analysis in relation to the safety and stability of structures in the built environment.

The first article entitled "Geotechnical Engineering in Nigeria: Past, Present and the Future" by Engr. Ronald Aborowa, Managing Director of Earth Engineering Services and Designs Ltd is a chronicle of some sorts. The author, who has been in practice for over 40 years in the field, has presented a lucid narrative worthy of record. On the government side, officials of the Department of Petroleum Resources, namely Mr. Olusegun O. Bankole, Engr. Oluwaseun T. Mumuni and Mr. Collins B. Zorasi unfold the guided geotechnical survey work scope and practices in Nigeria's oil and gas industry.
The other articles are as follows:

- Geotechnical Engineering Practice in the Oil and Gas Industry by Engr. Ben McDavid, Principal Partner, Primemover Engineers
- A Jetty Upgrade Project in Shallow to Deep Offshore by Engr. Kabir Haruna, Head of Unit, Structures, Primetech Design and Engineering Ltd (A Subsidiary of Julius Berger Nigeria PLC)
- Geotechnical Engineering Practice in High-Rise Building Design and Construction by Engr. Prof. Samuel Ejezie, FNSE, Chair Occupant, Enoch George Professorial Chair in Geotechnical Engineering, University of Port-Harcourt
- The Role of Geotechnical Engineers in Soil Erosion and Landslides Control by Engr. Dr. Edward Moore, FNSE, CEO, E. N. Moore Associates
- Rock Engineering as a Tool in Geotechnical Services by Engr. Yemi Kehinde, Managing Partner, Dynamics Civil Services Ltd.
- Commercial Management of Geotechnical Engineering Services by Engr. Prof. Yinusa A. Jimoh, FNSE, FAEng, President, Nigerian Geotechnical Association and Former Dean of Engineering, University of Ilorin.

The Personality presented in this edition is Engr. Nurudeen Oyebanji Kareem. He has distinguished himself as a quality services provider in the engineering industry. The features on special supplements are on Sitech Engineering Ltd, headed by Engr. Mudashir Shittu and Ankabut Engineering Ltd, headed by Engr. Bukar Kam-Selem. We salute them over their enormous contributions to the practice of engineering.

ACEN events are presented in the form of advertorials. This is because the events took place virtually without physical assembly in the new norm of the last several months in 2020 necessitated by the novel COVID-19 pandemic. These events include:

- Business Evening of June 23, 2020
- Business Evening of August 27, 2020
- ACEN 2020 Extra-ordinary General Meeting (EGM) of July 30, 2020
- LACIAC & ACEN Workshop on "Dispute Management in Africa Infrastructure Projects" of October 2020

Interestingly, in this edition, the Tit-bits Columnist, Engr. Enefiok Ubom went poetic in a part of his presentation. You will simply discover how important geotechnical engineers are within the larger community of engineers when it comes to safety and stability of structures. Do you want to know about the "Leaning Tower of Pisa" in Italy? Read about this too in the column.

Finally, we deeply appreciate all those who contributed to the successful publication of this edition.

We look forward to more feedback from our readers. Stay safe! Relax and enjoy your reading.

Engr. Ajibade Oke, *FNSE*
(Chairman, Editorial Committee)

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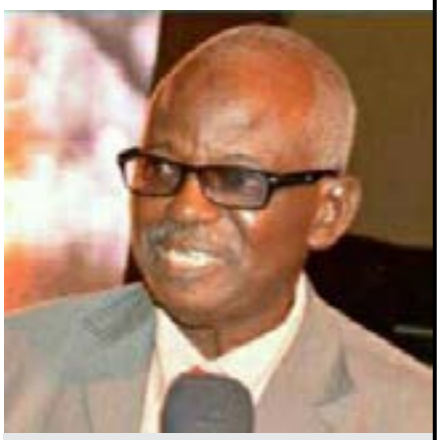

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THE ASSOCIATION FOR CONSULTING ENGINEERING IN NIGERIA (ACEN)

The Association for Consulting Engineering in Nigeria, ACEN, was founded in 1972 and registered in 1979. ACEN is a body of registered independent private engineering consultancy firms and voice of the profession in Nigeria.

MISSION STATEMENT

"ACEN shall build a strong membership that fosters equal opportunities, creates competitive advantage through increased visibility with strategic partners and improves the standards of consulting engineering in line with international best practice".

VISION STATEMENT

"To remain the ultimate reference business association of choice for organisations providing professional engineering consultancy services in Nigeria."

FUNDAMENTAL OBJECTIVES

- Ensure that the highest level of technical competence and business ethics are brought to bear on the practice of the profession in Nigeria.
- Ensure that every State has the highest level of Consulting Engineering practice by having members in every state of the federation and the federal capital.
- Increase the number of engineering firms in the country relative to the size of the nation.
- Ensure that stakeholders in the built environment get maximum value for their investments by monitoring standards of practice within the industry.
- Grow the industry by promoting the growth of large consulting engineering firms.

ACEN MEMBERSHIP

Prior to December 2007, ACEN membership was open to individual and firm members, who possessed the required experience and professional integrity. At the 2007 AGM, a motion was passed limiting ACEN membership to firms. This was to further emphasize the business nature and focus of the association. Membership is therefore now open to Consulting Engineering firms with the adequate experience and commitment to continuous improvement in technical and business integrity. Today, ACEN's member firms numbering about 300 are located in the 6 geo-political zones and the FCT.

ACEN & COREN

The Council for the Regulation of Engineering in Nigeria is the statutory body with responsibility for the regulation of all Engineering activities in Nigeria. It is empowered to keep a register of all Engineering craftsmen, technicians, technologists, Engineers and Consulting Engineering Firms who wish to practise in the country. No individual or organization is allowed to practise Engineering in Nigeria without the approval of COREN. Thus, all member firms of ACEN must be registered with COREN and the members of such firms must also be individually registered by COREN.

ACEN has just recently been mandated by COREN to register on its behalf all consulting engineering firms in the country. Furthermore, ACEN President now seats on the Council of COREN. Thus, ACEN is now better positioned within the built industry.

ACEN & NSE

The Nigerian Society of Engineers is the umbrella association of all graduate Engineers in Nigeria and all Engineers employed in ACEN member firms are members of NSE. Conversely, most members of NSE with interest in Consulting Engineering practice are members of ACEN. ACEN focuses only on the business interest of Consulting Engineering Firms and her interest is, therefore, specific and complementary to the scope of COREN and NSE.

ACEN & FIDIC

The International Federation of Consulting Engineers is a 102-member organisation which provides the strongest platform for our international activities. FIDIC is the voice of Consulting Engineering all over the world, and this it does through seven major focus areas: Representation, Business Practice, Ethics/ Integrity, Image, Sustainability, Globalization and Quality.

FIDIC is perhaps best known for its contracts documents, which are used all over the world, especially for international projects in the third world. The documents are used extensively by the Nigerian Federal Ministry of Works. In addition, FIDIC has Manuals on a Guide to Practice that teaches best practice in Consulting Engineering, Business Integrity Management and Quality Management amongst several others.

Two (2) ACEN members, Engrs. J.I. Folayan and Bayo Adeola have served on the FIDIC Executive Committee, the highest level of the organization. Other ACEN members have served on committees and task forces of the organization, and members attend the yearly annual conferences in large numbers regularly.

ACEN & FIDIC Africa

FIDIC Africa is made up of African Member Associations in FIDIC. It is a subset of FIDIC that addresses specifically African concerns. FIDIC Africa currently has 17 members, holds regular annual conferences and AGMs and promotes networking among its members. Nigeria played a very active role in the formation of FIDIC Africa and has continued to be very active in the association. ACEN former President, Engr. (Mrs.) Mayen Adetiba, FNSE, FAEng was once Chairman of FIDIC Africa (which was then called GAMA) while several ACEN members served on the Executive Committee. The current ACEN President, Engr. George Okoroma, FNSE is a member of the FIDIC Africa Executive Committee.

ACEN ACTIVITIES

ACEN provides a series of activities tailored to deliver service and benefits to our members in these key areas:

- Training through the ACEN School of Consulting Engineering.
- AGM & EGM for effective dissemination of information to members.
- Attending International Conferences.
- Membership / Certifying Standards.
- Advocacy.
- Quarterly Business Evening meetings to discuss topical issues affecting members.
- The Young Professionals Forum.
- Triannual publication of "The Consulting Engineer" magazine.
- Monitoring and follow-up on policies and bills relating to matters of engineering practice.
- Legal retainership program to advise members on legal issues.
- Advancing the practice of consulting engineering for favourable business environment for members.

Setting up of Special Task Forces on:
Collapse of buildings, conditions of engagement/ scale of consultancy remunerations, quackery, Industry study, formation of built industry transparency initiative, local content for the construction industry, etc.

CHALLENGES OF ACEN

Despite the fact that ACEN has been in existence for forty-one (41) years, some of the challenges leading to its formation have remained while new ones have emerged. The most notable current challenges are as follows:

- Unfavourable Government procurement policies especially in the states.
- Private sector perception.
- Loss of Engineers to other sectors due to low remunerations.
- Number, size and scope of ACEN Member firms.
- Delayed payments to members.
- Limited awareness and knowledge of the savings consultants contribute to the overall cost of projects if employed by governments and entrepreneurs.
- Inadequate corporate sponsorship to enhance smooth operations of the organisation.

GEOTECHNICAL ENGINEERING IN NIGERIA: PAST, PRESENT AND THE FUTURE

BY ENGR. RONALD ABOROWA

***Engr. Ronald O. Aborowa**, MNSE, BSc. (MD, Earth Engineering Services & Designs Ltd.)*

1.0 INTRODUCTION

Geotechnical engineering is a versatile and a demanding aspect of civil engineering. It is a professional discipline sometimes taken for granted. It cannot be so and should not be so! Geotechnical Engineering in Nigeria: Past, present and the future may be considered both technically and historically in the context of:

- Early years including the colonial era
- Immediate post-independence years
- Modern day professional development, anomalies and challenges
- Future and conclusion.

2.0 EARLY YEARS INCLUDING THE COLONIAL ERA

2.1 GENERAL

As should be expected, there would be some form of records, even if oral, for the early years in the history of "Geotechnical Engineering" in Nigeria. These early years would actually be in tandem with civilization in terms of shelter and the colonial era impact.

2.2 FOUNDATION SOILS FROM THE EARLY DAYS

No matter how inaccurate they could be, the British provided some geological maps for Nigeria. Over 85% of Nigeria's landmass has relatively shallow and "rich" earth cover over one type of rock or the other. A few of the underlying rock types generally occurring at near surface are:
Rocks of the Basement Complex, Keri Keri Formation, Ewekoro Formation, Shales of various types and groups, Sandstones, Limestone, Abeokuta Formation, etc.

For the earth cover, there is the preponderance of red/ rust brown earth, often or generally referred to as laterite/top soil or lateritic clays. They make excellent building/foundation soils. These same lateritic sandy clays were the primary road building materials in colonial Nigeria and immediately after independence using British Standards: and those obtained too in faraway India, a former British Colony. The technical synergy between soils, roads and foundations cannot be over emphasized in geotechnical engineering, particularly in the pre and post-independence years in Nigeria. The foundations laid for training and practice were solid, thorough and enduring.

3.0 IMMEDIATE POST-COLONIAL ERA (1960 -1966)

The British organizational skill, blue print and attitude were still very much around in those early post-independence years. Professional bodies were models from the parent British companies. Design and construction codes were British. There was order and decorum. Education was primarily British with some sprinklings from the United States of America. Geotechnical engineering profession was taken seriously and well respected.

There was continuity from the later pre independence days in the design and construction of airfields, sea and river ports, highways and bridges and irrigation works. Indeed, the hydropower dam at Kainji was already coming on stream as also some moderately high-rise buildings around Lagos, Ibadan and Kaduna. It is important at this stage to emphasize that for the numerous civil engineering schemes listed, there were peculiar and specialized geotechnical engineering inputs required including structural engineering, mechanical and electrical engineering inputs. There were no known unethical practices at the time.

3.1 SOILS

Soils in geotechnical engineering are very important as can be assessed from the following inputs required in pavement designs for roads, airfields, dams and foundations for buildings:

3.1.1 Roads and Airfield

- Natural moisture content
- Atterberg limits
- Compaction studies for maximum dry density (MDD) and optimum moisture content (OMC) plots (Proctor, Mod AASHO and West African Standard Compaction)
- Determination of California Bearing Ratio (CBR) values (soaked and unsoaked)
- Thickness and quality of individual layer for the road or pavement in respect of simulated wheel loadings
- Soil – cement stabilization
- Pavement evaluation

3.1.2 Dams and Retaining Wall structures

- Material characterization including borrow areas
- Compaction studies
- Optimum moisture content vs dry density curves
- Graphical design of sheet pile walls, tie rods, effective depth, etc.
- Permeability studies

3.1.3 Foundation for Buildings and Other Structures

- Foundation options (The options are spread footings, piling options and ground treatment).

The important role of the geotechnical engineer is defined to be in a specialist class. There are no short cuts to these parameters nor in their interpretations.

3.2 OUTSTANDING FIRMS: 1960 - 1966

It is worthy to note that some of the consulting engineering firms between 1960 and 1966 had geotechnical engineering departments and are still in operation today. They include: *Morgan Omonitan & Partners, Hancock Ogundiya & Partners, Dar Al-Handasah Consultants (Shair and Partners), Ove Arup & Partners, Oscar Faber & Partners, Scot Wilson Kirkpatrick & Co., AIM Consultants Limited, Louis Berger and Enoch George Associates.*

The period was characterized by saneness and the professionals practised into the "Oil Boom Years" which, in fairness, laid excellent foundations for the practice of geotechnical, civil/structural engineering consultancy services. There was an avalanche of engineering designs for roads, bridges, port facilities, dams etc. The geotechnical engineers built themselves up remarkably through the establishment and operation of the following firms: *Foundation Engineering Limited of the Costain Group, Nigerian Soil Engineering Company Limited, Soil Statics Limited, Rock & Stone Limited, Louis Berger, Sol-Fond Limited and Progress Engineers.*

4.0 MODERN DAY PROFESSIONAL DEVELOPMENT AND ANOMALIES

4.1 CONSCIENTIOUS YEARS OF DEVELOPMENT

The oil boom years of about the last quarter of the last century had a salutary effect of providing very good and disciplined growth for the professionals in engineering. There was sanity, professional astuteness, self-pride and an excellent and genuine desire for development.

During this period, the Nigeria Steel Development Authority (NSDA) had over 250 exploratory boreholes undertaken across various sectors of the proposed Ajaokuta Steel complex. Testing protocol included coring and recovery of rock cores.

The Nigeria Steel Development Authority had experts from Russia who thoroughly and whole heartedly supervised Sol-Fond Limited. The experts and consultants worked on the project and there was actually transfer and cross fertilization of knowledge in:

- Description of soils and rock samples
- Type and classic description of rock samples
- Rock permeability test with rubber parkers
- Computations for the required design parameters and analysis

These were with an adequate and appropriate laboratory testing program. For the number of boreholes undertaken over the period of the investigation, one can only imagine the man-hours associated with training in field works, laboratory testing and analysis. Consultancy and contracting both should lead to the same goal for excellent delivery of projects. None is superior to the other. The world 'listened' to Nigeria then. As a matter of fact, Soil Mechanics & Foundations Engineering had its 9th Regional Conference

for Africa in Lagos in 1987. Contributions to the conference were adjudged to be excellent in quality of contents and delivery.

4.2 SETTING IN OF ANOMALIES

All was fine and going well for the classic geotechnical engineer as a specialist professional quality service provider in Nigeria with some reputable firms involved. Growth was then focused and directed. This was at the beginning of the 21st century – this century and in the first decade. Then with a bang came the massive telecommunication revolution in Nigeria. Telecom towers and related facilities had to be put in place. They came in hundreds and technically each site needed geotechnical investigation and unfortunately in whatever manner of it too!

The situation was like the Spanish Armada of the 16th century in Europe when canoes and boats were in tow with frigates and other war ships for a naval war! Here, all manners of people became 'geotechnical engineers' and with all mannersof contraptions for boring rigs. Drilling hands overnight became engineers of all sorts. The quantum of jobs and potential employers were just overwhelming. Anything was the order of the day. What an anomaly!

It is just about time in our country that engineering in any form or description be practised within standard regulations, particularly in delivery. It cannot just be a free racing circuit where the lame, crippled and crassly ignorant take to the field. Apart from killing morale, the present situation significantly truncates professional development and direction for growth. This is grim and shall remain so until the Nigerian Geotechnical Association (NGA) or other relevant bodies rediscover themselves.

4.3 GEOTECHNICAL ENGINEERING DELIVERY/REPORT

The Geotechnical Engineering Report is the traditional deliverable expected after offering standard geotechnical engineering services. The report more than anything else captures in details: the professional competence of the consultant/ contractor, quality of service of the provider, degree of knowledge, understanding and with capability of providing excellent delivery for the purpose of design. These have not eliminated the desire for good field performance and judgement vis-à-vis excellent laboratory testing and interpretation.

The itemized format for the report should comprise:

- Cover Page
- Introduction
- Logs and standards adopted
- Laboratory test results
- Strength and compressibility values for compressible and plastic materials
- Any other technical details as may be relevant and required such as permeability test results including codes or standards used

The Geotechnical Engineering Report should also include the following basic outlines:

- Site plan showing all test locations
- A summary of the subsoil condition as proved from the aggregation of materials encountered in boreholes and assessment from field and laboratory test results

All these make up the factual report. The report may conveniently end with the technical narrative of the subsoil.

The next stage is to provide geotechnical engineering analysis covering aspects of the project such as foundations, pavements, retaining wall, possible dewatering exercise and provision of other geotechnical engineering parameters as considered useful and relevant for the project.

These may include:

- Bearing capacity and settlement analysis for conventional near surface foundations placed within existing soils at depth range of 600 to 1,200mm or as applicable
- Analysis for piles constructed to 25 and 28m depth for foundation or as considered relevant
- Analysis and suggestions for pavement construction within the site
- Earth works including retaining wall analysis

These are obtained by way of computations and assessment, using appropriate theories and softwares for project design development.

A soil profile and a table summarizing key parameters as may be further developed are quite desirable. See Fig. 1.

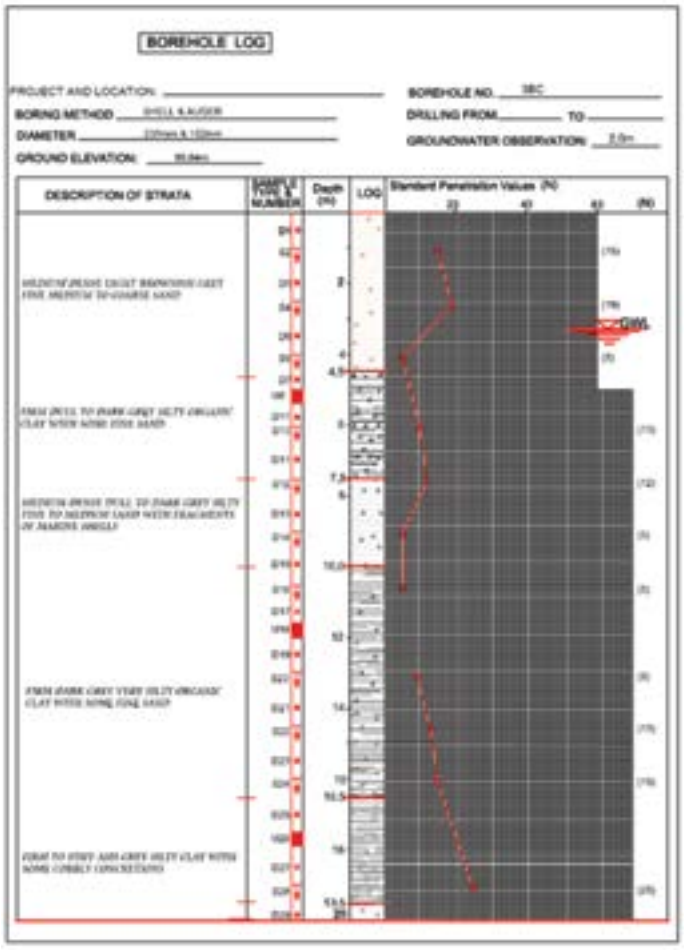

Fig. 1: *A typical borehole log from a "dummy" site*

The site profile provides the direction of analysis of results from the field and laboratory. Other targets in the analysis are:

- Computations for bearing capacity and settlement values
- Ground improvement through vibro-floatation technique if technically appropriate
- Piled foundation ain reference to continuous flight auger (CFA) process
- Analysis for retaining wall structure (basement),
- Ground works and the use of sound engineering judgement.

There are quite a number of equations/relations as provided in numerous journals of geotechnical engineering. The practitioner should always apply the "sixth sense" and ask himself – Yes, it is acceptable in 'Turkey', but can it hold here in Nigeria? Local experience and considerations are just not jettisoned for a new fancy stuff.

5.0 THE FUTURE

5.1 GENERAL EXPECTATION

An accomplished geotechnical engineer should be able to provide suitable parameters and analysis in respect of foundations for: buildings of whatever type, storm water drainage schemes, land erosion, airfield and highways, multi-purpose dam sites, irrigation facilities, marine structures, sea defence schemes or walls, masts of all types and launching pads for space shuttles etc.

For all these, there should be soil sampling and testing, with appropriate analysis for the "seated" structures even if for just a moment as related to safety, both structurally and environmentally. And of course, there is also the issue of costs. For all these, in-situ testing in geotechnical engineering boreholes are still very fundamental and relevant. Execution, testing in boreholes, laboratory testing remain major requirements for a balanced and sound professional geotechnical engineering delivery.

It may be asserted that soil ageing into the imagination of millennial years remains in its "original primary" state unless earth tremors or tsunamis take place. Natural phenomena can collapse soils or mobilize more strength. It is just a must that soil parameters should be checked out for the design and development of structures within the earth crust.

5.2 TRAINING AND CAPACITY BUILDING

Since post-independence, trainings have been through the graphical and theoretical line with a spate of laboratory works as provided in our tertiary institutions. Beyond the fundamentals found in text books for computations of "Bearing Capacity and Settlements Values", the world has now moved into the digital age. Computers are now used for all manners of computations in geotechnical engineering. Today, even where the machine has the intelligence of the human, the man must remain the "numero uno" – number one with 100% absolute control over the machine, device or software, which he the man created.

The bigger bodies in law and in professional corporate standing – Nigerian Society of Engineers (NSE), Council for the Regulation of Engineering in Nigeria (COREN) and Association for Consulting Engineering in Nigeria (ACEN) have to reexamine their position within the present state and insist on modern and relevant curricular.

5.3 FUTURE FOR THE BOREHOLES

For the geotechnical engineer, a well-prepared borehole from an investigation provides almost 60% of positive reality check for the properties of the soils encountered. This is, particularly so when samples are recovered through the shell and auger boring technique. These properties can further be enhanced using the Dutch Cone Penetrometer tests with the 200KN version and with generous laboratory testings in place. Without doubt, despite the apparent success of the current probing methods, the world, particularly Nigeria should be considering probes that penetrate the earth crust to depths in excess of 100m and provide data in their finished, consistent and most accurate forms to provide values at the depth in respect of:

- Moisture content
- Soil type including mix percentages of sands, silt and clay
- Cohesion values
- Standard penetration resistance (N-values)
- Compressibility characteristics of coefficient of volume compressibility (Mv) and coefficient of consolidation (Cv)
- Relative penetration values in strength values, etc.

It is expected that these should be possible by the middle of this century if not earlier.

6.0 CONCLUSION

Traditionally, geotechnical engineering has always shared its 'umbilical cord' with civil engineering. It is a well-documented prime division of civil engineering. Indeed, the future of geotechnical engineering lies in the future of civil engineering in broadness and in depth.

The quotation from the paper, "Future of Geotechnical Engineering" by James K. Mitchell and John Kopmann describing the present status of geotechnical engineering is instructive.

"The range of problems and projects that now form a part of geotechnical engineering include:

- Foundations for structures of all types
- Transportation infrastructure, including roads, airfields, railroads, pipelines, rivers and canals, ports and harbors, tunnels and subways
- Land reclamation
- Seismic safety and mitigation of seismic risk
- Resource recovery
- Energy
- Preservation and restoration of historic structures
- Waste disposal and waste containment structures
- Site remediation and environmental enhancement
- Soil and rock as construction materials
- Exploration and development in cold regions, the deep oceans, and space
- Natural hazard protection and risk reduction (landslides, tornadoes, hurricanes, earthquakes, tsunamis, expansive soils, floods)
- Sustainability
- There are also geotechnical engineering based studies on materials and technologies particularly for earth works, ground improvements and waste containments application:
- Many types of in-situ earth reinforcement earth work
- Deep soil mixing
- Jet grouting
- Compaction grouting
- Geosynthetics and geocomposites of many types for many purposes
- Micro-piles
- Very large diameters driven or bored piles
- Micro-tunneling
- Bio-treatment of soils for environmental and ground improvement purposes
- Light weight and foam fills
- New and improved geophysical methods for "seeing into the earth" for site characterization, property determination and monitoring purposes."

It is apparent from all the examples and links that geotechnical engineering is without doubt a major aspect in the living civil engineering practice.

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*** The Coastal Plain Sands of:**
- Benin City – Edo State
- Lagos – MainLand and her Northern fringes
- Owerri in Imo State
- Ikot-Ekpene in Akwa Ibom State
- Calabar – Cross River State

*** The Chad Formation of :**
- Maiduguri
- Damaturu
- Kotangora
- Bama, etc

*** The Gwandu Formation of the North West tip of Nigeria:**
- Gwandu
- Birni Kebbi
- Kangiwa

*** The Clay and Shale formation of Sokoto**
- Sokoto

*** Southern Coastland from Lagos to Calabar of:**
- lluvium
- Wooded Back swamps
- Mangrove swamps
- Abandoned Beach Reaches
- Deltanic Plain along River Niger and reaching Onitsha and Port-Harcourt

Off Shore drilling - Percussion Drilling from the top

Pavement Evaluation in progress: Dynamic Cone Penetration

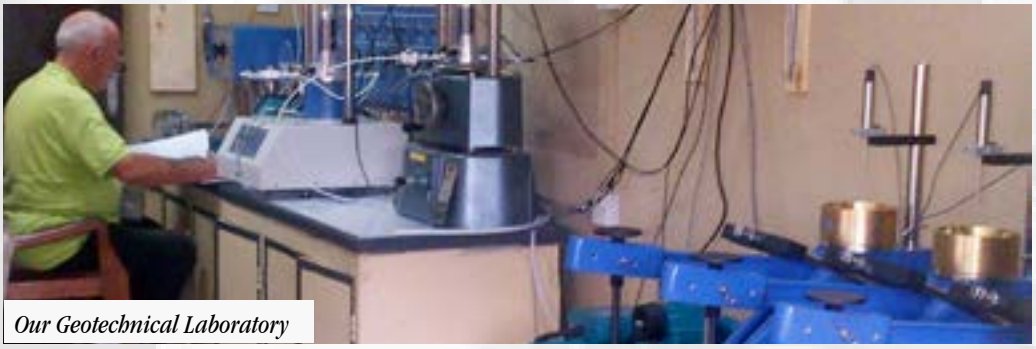
Pavement Evaluation in progress: Benkelman Beam Apparatus

Some Specific EESDL PROJECTS in GEOTECHNICAL / CIVIL ENGINEERING

- Jabi Lake Mall, Abuja
- FIRS Headquarters 18 Floor Multi-Storey Building, Abuja
- Abule Egba FlyOver Bridge, Abule Egba, Lagos
- Lekki-Epe Road Project – Bridges, Pavement Evaluation
- Escravos Expansion Infrastructure Facilities, Water Disposal Projects
- Geotechnical Survey of the Southern Swamp Associated Gas Solution Project (SSAGS)
- Proposed Industrial Port Complex, Creek Road, Apapa
- NAVGAS Project, Snake Island
- Geotechnical Investigation for Calabar Portside Industrial Park
- Proposed Multi-Purpose Terminal Development (CRMPT) on Creek Road Apapa, Lagos
- Proposed Berthing Facilities at Ijegun, Lagos
- Proposed Facilities Approach at Creek Road, Apapa , Lagos

CIVIL ENGINEERING CONSULTANCY SERVICES

- Shore Protection and Reclamation Works
- Hydropower
- Roads
- Design of Perimeter Fence for Chevron's Twin Lake Estate, Lekki, Lagos-Nigeria.
- Rehabilitation of AMS Terminal "B" Old Port Warri , Delta State, Nigeria
- Design of Shore Protection Works for Ugborodo, Warri South L.G.A, Delta State
- Adagbakuja New Town Development, Ondo State.
- Small and Medium Hydropower Consulting Services – Ile-Ife Dam, Osun State Nigeria
- Small and Medium Hydropower Consulting Services – Jibya, Kastina State Nigeria



Our Geotechnical Laboratory

GEOTECHNICAL SURVEY AND PRACTICES IN THE NIGERIA OIL AND GAS INDUSTRY

BY MR. OLUSEGUN O. BANKOLE, ENGR. OLUWASEUN T. MUMUNI, MR. COLLINS B. ZORASI (Department of Petroleum Resources)

1.0 INTRODUCTION

In general terms, geotechnics is the mechanics of soil and rock modifications and how it applies to the development of humankind. Geotechnical engineers are charged with determining the composition, stress-bearing capacity, stability, movement and other conditions of the soil and rock that are hidden beneath the surface of a construction site for oil and gas infrastructure (Oswald, 2017). In addition, the objectives of subsurface survey investigation are to determine the physical, mechanical, sequence and nature of the subsurface strata (geologic regime) and determine groundwater conditions (hydrologic regime).

Consequently, geotechnical engineering uses the principles of soil mechanics, rock mechanics and geology to:

- Determine the relevant physical/mechanical properties of materials
- Investigate subsurface conditions and materials
- Assess risks posed by site conditions
- Evaluate stability of natural slopes
- Design stable man-made slopes and underground excavations
- Design earthworks and structure foundations
- Monitor and manage risks related to site conditions and earthworks (Vyazmensky 2017)

Furthermore, a geotechnical survey aims to develop the ground model for every site, determine the vertical and lateral variation in seabed conditions and provide the relevant geotechnical data for planning installation activities (including foundations for the installation vessel), foundation design, operations, maintenance and cable protection/burial.

2.0 GEOTECHNICAL METHODS AND APPLICATIONS

There are several geotechnical methods used in the oil and gas industry which include cone penetration test (CPT), seismic acquisition, side scan magnetometer, electrical resistivity tomography (ERT), vertical electrical sounding and electromagnetic conductivity etc. (Lunne et al., 1997; Coerts, 1996; Eslaamiz and Robertson, 1998). However, a combination of factors including cost, efficiency, speed, simplicity, reliability and the ability to provide continuous information on soil properties proportionate to depth are important reasons for the increasing popularity of integrated CPT and electrical resistivity methods.

Geotechnical applications are broadly evident in the design input for pipeline infrastructure, oil and gas facility development, oil and gas platform foundation, crude oil and gas terminals, anchor systems for floating production storage and offloading (FPSO), oil rig platforms and other seabed infrastructure, whether nearshore on the continental shelf or in deep waters (Geoquipmarine, 2020). Accordingly, geotechnical investigations are crucial in the development of oil and gas resources.

Some incidences of infrastructure integrity concerns have been reported in the industry owing to neglect of robust geotechnical considerations. Although several causes have been highlighted by the engineering community for infrastructural failures, it is important to emphasise that conducting pre-construction and pre-installation investigation of the subsurface is imperative to ascertain strength, competence and adequacy of the subsoil environment and earth materials. Geotechnical investigation should provide all the necessary soil and rock data to allow detailed design and installation during project execution.

3.0 GEOTECHNICAL SURVEY AND INVESTIGATIONS IN OIL AND GAS FIELD DEVELOPMENT IN NIGERIA

The process of geotechnical site investigation entails the recovery of high-quality samples and the recording of high quality in-situ test data for the performance of spudcan penetration analyses. All recovered samples

are uniquely identified, photographed and described prior to carrying out appropriate tests in a dedicated laboratory. This process enables optimisation and overall efficiency in operations. Characterization of subsurface soil and determination of soil strength are also pre-requisites for foundation designs of oil and gas engineering structures as this will enhance the selection of an appropriate foundation design for the proposed structure.

Engr. Sarki Auwalu, *MNSE (Director/CEO, Department of Petroleun Resources)*

The existing oil and gas regulatory framework ensures that companies carry out holistic geotechnical surveys before facilities and infrastructure – whether in the onshore, swamp and offshore terrain – are installed. The surveys are carried out by certified geotechnical survey companies comprising multi-disciplinary teams of engineers, geologists, hydrogeologists and environmental scientists using state-of-the-art technology and techniques.

Geotechnical site investigations involve geotechnical drilling using drilling vessels as well as mobile drilling technologies. These surveys have capability to efficiently obtain information on the physical properties of the soil and rock around a site. These properties are used to design earthworks and foundations for the proposed structures and for repair of distress to earthworks and structures caused by subsurface conditions.

3.1 SCOPE AND DATA REQUIRED FOR GEOTECHNICAL SURVEY

Appropriate scoping of geotechnical investigation is critical to a successful survey operation. Adequate consideration should be given to project-specific factors such as size, location and foundation type of all the proposed seabed structures, complexity of ground model, presence and distribution of geotechnical hazards, variability and uncertainty in geotechnical properties, uncertainty regarding final layout of structures, position of inter-array and export cables, installation vessel or methodology.

In addition, the availability of high-quality sample data for proper interpretation across all sites and to select design parameters is *sine qua non* to success. Generally, as a rule of thumb, at least 10% of borehole site should be selected to obtain high quality samples. The extent of the investigation and the choice of methods should consider type, size and number of structures, the range of foundation options and the uniformity and type of seabed and sub-seabed conditions. The geotechnical investigation should provide relevant information to a depth below which the underlying conditions will not influence the safety or performance of the structures being considered or of the installation vessels to be used.

Vessel selection is critical to gaining high quality data in a timely and cost-effective manner. Depending upon the specific site environmental conditions, fixed platforms, jack-up rigs and anchored or dynamically positioned vessels can be used. In the case of floating facilities, the use of motion compensated drilling equipment is recommended. Appropriately equipped vessels can also deploy seabed drills and shallow sampling or CPT equipment for applications such as cable route surveys.

Geotechnical data relevant for structural foundations and cable installation design include, but are not limited to description and index classification, strength parameters (for different failure modes, monotonic and cyclic), soil modulus and damping parameters, permeability and consolidation parameters, liquefaction potential, thermal conductivity and chemical composition.

3.2 GEOTECHNICAL SURVEY INDUSTRY BEST PRACTICES

In line with industry best practice, each project should be treated on its merit and evaluated to enable the determination of the appropriate sampling and testing programme determined by a competent geotechnical engineer. As a guide, a best practice geotechnical survey scope of work should include the following:

FOUNDATION STRUCTURE TYPE	GEOTECHNICAL WORK SCOPE
Monopile	For a pile that does not rely on end bearing, a continuous CPT, (from seabed or down hole) to the anticipated depth of the pile plus 0.5 times the pile diameter. Adjacent to at least 10% of the CPTs there should also be a selected high-quality sample borehole to obtain sufficient samples for laboratory testing. The number of samples required will depend upon site variability. Downhole geophysical logging and in-situ stiffness measurements may also be used.

FOUNDATION STRUCTURE TYPE	GEOTECHNICAL WORK SCOPE
Monopile in rock or combination of soil/rock	For a pile that does not rely on end bearing, a combined borehole including soil sampling and rock coring to the anticipated depth of the pile plus 0.5 times the pile diameter should be used. Additional CPT tests can be used to enhance data quality in soils and weak rocks. Downhole geophysical logging and in-situ stiffness measurements may also be used.
Jackets and tripods, substations	Same as for monopile, except the depth of borehole beyond the expected pile penetration should account for mobilisation of end bearing. Additional CPTs may be necessary if significant lateral variability is anticipated across the foundation base.
Gravity base	A sample borehole or deep continuous CPT borehole at the centre of the proposed structure to the skirt embedment depth plus 1.5 times the base diameter/breadth should be used. Further shallow CPTs or sample boreholes should be performed around the base if significant soil variability is expected. Sufficient high-quality samples need to be obtained for laboratory testing. Downhole geophysical logging and in-situ stiffness measurements may also be used.
Gravity base on rock	Depending on the configuration of the foundation, it may be necessary to obtain rock samples to get an understanding of the bearing capacity and interface friction properties of the rock. The properties of any infill pockets may also require investigation.
Suction installed foundations	A sample borehole or continuous CPT borehole to a depth equivalent to the diameter of the suction can plus the embedment depth of the can with emphasis on high quality sampling in the upper layers (to a minimum of 1.5 times the diameter) should be used. Further shallow CPTs or sample boreholes should be performed around the foundation if significant soil variability is expected.
Jack-up installation and Operation and Maintenance vessels	Further sub-surface investigation may be required where there is significant variability in soil conditions or very hard or very soft soils are encountered and/or the possibility of punch-through is predicted in the area where these vessels will be located.
Anchored or tethered foundations	A borehole with samples/CPT or a seabed CPT at each anchor location should be used. The investigation depth is dependent upon the geology.

Table 1: *Recommended practices for geotechnical survey work scope*

4.0 REGULATORY FRAMEWORK FOR THE NIGERIAN OIL AND GAS INDUSTRY

The extant Nigerian Petroleum Laws and Statutes provide the legal and regulatory framework for the Nigerian Oil and Gas Industry, principal amongst which is the Petroleum Act 1969 and its subsidiary legislations. In furtherance of the above, the Department of Petroleum Resources (DPR) issues guidelines to monitor the activities of the industry and ensure compliance with the provisions of the extant laws.

To this end, the DPR is the government agency that ensures appropriate supervision and regulatory oversight of the industry to ensure compliance and adherence with the tenets of good oil field practice. As a result, the DPR uses tools and its service instruments (Licences, Permits and Approvals) to entrench its mandate as an Opportunity House and Business Enabler for all stakeholders.

4.1 POWERS OF THE DIRECTOR OF PETROLEUM RESOURCES AND REQUIREMENTS FOR GEOTECHNICAL SURVEYS

Section 43 of the Petroleum (Drilling and Production) Regulations, 1969 empowers the Director of Petroleum Resources to "***give such directions as may in his opinion be necessary from time to time, to ensure the proper exploitation of petroleum and to encourage good conservation practices in any licensed or leased lands; and the licensee or lessee shall comply with any such directions which affect him***". Also, section 44 highlights that the "***licensee or lessee shall comply with all existing safety regulations and all such instructions as may, from time to time, be given in writing by the Director of Petroleum Resources for securing the health and safety of persons engaged on or in connection with operations under his licence or lease***"

Specifically, however, section 30 (a) of the Petroleum (Drilling and Production) Regulations 1969 as amended states that "***every licensee or lessee, shall explore the relevant area, using geological, geophysical and any other acceptable methods of examination for the purpose of arriving at the petroleum-producing prospect, until the area has been adequately explored for that purpose, giving in this respect due regard to the reasonable wishes of the Minister***".

In light of the above, the DPR oversees geotechnical activities through the issuance of applicable Guidelines and Procedure Guides.

4.2 GUIDELINES FOR APPROVAL TO CONDUCT GEOTECHNICAL SURVEYS

In 2019, the DPR Upstream Division developed a Procedure Guide to provide uniformity in evaluating geotechnical survey applications. The document, which is in line with industry best practices, will ensure that obligations are clearly itemized to promote ease of doing business.

The licensee or lessee has to submit a number of documents specified in the Procedure Guide in order to obtain approval to conduct a geotechnical survey.

4.3 GEOTECHNICAL SURVEYS IN NIGERIA

Table 2 itemizes the upstream operators, designated in alphabets, for which geotechnical survey approvals were recently granted by the DPR.

S/N	COMPANY NAME	TYPE OF SURVEY	OBJECTIVE	TERRAIN
1	A	Geotechnical (Geohazard)	To identify and prevent shallow gas related problems that may be encountered in the fields during well drilling operations	Offshore
2	B	Geotechnical (Geohazard)	To delineate the seabed topography, soil strength and possible shallow hazards (shipwreck, buried pipeline, etc.) beneath the surface of a proposed well location	Swamp
3	C	Geophysical/ Geotechnical	To determine the position of existing flow lines, pipelines, optic fibres, coordinates of pipelines, pipeline route crossings for field development purposes	Offshore
4	D	Geotechnical	To support engineering design decisions for drilling, installation of subsea infrastructure and optimize location of facilities for field development activities	Offshore
5	E	Geotechnical	To investigate and delineate areas of shallow/free gas accumulations to ensure successful and safe development of proposed wells and facilities in the field development program	Offshore
6	F	Geotechnical	To determine seabed competence, soil strength investigation and geohazard that may impede seabed installation and drilling rig deployment	Offshore

Table 2: *Examples of geotechnical survey approvals in Nigeria*

5.0 CONCLUSION

Geotechnical surveys are critical part of oil and gas development and operations. As such, a successful geotechnical survey must have a clearly defined objective and scope that align with applicable regulations and good oil field practices.

The DPR, as opportunity house and business enabler, facilitates geotechnical surveys across the oil and gas industry by granting approvals in accordance with the provisions of extant laws and guidelines.

It is, therefore, envisaged that the DPR Guide will achieve the intent of all applicable legislations whilst entrenching transparency and ease of doing business.

Finally, it is our conclusion that geotechnical survey services would further be enabled through the effort of strengthening the geotechnical survey guidelines in furtherance of relevant extant regulations in the oil and gas industry.

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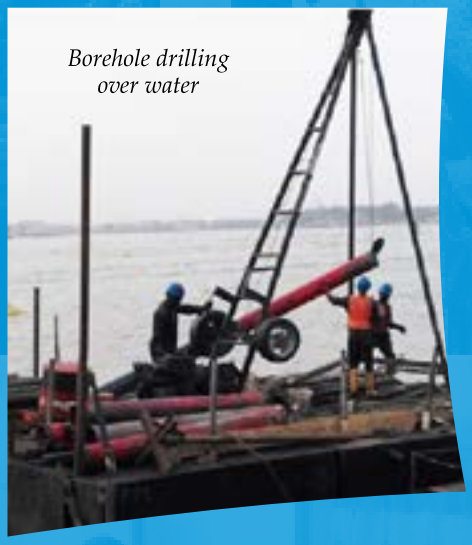

Borehole drilling over water

Cone Penetration Test Machine (20 T) in operation

Geotechnical Engineering Laboratory in operation

Pile load Testing (Analyzer) in operation

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GEOTECHNICAL ENGINEERING PRACTICE IN THE OIL AND GAS SECTOR

BY ENGR. BEN MCDAVID

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ABSTRACT

In the years shortly before and after independence in Nigeria, geotechnical engineering was practised as a component part of civil engineering until the 1980s. However, after the first International Conference on Soil Mechanics and Foundation Engineering was held in Lagos in the early 1980s, the entire approach to training and practice changed drastically. Also, at the international level, the society that coordinates activities of practitioners was changed from International Society of Soil Mechanics and Foundation Engineering to International Society of Soil Mechanics and Geotechnical Engineering in the early 1990s. This led to the acceptance of engineering geology as one of the disciplines relevant to the practice of geotechnical engineering in Nigeria.

The implication of the change in nomenclature broadened the operational horizon of the profession locally and internationally. The advent of oil and gas exploration and exploitation in Nigeria also necessitated the use of experts to attend to the geotechnical engineering needs of the new sector. This was promptly embraced by the expatriates engaged in the international oil companies (IOCS). This paper reveals that the limited impact of indigenous professionals in this sector from inception still persists till today. Some plausible solutions that would catapult indigenous participation is believed to be by liaising with the nation's higher institutions offering courses in civil and geotechnical engineering and engineering geology and to increase intake of students and provide opportunity for specialization in geotechnical engineering. It would also require strengthening and implementing the Local Content Act in the oil and gas sector with respect to geotechnical engineering practice. Finally, the umbrella society for the profession should also be empowered to sanitize and sanction infiltrators and impostors in the profession.

1.0 INTRODUCTION

Geotechnical engineering is the application of scientific methods and engineering principles to the acquisition, interpretation and use of knowledge of materials of the earth's crust and earth materials for the solution and design of engineering facilities. It is the applied science of predicting the behaviour of the earth, its various materials and processes towards making the earth more suitable for human development (Bowles, 1997; Das, 2020; Wikipedia, 2020).

Geotechnical engineering embraces the fields of soil mechanics and rock mechanics and has applications in the fields of geology, geophysics, hydrology and other related sciences. It is practised by both geotechnical engineers and engineering geologists. Examples of the application of geotechnical engineering include the prediction, prevention or mitigation of damages caused by natural hazards, such as avalanches and mudflow, landslides, rockslides, sinkholes and volcanic eruption (Murthy, 2002;Venkatriamaiah, 2006). It also includes the application of soil, rock and groundwater mechanics to the design and predicted performance of concrete, steel and earthen structures for infrastructure development over water and on land.

Also, in the built environment, any structure or facility proposed to derive its support from the earth materials (soil or rock) will certainly require geotechnical input for the foundation support. In recent years, the quantum of infrastructure and other projects' development in Nigeria, like in other developing economies, necessitates the observed high-level demand for geotechnical engineering inputs in all sectors of the economy.

The significant rise in world energy consumption has led to hydrocarbon (oil and gas) exploration under the oceans. This has resulted in major oceanic structural developments in the near-shore and offshore locations. These structures are the upstream (offshore) oil and gas facilities. A typical oil and gas platform in offshore location is shown in Fig. 1.

Fig. 1: *An oil and gas platform (Source: work.chron.com)*

Offshore (Upstream) geotechnical engineering is concerned with foundation design for human-made structures in the deep sea, away from the coastline. Fig. 2 shows a typical offshore structure that remains stable in spite of wave actions. The stability is due to the initial involvement of geotechnical engineers in the project.

Fig. 2: *A wave action on a typical offshore structure (Source: Wikipedia, 2020)*

Fig. 3: *A creek access to a typical oil and gas site in the swamp (on-shore site)*

On the other hand, onshore or near-shore facilities are founded on land or in shallow waters close to the coastline. Fig. 3 shows a creek access to a typical onshore site in a swampy area.

Fig. 4 shows geotechnical borehole drilling on water at a near-shore site. Oil platforms and submarine pipelines form a major part of such structures. There are some significant differences between

Fig. 4: *Geotechnical borehole drilling on water at a near-shore site*

onshore and offshore geotechnical engineering requirements. Notably, ground improvements on the seabed and site investigations are more expensive. The offshore structures are exposed to a wider range of geohazards and the environmental and financial consequences are much higher in case of failure or remediation, (Dean, 2010).

The oil and gas sector has been described as the main driver of the Nigerian economy. Thus, it is expected that a significant proportion of project development in the country will be in the sector. This sector has two main sub-sectors: upstream and downstream subsectors. The upstream subsector is sometimes divided into upstream (offshore) and mid-stream (near-shore) to demarcate the deep-water facilities from the shallow-water facilities.
For certain reasons, the upstream subsector is largely dominated by multi-national organizations often called international oil companies (IOCS), while the downstream subsector accommodates the indigenous players. This may be expected, considering the technological complexity, geotechnical ingenuity, huge financial and human resources requirement to execute most upstream subsector projects.

It has been established from reliable sources that the oil and gas sector provides 95% of Nigeria's foreign exchange earnings and 80% of budgetary revenues. Although the petroleum sector is considered important, as government revenues still heavily rely on this sector, it remains a small part of the country's overall economy (NBS, 2015). In 2012, the GDP analysis comprised the following sectors: Agriculture 40%, Services 30%, Manufacturing 15%, Oil 14%. By 2015, the

following composition was presented: Agriculture 18%, Services 55%, Manufacturing 16%, Oil 8% (NBS, 2015). However, about 20% of the budget was expended on the downstream subsector which is the area of involvement of indigenous geotechnical engineering practitioners.

2.0 COMPONENTS OF GEOTECHNICAL ENGINEERING PRACTICE

Geotechnical engineering procedure to achieve desired results comprises the following:

- Desk Study
- Site Investigation
- Laboratory Testing
- Foundation Design
- Supervision - Quality Assurance and Quality Control (QA/QC)

A typical geotechnical engineering project begins with a review of the project needs to define the required material properties. This leads to scheduled site investigation of soil, rock, fault distribution and bedrock properties, within the area of interest, to determine their engineering properties. Site investigation is needed to gain an understanding of the ground condition on which the proposed facility or structure will be placed.

3.0 GEOTECHNICAL ENGINEERING IN THE OIL AND GAS SECTOR

Geotechnical engineering practice in the oil and gas sector is categorized into two: upstream and downstream subsectors. Most projects in the upstream sub-sector usually take off from the country of origin of the joint venture company or consortium (usually the United States or European Union countries). The implication of this is that the needed geotechnical resources (men and materials) for such projects are often imported with other engineering inputs. This attracts little or no competition from indigenous practitioners because of the technical complexity and huge financial capital required for such projects.

On the other hand, the geotechnical component of most of these projects in the oil sector which are available for indigenous consultants are from the downstream sector. As will be expected, this is usually not very significant in the overall sectoral project development. This has been the story from the early years of geotechnical engineering practice in Nigeria. It has not changed till date within this sector. A typical geotechnical project in the downstream sector is shown in Fig. 5.

4.0 GEOTECHNICAL ENGINEERING ACTIVITIES IN THE SUBSECTORS

4.1 UPSTREAM SUBSECTOR

The complexity of the facilities for operations in the upstream sub-sector requires high-ended digital compliance for investigation and design. Locations of most of these facilities are usually off-shore and near-shore.

Fig. 5: *A petroleum tank farm and terminals on geotechnically modified ground (Source:saratovnetft.com)*

They are usually in marine, oceanic or other deep-water environments. Multi-skill experts from diverse engineering backgrounds are often required to work together. Huge capital is often required for acquiring relevant digital software and other resources.

In view of these upstream subsector peculiarities, foreign experts dominate the sector. Practically, only a few indigenous geotechnical engineering professionals have been involved in preliminary stages of some proposed liquefied natural gas facilities. Also, some indigenous engineers have gone beyond site investigation to front-end engineering design stages in such projects. The upstream sub-sector is extremely important to the overall development in the oil and gas industry as it dictates the pace for the downstream sub-sector.

4.2 DOWNSTREAM SUBSECTOR

As a result of limited access to high-ended relevant design software, requisite training and cognate experience required for upstream projects, indigenous geotechnical engineering practitioners

in the oil and gas sector are mostly involved only in the downstream sub-sector.

The main jobs for the practitioners in the downstream sub-sector are the following:

4.2.1 Tank Farms Development

These are usually carried out near the lagoons, creeks and marine water. The services include ground improvement and piling for foundation supports (See Fig. 6).

Fig. 6: *An oil tank farm for downstream operations (Source: cakasang.com)*

4.2.2 Storage and Loading Depots

The construction sometimes requires geotechnically modified ground. The depots are used for both local and imported refined products.

4.2.3 Access Roads to Depots

The construction of these types of roads requires expert inputs of geotechnical engineers because they are usually located in swamps and difficult terrains.

4.2.4 Jetties (Floating and Conventional)

There is a need for involvement of geotechnical engineers in the design and construction of gangways and walkways to achieve stability.

4.2.5 Shoreline Protection

Sheet piles are normally used for shoreline protection works. Figs. 7 and 8 show pile load testing in progress.

A number of these projects also provide challenging moments to geotechnical engineering practitioners because of the site environments which are often swampy. Similarly, the depth of water and the

Fig. 7: *A pile load testing for QAQC monitoring, Kentledge Method*

Fig. 8: *A digital pile load testing (using a Load Analyzer)*

encountered unsuitable material, in the form of highly compressible soft clayey material, are sometimes significant.

5.0 CHALLENGES AFFECTING INDIGENOUS PRACTICIONERS IN THE SECTOR

The practice of geotechnical engineering in the oil and gas sector is crucial to the development of the sector. This is more so as the products of geotechnical engineering activities will determine the safety and stability of facilities in both the upstream and downstream project sites. The international engineering consulting firms mostly monopolize the engineering activities in the upstream sub-sector where they earn ample revenues while the 'not-too-juicy' downstream subsector finds the indigenous geotechnical engineering practitioners as the key players.

This fundamental challenge has limited the capacity of indigenous professionals from achieving full potential while operating in the

sector. Other obstacles to the developmental vision of contemporary practitioners are the scarcity of indigenous experts and specialists as mentors, lack of hands-on experience, inadequate funds to invest in software procurement, lack of patronage from project sponsors. The obvious inference from these obstacles is that the Nigerian Content Act is not effectively implemented in the upstream sub-sector. In the downstream sub-sector, other major challenges observed are: the stiff competition among practitioners, involvement of low skilled engineers and clients' penchant for the cheapest professional service provider. These have resulted in infiltration of the ranks by quacks and poorly trained practitioners.

6.0 STRATEGIES FOR OVERCOMING THE CHALLENGES

The issue of challenges is not strange to many engineering practitioners in Nigeria. Government policy on Nigerian content development should be reviewed to include modalities for empowering indigenous practitioners through statutory engagement. Most indigenous geotechnical engineers are certainly willing to invest in digital capability and hands-on training in off-shore and marine geotechnical engineering skills so as to improve their competencies. Every major oil and gas project must have an indigenous firm as one of the companies participating in the consortium through a credible selection process.

In the downstream sub-sector, the indigenous practitioners should carve a niche for themselves by maintaining excellence in service and keeping away quacks. One way of achieving excellence is for indigenous engineers to set up well equipped geotechnical engineering laboratories as part of the facilities for use in their practice. Fig. 9 shows a typical geotechnical engineering laboratory. In general, the umbrella association of geotechnical engineering practitioners (Nigerian Geotechnical Association) should be sufficiently empowered to monitor and possibly sanction erring firms and practitioners with the support of the Council for the Regulation of Engineering in Nigeria (COREN). This will be a major step towards sanitizing the profession.

Fig. 9: *A geotechnical engineering laboratory*

7.0 CONCLUSION

In order for indigenous geotechnical engineers to make more impact in the oil and gas industry, the starting point is to use a strong forum through the umbrella society i.e the Nigerian Geotechnical Association (NGA). The NGA can be made more virile with very strong legal backing to register and monitor activities of members. Practitioners should embark on an aggressive membership drive across the country. Young engineers should be encouraged to join the Association. The need for government support in ensuring effective implementation of the Nigerian Content Act by stakeholders in the oil and gas sector cannot be over-emphasized. Finally, the issue of quacks, which has become a 'Frankenstein' to many technical and non-technical professional bodies in the country, has to be addressed and resisted by every available legitimate instrument.

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"THE CONSULTING ENGINEER" PERSONALITY

ENGR. NURUDEEN OYEBANJI ABDULKAREEM

Engr. N. O. Abdulkareem
(Principal Partner, Nok Associates Ltd)

Engr. Nurudeen Oyebanji Abdulkareem is a seasoned Civil Engineer with over 15 years of experience in the design and construction industry. He has a proven track record of successfully managing and coordinating multi-million naira projects from inception/design to completion/ commissioning. His ability to co-ordinate younger engineers, build partnerships and work collaboratively with other professionals such as architects, quantity surveyors, among others, has enhanced his capacity to complete projects within budget and in a timely manner over the years.

Engr. Abdulkareem was born on March 8, 1972 in Oyo Town and attended The Polytechnic, Ibadan, Oyo State from September 1992 to December 1998 where he obtained a Higher Diploma in Civil Engineering/Structures. He proceeded to Federal University of Technology, Minna, Niger State in October 2001 and graduated with a Bachelor of Science degree in Civil Engineering in December 2005. He is a registered professional engineer with the Council for the Regulation of Engineering in Nigeria (COREN) with COREN Reg. No. R.17,632. He is a recipient of The National Association of University Students (NANS) "National Outstanding Leadership Award" in recognition of his dexterous leadership acumen, passionate professional capabilities and outstanding contributions towards the development of the Nigerian economy in the engineering/construction sector.

In the course of his career, Engr. Abdulkareem has served in the following firms:

1. Associated Real-Estate Development Consultants (ARDC), Abuja as Consultant Civil /Structural Engineer, July 2005 – October 2020
2. Lans Consult, Abuja, Jos as Resident Civil/ Structural Engineer, July 2011 – December 2018
3. Nok Associates Ltd. (Consulting Engineers), Abuja as Principal Partner, March 2010 to date

Engr. Abdulkareem has provided a number of consultancy services and executed various projects in the last 10 years as itemized below:

- Emergency Accelerated Consultancy Services for Ondo Township Erosion Control Works, Ondo State. (2017-2020)
- Consultancy Services for Onuiyi Afor Erosion/Flood Control Works, Okwuohia, Obowo LGA, Imo State. (2017)
- Consultancy Services for Ubulu-Ukwu Erosion/ Flood Control Works, Aniocha South LGA, Delta State. (2017 – 2018)
- Consultancy Services for Eruwa Erosion Control Works, Ibarapa West LGA, Oyo State. (2017 – 2018)
- University of Calabar Erosion/Flood Control Works, Calabar, Cross River State. (2017 – 2018)
- Leadership Training Centre, Ishiagu, Ebonyi State. (2015 – date)
- PEF Office Parking Lot Arrangement and Marking. (2014)
- Proposed Residential Development at Plot 35, 5TH Avenue, Gwarinpa Abuja. (2016)
- Proposed Hotel Development at Plot 1065, Cad. Zone B11, Gudu Abuja. (2015)
- Proposed Classroom and Hostel Development at New Hope International School, Kuje Abuja. (2017)
- Proposed Capital Science Academy 10th Year Anniversary Memorial Garden. (2013)
- Proposed Estate Development at Gudu District, Abuja. (2014)
- Proposed Estate Development at Plot 1393, Gudu District, Abuja. (2010 – date)
- Proposed Terrace Apartment at Plot 922, 4th Avenue, Gwarinpa Abuja. (2012)
- Provision of Infrastructure (Roads, Culverts and Drains) for the proposed NBC Infrastructure Ltd. (2018)

Construction of Boys and Girls Hostel for New Hope

Construction of Classrooms

Boys and Girls Hostel Foundation works for New Hope

Construction of Administrative Block

Construction of Indoor Sports Hall

Construction 6M High Retaining Wall at Guzape District, Abuja

A WORD FOR YOUNG ENGINEERS

My word to you, young engineers, is that the world of engineering is so vast that we can safely say that almost everything in our technological world today is a product of engineering from the environment, telecommunications, transportation to manufacturing, security and even the medical field. The difference between Scientists and Engineers according to Theodore von Karman is that: "Scientists study the world as it is; engineers create the world that has never been." "Engineering is the act of organizing and directing men and controlling the forces and materials of nature for the benefit of the human race" (Henry Stott).

My dear fellow engineers, please be reminded that engineering is a body of knowledge that deals with a lot of calculations and data analysis. It is a world that mixes words with numbers and applies mathematics and physics in solving real-life complex problems. But what is the secret of efficient engineering problem solving? It is very simple: practice, practice and practice! The old adage, "practice makes perfect", does not only apply to sports but to learning engineering as well.

Engr. N.O. Abdulkareem
(Principal Partner, Nok Associates Ltd

A young engineer at work

Solving problems over and over again makes you better at them. Invest more time on solving problems rather than merely staring at the problems. Young engineers should be ready physically and mentally to take on challenges and should not be illegitimately attracted or wrongly distracted by money.

"Note that some challenges may not be overcome by the individual acting as a loner. You may need to share your challenges with others of like mind, older and more experienced colleagues in the profession."

Note that some challenges may not be overcome by the individual acting as a loner. You may need to share your challenges with others of like mind, older and more experienced colleagues in the profession. You may need to refer to publications in addition to other legitimate approaches needed in order to solve problems or overcome challenges. What is important is to be able to solve problems, meet the needs of humanity and add value to yourself and the society in general.

Remain internally motivated.

Thank you all and have a great life.

Engr. Nurudeen Abdulkareem
(Principal Partner, Nok Associates Ltd)

"Engineering is the act of organizing and directing men and controlling the forces and materials of nature for the benefit of the human race." (Henry Stott)

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A JETTY UPGRADE PROJECT IN SHALLOW TO DEEP OFFSHORE

BY ENGR. KABIR HARUNA

Engr. Kabir Haruna
(Head of Structures Unit, PDENL)

1.0 INTRODUCTION

A jetty upgrade project in shallow to deep offshore was executed by Primetech Design and Engineering Nigeria Limited (PDENL) for Nigeria Liquefied Natural Gas Limited (NLNG). PDENL is a full subsidiary of Julius Berger Nigeria Plc (JBN). It was established to carry out design and engineering services in Nigeria in 2011 primarily in full compliance with the Nigerian Oil and Gas Industry Content Development Act (NOGICD Act or Nigerian Content Act). It is a full Nigerian company with over 90% of its workforce being Nigerian engineers in full time employment.

A jetty is a structure that projects from the land out into water. Often, "jetty" refers to a walkway accessing the centre of an enclosed waterbody. The term is derived from the French word "jetée," "thrown", and signifies something thrown out. It serves as an essential geotechnical engineering infrastructure to support marine transportation. An upgrade generally means to raise something to a higher standard by adding or replacing components. Specifically, the one executed by PDENL for NLNG in Bonny Island was the upgrade of Material Off-loading Jetty 2. This article seeks to explain how the project was executed.

2.0 BACKGROUND TO THE JETTY UPGRADE PROJECT

2.1 MATERIAL OFF-LOADING JETTY 2

The Material Off-Loading Jetty (MOJ 2) was built during the NLNG Plus Project in 2003 with a limited service life of 5 years. Owing to the limited design life, no corrosion protection measures were applied to the steel structures.The MOJ 2 consists of the following four different sections:

2.1.1 General Cargo Berth

The General Cargo Berth is 140m long and 15m wide located parallel to the Bonny River tidal stream. It was designed as a one-way reinforced concrete deck, spanning between longitudinal beams, which are supported on tubular steel piles. The concrete deck was constructed using precast concrete elements with in-situ concrete.

2.1.2 Approach

The berth approach trestle was designed with a similar form of construction as the General Cargo Berth.

2.1.3 Aggregate Berth

The Aggregate Berth is a sheet piled land backed wharf 120m long. The berthing face is fendered by arch fenders.

2.1.4 Ro-Ro Berth

The Ro-Ro Berth is a sheet piled land backed structure with reinforced concrete barge ramps designed to accommodate local barges. Guide/mooring piles were provided for each berth. A detailed inspection of the MOJ 2 in 2009 showed an average corrosion rate of 0.45mm/yr for the steel tubular and sheet piles implying that some of the steel sections had already lost more than half of their wall thickness since the commissioning in 2003. Due to the reduced wall thickness, there were frequent perforations in the sheet pile walls resulting in the wash out of backfill material, which resulted in the collapse of the adjacent flexible pavement on two occasions. Thus, the bearing capacities for the piles were expected to significantly decrease over the next few years which would eventually lead to a functional failure in the absence of any form of intervention. (See Figs. 1, 2,3 and 4)

Fig. 1: *An existing quay deck*

Fig. 2: *Material Offloading Jetty 2*

Fig. 3: *Pavement caving in*

Fig. 4: *An exposed reabar*

2.2 SLOPE PROTECTION OF THE NORTHERN PERIMETER ROAD

The existing slope protection between the new passenger jetty and the MOF Jetty 2 along the northern perimeter road was fast deteriorating due to the failure of the erosion protection of the road embankment slope. The slope protection consisted of a revetment of sand bags in one area and sand-cement bags in another area. The effect of wave action on the embankment had led to the loss of the road shoulder in some areas and the loss of fill material resulted in the excessive settlement and cracking of the adjoining flexible road pavement. The objective of the MOF Jetty 2 Upgrade Project was to address the degradation of the sheet pile wall bordering the aggregate and RO-RO berths as well as the effects of erosion on the northern perimeter road between the new passenger jetty and the RO-RO berth. (See Fig. 5)

3.0 ENGINEERING

Engineering of the MOJ 2 took place in 3 steps, namely:

- Engineering study and options analysis
- Basic engineering design
- Detailed engineering design as part of engineering procurement construction (EPC) contract

3.1 ENGINEERING STUDY AND OPTIONS ANALYSIS

In a jetty upgrade project, the client must decide the best option to ensure cost effectiveness whilst having an excellent facility after the upgrade. Most often, the client engages competent engineering firms to perform this task and thereafter submit a report for consideration. For the MOF jetty, the client initiated an engineering study and options analysis study for the upgrade in 2012. Primetech Design and Engineering Ltd performed this task for the client.

The study checked the integrity of existing structures and tried as much as possible to make use of parts of the existing structure that were in good condition or which could be made good so as to save cost. The study also analysed two options (concrete and steel sheet pile) for the upgrade. The pros and cons associated with both materials were well scrutinized and presented to the client. Cost benefit analysis and life cycle cost were presented and analysed. Results were presented in an "Engineering and Options Analysis Report". From the analysis report, the recommendation was that steel sheet piles with corrosion protection be used for the jetty upgrade. This was because it outperformed concrete sheet piles in most of the critical parameters.

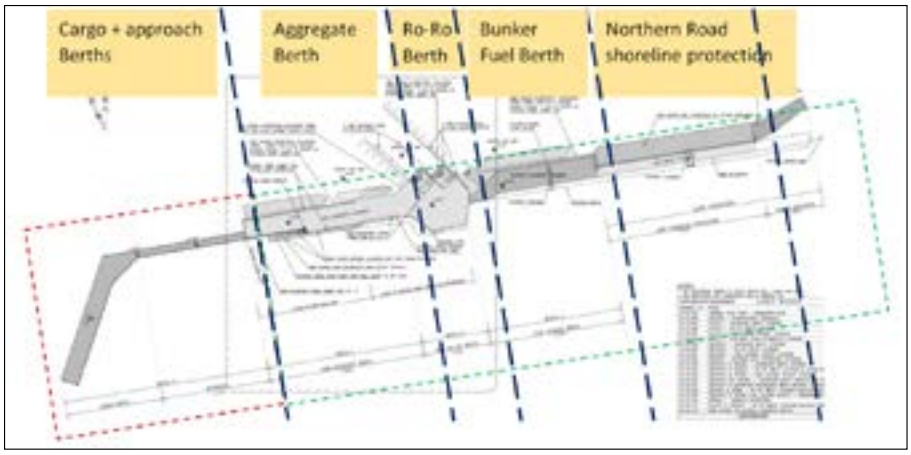

Fig. 5: *MOJ 2 sectional demarcations*

3.2 BASIC ENGINEERING DESIGN

The study of the analysis report led to the development of basic engineering design documents which included preliminary sizing, basic calculation, specification and the bill of quantities. This stage delivered a rough target price for construction with accuracy of about ±30%.

3.3 DETAILED ENGINEERING DESIGN

3.3.1 MOJ 2 Design Data

The design data provided by the client included:

- Vessel data
- 25 years design life
- Motorised gangway required in aggregate berth
- No crane
- Design standard – Eurocode & Shell DEP
- Jetty furniture such as ladders, fenders and bollards
- Preferred timeline

PDENL produced a design manual that contained:

- Reference levels based on datum provided by the client

- Site data like water levels recordings from the last 25 years to derive low, mean and high water levels.
- Boreholes sunk in each berth to 30m depth. Cone penetration tests (CPT) at several locations were also done
- Wave and current loads on structure
- Topographic survey prior to start
- Bathymetry surveys done for sea bed levels
- Dredging requirements provided based on water depths required for vessels
- Water analysis of samples taken from the river were done in a competent laboratory
- Design standard – Eurocode & Shell DEP
- Load cases, load combinations, crack widths, exposure classification, concrete covers according to design standards
- Mooring loads calculated based on vessel data
- Mooring dolphins provided at Ro-Ro berths
- Scour protection allowance according to EAU 2004
- Nominal and design depths according to EAU 2004
- Fender type – Arch Fenders
- Edge protection – steel plate nosing
- Cathodic protection and/or coatings for design life – combination of coating and sacrificial aluminium anodes
- Software to be used
- A report on existing anchors and structures was done before upgrade

PDENL considered the following in performing the design:

- Availability of materials and workmanship
- Design and construction requirements by the client
- Impact of dredging on the environment and existing structures
- Consideration of the stability of all temporary works required for the project
- Cost saving opportunities for the client whilst not compromising quality

3.3.2 MOJ 2 Quay Wall

The quay wall was designed as Arcelor AZ 24-700 steel sheet pile placed 1.5m in front of existing Larsen 606steel sheet pile for the aggregate berth. The aggregate berth is mostly a double-wall sheet pile structure. Both sheet piles are AZ 24-700. Anchor M52 ASDO500 (Anker Schroeder) received by 2U220 wailing. The quay wall was designed as Arcelor AZ 17-700 steel sheet pile placed 1.5m in front of existing Larsen 605 steel sheet pile for the Ro-Ro berth. Anchor M36 ASDO500 (Anker Schroeder) received by 2U220 wailing.AZ 17-700 for the Ro-Ro Berth.

The quay wall was designed as Arcelor AZ 17-700 steel sheet pile placed 1.5m in front of existing Larsen 605 steel sheet pile for the bunker fuel Berth. Anchor M45 ASDO500 (Anker Schroeder) received by 2U220 wailing.AZ 17-700 for the Ro-Ro berth.

Reinforced capping beam 1m x 1m fixed to sheet piles. All reinforcing steel was 500 N/mm2.
All sheet piles were coated to category C5M according to ISO 12944-5. Sacrificial anodes were also provided at the splash zone, which has the highest propensity for corrosion.

3.3.3 Quay Apron/Concrete Pavement

Quay apron and Ro-Ro ramps were 250mm thick grade C35/45 concrete. The concrete was provided with cross wise 2-layer reinforcement. Due to thermal and shrinkage forces, expansion and contraction joints were provided according to Shell DEP. The sub-base was sand-cement mixture on well-compacted sand subgrade to 95% proctor density.

3.3.4 MOF Jetty Furniture

Jetty furniture installed were:

- Fenders SX-P 400 arch fenders with fender facing pads on fender piles (HEB 240) to ensure berthing at low and high tides
- 300kN and 100kN bollards provided with break-off anchors
- Motorised gangway
- Street lights
- Cable trays

3.3.5 MOF Jetty Mooring Piles

A set of 610mm diameter hollow steel pipes was driven to termination depth below seabed as mooring dolphins. The dolphins were provided with hooks and navigational aid at nights. Mooring dolphins were coated up to seabed level to limit corrosion.

3.3.6 Selected MOJ 2 Sample Drawings

The sample drawings are shown in Figs. 6 to 8

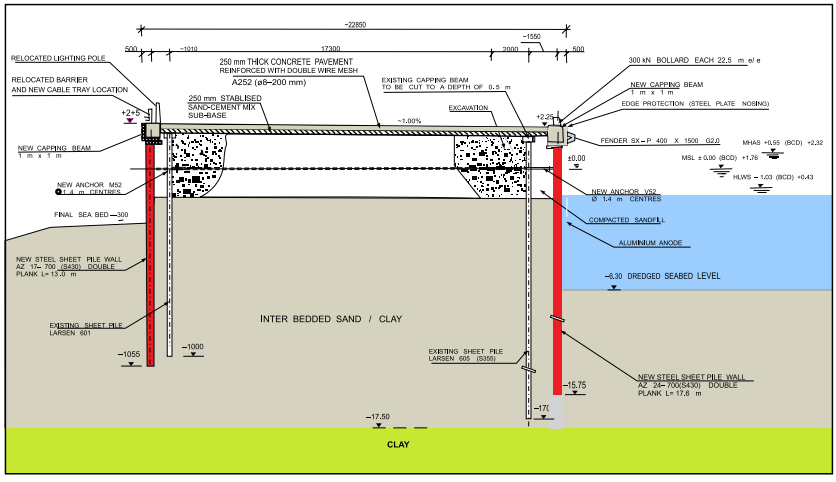

Fig. 6: *Aggregate berth section 1*

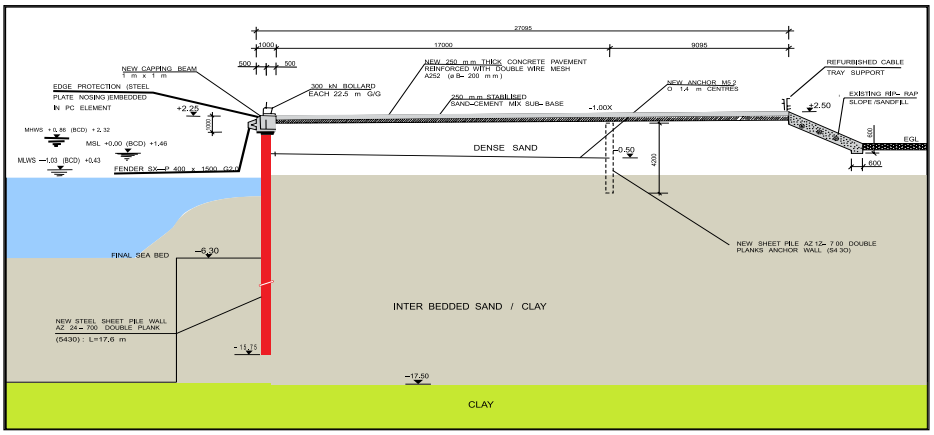

Fig. 7: *Aggregate berth section 2*

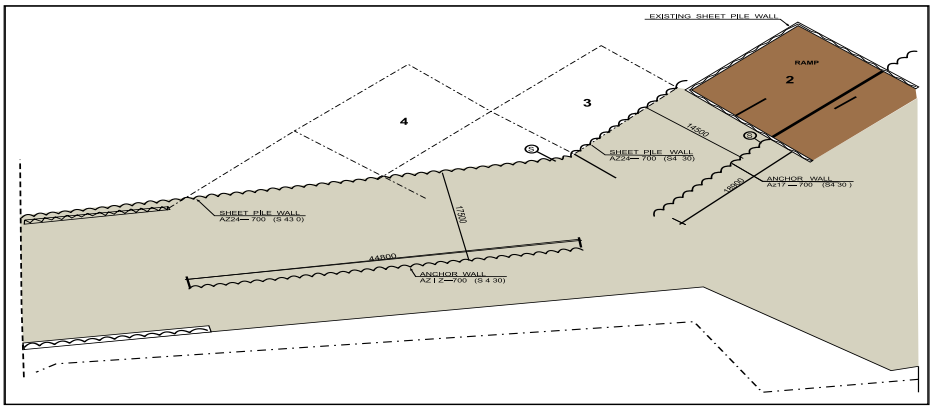

Fig. 8: *Ro-Ro Berth sheet pile layout*

4.0 CONSTRUCTION IMAGES

Construction images are shown in Figs. 9 to 14

Fig. 9: *Pile driving*

Fig. 10: *A driven sheet pile*

Fig. 11: *A precast capping beam*

Fig. 12: *Completed fenders*

Fig. 13: *A motorized gangway*

Fig. 14: *A precast capping beam*

5.0 IMAGE OF COMPLETED STRUCTURE

This is shown in Fig. 15

Fig. 15: *Image of the completed jetty structure*

6.0 IMPACT ON NIGERIAN ENGINEERS

The project had a great impact on Nigerian engineers involved in the engineering and construction as described hereunder:

- Detailed Engineering achieved 75% Nigerian content
- Nigerian engineers received training from foreign partners including Arcelor Mittal and Julius Berger International
- Exposure of young engineers to the use of oil & gas codes like the Shell DEP and NLNG Specifications
- Critical understanding on how to present technical drawings which include steel and concrete structures for shallow offshore structures
- How to use standard templates and check procedures in engineering drawings to ensure quality of work irrespective of who is making it
- How to make construction savings through critical thinking and articulation of well planned designs
- Understanding the impact of procurement on design and construction of projects
- Contributing to national development through the oil and gas sector
- How to work in a team
- Construction achieved 85% Nigerian content in construction management and supervision of the project
- All steelworks like ladders, mooring dolphins, bollards protective coating were handled in Nigeria by reputable companies with Nigerian engineers in their employment. Coating was handled in Nigeria by reputable companies with Nigerian Engineers in their employment.

ACEN ACTIVITIES: JUNE - OCTOBER 2020

ACEN ACTIVITIES: JUNE - OCTOBER 2020

ASSOCIATION FOR CONSULTING ENGINEERING IN NIGERIA-ACEN

2020 EXTRA-ORDINARY GENERAL MEETING

Thursday 30th July, 2020
Time: 10am

Theme:
'THE SURVIVAL AND STRENGTHENING OF CONSULTING ENGINEERING PRACTICE IN DISRUPTIVE AND UNCERTAIN TIMES'

Engr Nelson Ogunshakin FICE OBE
FIDIC CEO
Guest Speaker

Engr George .C. Okoroma FNSE JP
President ACEN

Engr Suleiman Adamu FAEng FNSE
Hon. Minister of Water Resources
Guest of Honour

Venue: By Zoom

Mandatory Registration at www.acen.org.ng

ACEN ACTIVITIES: JUNE - OCTOBER 2020

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SITECH ENGINEERING LIMITED

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P. O. Box 10780, Kaduna, Kaduna State, Nigeria
Mobile: 08033146044, 08034555805 **E-mail:** sitechng@yahoo.com
Website: www.sitech-engineering.com.ng

OUR VISION

To be a major engineering firm in the development of quality and durable infrastructures.

MISSION

To provide adequate ground engineering (foundation) data for the design of various infrastructures using the latest field technology device to obtain reliable results.

ABOUT US

Sitech Engineering Limited was incorporated on the 6th day of June 1989, with CAC Registration Number RC: 132307. Our services cover the provision of geotechnical & foundation engineering specialist works, laboratory testing and quality control works to consulting and construction firms in the engineering industry as well as solid mineral exploration companies, and building and civil engineering contractors.

We offer our clients a full range of geotechnical, foundation engineering and geological services including site exploration, evaluation of geologic hazards, development of foundation, earthwork recommendations and construction monitoring. We can also integrate geotechnical engineering, engineering geology, seismology and environmental services to facilitate the siting and design of structures.

OBJECTIVES

As a well-established firm in the engineering industry, we are known to be focused on achieving a high degree of customer satisfaction, early projects completion, high degree of work standards, safety management, sound financial management, deep involvement in research and development (R&D) and development of technological innovations in foundation engineering.

Engr. Mudashir Shittu
(MD, Sitech Engineering Ltd)

Our objectives are further enumerated as follows:

- Quality services in conformity with international standards
- Design, development, testing and implementation of special technologies and new construction methods
- Research and development of new technologies and improvement of existing ones
- Timely or early completion of projects
- Development of skills and training of engineers and technologists in the field of foundation studies, geotechnical engineering and solid mineral exploration

OUR SERVICES

Sitech Engineering Limited (SEL) has continued for the past three decades to be a successful executor of large infrastructure projects with sensitive geotechnical and foundation engineering related component and a recognized consultant in the field of geotechnical and foundation engineering applications, deep foundation works, bridges and bridge related engineering works, soil remediation, large excavations, hydro–structures, design and development of construction methodologies and technologies. Our core services are enumerated below:

- Geotechnical and foundation investigation for engineering design and construction works
- Soil and materials laboratory services

A cone penetration test site

- Material testing (Quality control and quality assurance)
- Pavement evaluation and design
- Route soil and material survey for new roads
- Pile foundations construction
- Ground improvement and grouting
- Mineral survey and exploration
- Geological and geophysical survey
- Structural testing (destructive and not-destructive testing on concrete)
- Land reclamation and remedial works
- Water studies and boreholes services
- Geotechnical training services for personnel
- Supply of laboratory and drilling equipment with their accessories

GEOTECHNICAL SITE INVESTIGATION

Foundation Studies: We conduct detailed site investigation which involves various subsurface data analysis for foundation studies for various construction activities. We have capacity to carry out various in-situ tests, soil sampling, rock coring, density test, and a wide range of site analysis to obtain required geotechnical parameters. Our soil engineers and geoscientist prepare reports for various uses. We undertake soils and foundation investigation and studies for bridge sites, dams, building construction as well as others structures according to needs and requirements. Various tests like standard penetration tests (SPT), cone penetration tests (CPT), other field tests like density test by sand replacement method, field California Bearing Ration (CBR), pile integrity tests, plate loading test, field permeability tests in soil and packer testing in rocks are part of our activities.

We do investigative boring for subsurface material characteristics, probing into various strata formation. This involves core drilling by rotary methods through hard strata, from the bottom of an exploration hole with core recovery and excavation trial pits or trenches. Special sampling technique sare employed specifically for soil and rock through undisturbed sampling, with U-tube sampler, Shelby tubes, split spoon sampling and single/double tube core barrels.

Pavement Evaluation and Route Soil Survey: We conduct pavement condition survey to assess the serviceability index of existing road and airport pavements. We carry out route soil and construction material survey along alignment of new road for design of the pavement based on conventional design parameters and determine suitable borrow areas that will be used as base and sub base as well as sources of other construction materials.

LABORATORY AND QUALITY CONTROL SERVICES

SEL has a well-equipped soil and materials laboratory with suitable and up to date equipment used by experienced engineering and technical staff. We specialize in carrying out comprehensive tests on materials and other quality control tests. The laboratory is equipped to conduct tests on soil, rock, steel reinforcement, aggregates, concrete and other construction materials.

Various laboratory tests are carried out on soil such as moisture content, specific gravity, Atterberg Limit Test, sieves analysis, compaction, triaxial compression, shear box test, consolidation and chemical tests. The chemical tests include sulphate, carbonate and chloride content, pH Rock tests like uniaxial, sonic velocity, point load index, young modulus determination and slake durability. Our tests also cover detailed water quality analysis. The various tests are carried out using digital equipment in accordance with relevant standards like BS, ASTM, and IS.

The quality control tests are conducted on various construction materials so as to ascertain that the requirements for such products are met in order to improve on the quality of our services. We specialize in carrying out comprehensive strength test on materials and other quality control tests. These include tests on concrete products, determination of mix design and strength test, tests on aggregates (i.e. abrasion, impact value, elongation, flakiness index, crushing value, etc), Asphalt,

cement, bitumen, steel reinforcement. Steel reinforcement tests cover compressive and tensile strength tests.

GEOLOGICAL STUDIES AND MINERAL EXPLORATION

In mineral exploration, we execute core exploratory drilling to help ascertain the economic quantity of solid mineral deposit with state-of-the-art equipment. This involves drilling through the subsurface of both consolidated and unconsolidated formations up to maximum depth of 450m. We provide technical assistance to intermediary financial institutions to assess the risk in lending to the mining sector.

We undertake geophysical investigation on various works using seismic and electrical resistivity methods. This includes geological mapping of various locations and delineating various geological and geographical features.

PILE FOUNDATIONS AND GROUND IMPROVEMENT WORKS

SEL has the capacity to undertake the construction bored and cast-in-place piles and micro piles of various diameters. The firm has the capability of conducting grouting in ground engineering by the process of controlled injection of fluid phase material into soil or rock. We provide the means to solve many ground engineering problems to effect ground improvement. We carry out soil studies with full and partial reclamation on erosion control sites, abandoned mine sites and risk prone areas.

SUPPLY OF LABORATORY AND DRILLING EQUIPMENT WITH THE ACCESSORIES

Over the years, we have helped many construction companies and agencies to establish and equip their laboratories with the latest laboratory equipment. Also, we have supplied various drilling equipment like rotary rigs, core barrels, diamond bits, rods, rimming shell, etc to various clients.

SAFETY POLICY

The management of SEL is fully committed to establishing, implementing and maintaining a management system where all hazards to health, safety and environment are identified and controlled to ensure a minimum risk work environment. In order to achieve the minimum risk to the environment at all levels of operations, SEL'S management directs and controls the activities of its employees and contractors to ensure that they participate in implementing and maintaining the organization's safety policy and objectives.

The firm's core business is to undertake engineering consultancy services from the initial planning through feasibility studies, outline planning, production of detailed designs, supervision and commissioning. Therefore, in undertaking these services, our firm complies with the relevant national and international Health, Safety and Environment (HSE) legislations in order to achieve the minimum risk to the environment at all levels of operation.

KEY PROJECTS EXECUTED

Sitech Engineering Limited has successfully executed many projects in different parts of Nigeria and the neighboring West African countries, including the coastal areas. The projects cover mainly geotechnical investigations, reclamation of land, roads and highways, mineral exploration and infrastructural development in general.

Key projects executed are as follows:

- Geotechnical investigation for 650,000bpd Dangote Oil Refinery and Petrochemical Complex
- Geotechnical site investigations for Cosgrove Smart Estate and Cosgrove Towers, Abuja
- Geotechnical investigation and topographical survey for the front end engineering design [FEED] for Crude and Products Pipeline Upgrade and Replacement Project for NETCO/NPSC/NNPC.

Drilling at an offshore location

- Geotechnical investigation for Ajaokuta – Abuja – Kaduna – Kano (AKK) Gas Pipeline Project
- Geotechnical investigation for Abeokuta Cargo Airport Project, Ogun State.
- Topographical survey for OCP Africa Fertilizer Blending Plants in Kaduna and Ogun State
- Geotechnical site investigations for Nassarawa Sugar Project (12000TCD Sugar Plant) and irrigation bulk water supply infrastructure.
- Geotechnical investigations for and topographical survey for 1,350MW Kano Independent Power Project (NETCO/GPIC/NNPC)
- Geotechnical site investigations for Dangote Rice Mill Project in Jigawa, Kebbi, Sokoto, Zamfara, Kano and Niger States.
- Geotechnical site investigations for Dangote Cement Okpella Plant, Edo State
- Geotechnical site investigations for Dangote Cement Ibese Plant, Ogun State
- Geotechnical site investigations for Dangote Cement Obajana Plant, Kogi State
- Geotechnical site investigations for Dangote Cement Grinding Plant in Ghana, Togo, Liberia, Sierra Leone and Gabon
- Subsurface site investigation for Ibadan City Integrated Flood Risks Management and Drainage Master Plan
- Geotechnical Investigation for 6 bridges and flyovers, ONEX, Abuja
- Geotechnical investigation for Abuja Centenary City Project
- Subsurface site investigations for Itisi Multipurpose Dam, Kaduna State
- Geotechnical site investigation for Mambilla Hydroelectric Power Project of the Federal Ministry of Power
- Geotechnical investigations for the Russian embassy building, CBD, Abuja
- Subsoil investigation of the Millennium Tower and Cultural Centre, Abuja
- Reclamation of abandoned mine site at Gwale, Kano State and Bukuru, Plateau State
- Subsoil investigations of Federal Secretariat, FCT Abuja
- Subsoil investigation of the Federal Ministry of Finance building, Abuja
- Deep soil investigation of the Mbiama and Patani Bridges along East-West Road, Bayelsa and Rivers State
- Geotechnical site investigations for Ashaka Cement Plant expansion Project, Gombe State
- Deep soil investigation for Bridges, pavement evaluation and route soil survey for the dualization project of Abuja – Nyanya - Keffi Road of the Federal Ministry of Works
- 9 No bridge deep soil investigations along Eastern Bypass, Kaduna for the Federal Ministry of Works (FMW).
- Galma Dam site investigation for the Federal Ministry of Water Resources
- Limestone exploratory coring for Dangote Cement Plc in Ogun State
- Limestone exploratory coring for BUA Cement Plc in Edo and Ogun State

EQUIPMENT

Sitech Engineering Limited is equipped with latest rotary drilling rigs for various geotechnical investigations and mineral exploration works in Nigeria and the West African sub region. The rotary rigs are capable of completing drill holes to a depth ranging between 200 - 600m at a boring diameter of 50mm - 600mm. The firm's rotary rigs have the following data shown in table 1.

S	Rig	Manufacturer	Country of Origin	Year of Manufacture/ Acquisition
1.	KB 20/100 Purple	Dipl. Ing Lutz Kurth	Germany	2018
2.	KB 20/100 Yellow	Dipl. Ing Lutz Kurth	Germany	2015
3.	LX 6 Multipurpose Rig (2)	BoartLongyear	Poland	2014
4.	LX 6 Multipurpose Rig (1)	BoartLongyear	Poland	2013
5.	KB 20/100 Red	Dipl. Ing Lutz Kurth	Germany	2012
6.	KB 20/100 Blue	Dipl. Ing Lutz Kurth	Germany	2011
7.	Acker Drill Rig	Acker Drill Co., Inc.	USA	2006
8.	Mobile Drill	Mobile Drill Co.	Holland	2006
9.	Ramrod II Core Drill	Joy Company Inc.	USA	2005

Table 1: *Drill rig details*

EQUIPMENT/KEY PROJECT PRODUCTS

Soil and Materials Laboratory equipped with Digital ELE Equipment

Site investigation for Mambilla Power Project

Offshore Drilling

Geotechnical investigation at Kaduna Refinery

LX6 Multipurpose Rotary Rig with Capacity to drill up to 600m

Geotechnical investigation at an SPDC Flow Station

Cored rock samples

Pile construction at a project site

Pile works at National Hospital, Abuja

SITECH ENGINEERING LIMITED

(Consulting Civil & Geotechnical Engineers)

OUR VISION

To be a major Engineering firm in the development of quality and durable Infrastructures.

MISSION

To provide adequate ground Engineering (Foundation) data for the design of various Infrastructures using the latest field Technology device to obtain reliable results.

CONTACTS DETAILS:

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OUR SERVICES:

SITECH has continued for the past three decades to be a successful partner of large infrastructure projects with sensitive Geotechnical & Foundation Engineering related component and a recognized consultant in the Field of Geotechnical and Foundation Engineering applications, Deep Foundation Works, Bridges and Bridge related Engineering Works, Soil Remediation, Large Excavations, Hydro-Structures and in the Desig n and Development of construction Methodologies and Technologies our core services are enumerated below:

- Geotechnical and Foundation Investigation for Engineering Design and Construction works
- Soil and materials Laboratory Services
- Material Testing (Quality Control and Quality Assurance)
- Pavement Evaluation and Design
- Route Soil and Material survey for new roads
- Pile Foundations Construction
- Ground Improvement and Grouting
- Mineral Survey and Exploration
- Geological and Geophysical Survey
- Structural Testing (destructive and NDT testing on concrete)
- Land Reclamation and Remedial Works
- Water Studies and Boreholes Services:
- Geotechnical Training Services for Personnel
- Supply of Laboratory and Drilling Equipment with their Accessories

Date of Incorporation:
6th June, 1989

Registration Unit CAC:
RC: 132307

GEOTECHNICAL ENGINEERING PRACTICE IN HIGH-RISE BUILDING DESIGN AND CONSTRUCTION

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Prof. S.U. Ejezie, FNSE, FNICE, FNGA, M. ISSMGE

1.0 INTRODUCTION

Geotechnical engineering is the branch of civil engineering hidden from general view yet having the overall control on the stability of structures and facilities that constitute the constructed environment. It is the area of Civil Engineering variously regarded as the "Unsung Hero of the Built Environment", the "Hidden Facilitator of construction in difficult ground", or, as maybe considered more appropriate for this paper, the "Cornerstone in the design and construction of High-Rise Buildings in all varieties of ground conditions". In fact, the term "Geotechnical Engineering" was introduced, following the rapid expansion of soil mechanics as a subject, to describe the application of soil mechanics principles to the analysis, design and construction of civil engineering structures which are in some way related to the earth (Powrie, W. 2004 2nd Edition).

From these definitions, it is readily deduced that geotechnical engineering is the branch of civil engineering that clearly defines the roles of earth materials – soils and rocks of the subsurface – in the development of the environment. Its achievements are like hidden treasures because most outputs of geotechnical engineers are concealed – either underground or below water.

The case of high-rise buildings is typical. The general observer easily notices the aesthetics and the complex structural configurations of the superstructure and showers praises on the architect and structural engineer. No mention is made of the substructure which comprises all parts of the structure located below the ground surface. In many instances, this part may consist of several storeys as is the case in deep basement construction or a complex array of deep foundation elements – piles and piers – as is common in soft ground environments. Despite being relegated to obscurity or seldom accorded any recognition, the substructure holds the key to the safety and stability of the entire structure. A failure that originates from any part of the superstructure can, in many cases, be arrested and fixed without affecting the entire structure. On the other hand, if failure originates from any part of the substructure owing to soil failure or defective design of foundation elements, the whole structure will most likely fail. (See Fig. 1)

Fig. 1: *An example of high-rise building failure caused by defective foundation design*

2.0 FEATURES OF HIGH-RISE BUILDINGS

2.1 SUPERSTRUCTURE AND SUBSTRUCTURE

The uniqueness of high-rise buildings is owing to the spectacular height of the superstructure – as reflected in the term "high-rise". Conventionally, they include the multi-storey buildings and skyscrapers with heights projecting several metres into the sky in developed cities of the world. They are particularly common in cities with limited land space which, invariably, favour vertical expansion rather than the usually less complicated horizontal extension in land development. This explains the predominance of high-rise buildings in megacities around the world.

Figs. 3a and 3b: *Recently completed 17- Floor NCDMB Headquarters Building in Yenagoa, Nigeria (at construction stage)*

Since the beginning of the 21st century, there has been a phenomenal increase in both the number and maximum height of these buildings globally. Poulos (2016) loosely classified those with heights up to or greater than 300m as "Super High-Rise" buildings. Available information on the total number of these buildings constructed globally since 1995 shows that their increase has been in geometric progression. In general, they are usually associated with more challenges than those whose height ranges are less than 300m. Nevertheless, the availability of modern high technology tools for application in the design and construction of these complex structures has greatly encouraged interest in their development. Consequently, high-rise buildings have, unconsciously, been accepted in virtually all cities of the world today to serve as an index of development. The more the number in a city, and/or the greater the height, the more developed the city is assumed to be (See Fig. 2). Nigeria, of course, is not left out in the race. The recently commissioned NCDMB Headquarters building in Yenagoa is a testimony (See Figs. 3a and 3b).

An equally (if not more) significant feature of high-rise buildings is the complexity of their substructure. In most cases, the higher the superstructure projects skyward, the deeper the substructure penetrates into the subsurface. This presents serious geotechnical engineering challenges in both the design and construction of the building. Unlike the superstructure that is above the ground and visible to all observers, the substructure is hidden inside the ground and is subject to the uncertainties in the interaction with surrounding earth materials – soils and rocks. Characteristically, the higher the building, the greater the magnitude of the vertical load on the foundation, the more susceptible to the adverse effects of wind-induced lateral loads and more complex the task of choosing the appropriate foundation type to guarantee stability.

Fig. 2: *Burj Khalifa, (Super high-rise) and other high-rise buildings in Dubai*

This brings to the fore the cardinal role of geotechnical engineering in high-rise buildings. The associated heavy foundation load gives rise to bearing capacity and settlement problems which call for specialist geotechnical engineering expertise. The lateral forces usually constitute the most critical component of the forces acting on the buildings because they induce severe bending moments on the superstructure. This gives rise to repetitive application of high uplift and compressive forces on the substructure, particularly on the exterior foundation elements. The repeated nature of the loading results in appreciable progressive degradation or weakening of the surrounding soil in a manner similar to a typical dynamic load response. All these and many other ground engineering considerations justify the prominence of geotechnical engineering practice in high-rise building designs and construction.

3.0 ASPECTS OF GEOTECHNICAL ENGINEERING PRACTICE OF RELEVANCE TO HIGH-RISE BUILDINGS

The focus of geotechnical engineers in the development of the constructed environment is generally on the subsurface – the supporting medium that bears the load imposed by the superstructure. The strength and compressibility characteristics of the earth materials govern the post-construction performance of the structures. Geotechnical engineering activities of relevance to high-rise buildings are, therefore, targeted at the subsurface and are essentially in two phases. The first phase involves investigating or probing the nature of the soils and rocks underlying the site of the building. The second dwells on the geotechnical design of the appropriate foundation type for the proposed high-rise building.

3.1 SUBSURFACE INVESTIGATION

The emphasis placed on subsurface investigation is generally owing to the uncertainties in the nature of soils and rocks which constitute the earth materials underlying the subsurface. These uncertainties need to be unravelled, failing which the consequences could be disastrous

and embarrassing because the sources of stability of any structure are hidden deep in the ground. Little wonder then that each time a building failure occurs the subsoil-foundation system is usually presumed guilty until exonerated through failure analysis by qualified personnel. For example, the tilting of the popular "Leaning Tower of Pisa after construction was traced to a

Fig. 4: *The Leaning Tower of Pisa, Italy (Before restoration) – caused by unidentified weak soil layer at initial construction phase*

previously unidentified weak soil layer (See Fig. 4).

3.1.1 Subsurface Probe

Different methods are currently employed for subsurface investigation. For high-rise buildings, these could indeed be highly sophisticated based on the general notion that the taller the superstructure, the deeper the penetration of the foundation element. The primary aim of the probe is to obtain information on the properties of the subsurface materials with a view to evaluating their engineering behaviour. In the process, the likely geologic problems in the site which may adversely affect the stability of the building would be identified and their mitigation thence becomes the target of the design process. The investigation would also reveal the nature of the subsurface in terms of the vertical and areal extent of the soils and rocks as well as their potential ability to support the proposed building. This task can be quite daunting for the great depths associated with high-rise building foundations – hence the complex nature of the probing techniques usually employed. The choice of the actual technique to use is generally determined by the nature of the project and the applicability of the method under prevailing site conditions. The basic questions whose answers serve as ultimate guide address the likelihood of the strata at the site serving satisfactorily under in-situ conditions and the susceptibility of the soils to significant alterations arising from imposed conditions. The answers specifically reveal if the strata possess adequate bearing capacity to support imposed loads and/or undergo objectionable excessive settlement. Furthermore, it could also be inferred if the strata would consolidate under a large sustained load, densify under dynamic loads or experience shear strength alterations arising from water table fluctuations as commonly observed in areas of high groundwater levels. The answers are normally obtained by combining the study of the properties of soils and rocks with sound judgment and relevant experience of the geotechnical engineer.

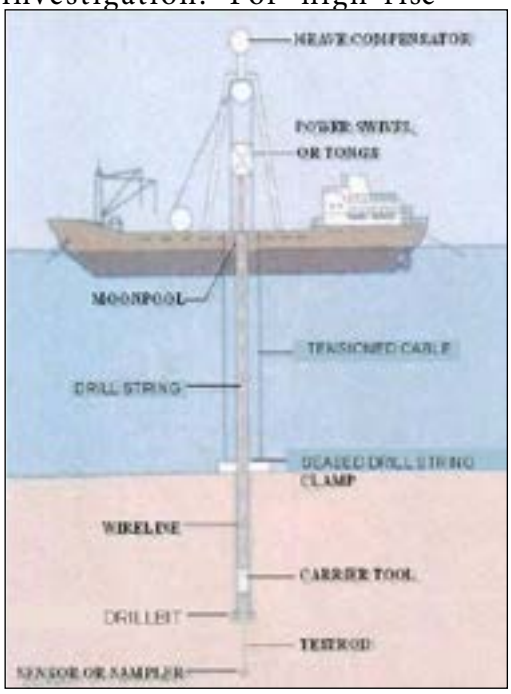


Fig. 5: *A typical drilling system for offshore geotechnical investigation*

Categorically, it could be stated that high-rise buildings require deep probing. The different methods and types of equipment available for this activity, as exemplified by Figs. 5, 6a and 6b, are readily available in geotechnical engineering texts and publications. In poor ground conditions for instance, the soils in the upper horizons of the subsurface are seldom ideal for the loads expected from these buildings. Consequently, the loads have to be transmitted through the unsuitable soils down to great depths where competent strata exist (Refer to Fig. 7).

Figs. 6a and 6b: *A typical set of drilling equipment for onshore geotechnical investigation*

As logically expected, this automatically shifts attention to the expected primary output of the subsurface geotechnical investigation for a high-rise building project, namely, choice of appropriate foundation type.

3.2 FOUNDATION TYPE SELECTION

The choice is a fairly complex task. There is no universally accepted simple formula or rule-of-thumb. Rather, the experience of the geotechnical engineer, enriched by information from the subsurface probe serves as the ultimate guide. In specific terms, the predicted response of the earth materials underlying the site to the expected superstructure-induced stresses serves as a major criterion. The superstructure load is usually of a high magnitude and generally increases with the height of the building. Correspondingly, the induced stresses are of high intensity and propagate to great depths before appreciable reduction is achieved through downward attenuation (both vertically and horizontally). Based on this scenario, it becomes generally evident that soils within the depth range for shallow foundations could hardly possess adequate bearing capacity to support a high-rise building. The

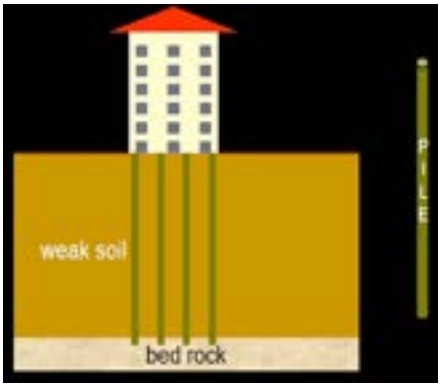


Fig. 7: *A schematic illustration of high-rise building load transfer to competent strata at great depth through weak soil deposit*

implication, therefore, is that deep foundations, as shown in Fig. 7, are the most appropriate for high-rise buildings.

Shallow foundations, though typically more economical, are seldom considered adequate for high-rise buildings. In most cases, the area required to spread the applied building load and achieve allowable contact pressures is excessive and may not be available. Exceptional cases may, however, be encountered where the bearing material is of good quality and extends to great depth below the surface. Here the geotechnical engineer's ingenuity is readily harnessed through an ingenious combination of shallow and deep foundations to ensure stability. The rationale for the choice of deep foundations as most appropriate for high-rise buildings derives from the earlier assertion which indicated that the "stress bulb" below the superstructure together with the associated shear zone penetrates deeply. Correspondingly, a safe foundation is expected to transfer the superstructure load, made up of vertical dead and live loads and horizontal wind loads, beyond the shear zone to greater depths where competent strata are more likely to exist. This explains why most high-rise buildings are on piles, piers (or caissons), deep basement foundations, compensated foundations or raft-on-pile foundations.

3.2.1 Description of Common Foundation Types for High-Rise Buildings

Common nomenclatures frequently adopted by geotechnical engineers for these foundation options include Raft or Mat foundation, Compensated Raft foundation, Pile foundation, and Piled Raft foundation (Poulos, 2016). A brief review of these is given below:

i. Raft or Mat Foundation

A raft or mat foundation is, strictly speaking in Geotechnical Engineering parlance, categorised as a shallow foundation. It has the semblance of a thick concrete slab covering the entire area under the building and tying all column footings together. It is usually adopted in conventional low-rise buildings where site conditions render other less expensive shallow foundation types non-feasible. Typical of such sites, conditions include thick deposit of soft and highly compressible clay, high likelihood of differential settlement associated with pronounced lateral variability of sub-soil, and close cluster of column footings (with gross area greater than half the building base area. A common rule of thumb is that raft should be used if $B \leq (\sqrt{½})S$ or $B2 \leq ½S2$, where B is the footing width, and S is the column spacing).

Its use in high-rise building construction is limited only to cases of moderate heights where the base of the building is founded close to or embedded in very competent layer or rock. It is particularly common in buildings with deep basements. Owing to the relatively large contact area, applied vertical pressure is not usually considered critical. Rather, the effects of lateral and moment loadings constitute the major factor controlling the stability of the foundation. Since the focus here is on foundations for high-rise buildings, it is appropriate to skip detailed discussion of raft foundation at this juncture.

ii. Compensated Raft (or Mat) Foundation

This is the commonest form of utilisation of raft or mat foundation in

high-rise building construction. It is particularly considered convenient and adopted in areas where there is no significant increase in soil strength with depth and there is need to provide additional storeys in the basement (below ground floor). It is also ideal for sites where the soil has a high potential for total and differential settlement, such as sites underlain by soft clay or loose sand. The philosophy here is to achieve stability through the dual factors of "depth of embedment" and "overburden weight balancing". The deep multi-storeyed basement provides adequate resistance against lateral forces and associated moments. The accompanying excavation, on the other hand, eliminates the settlement associated with the soil compressibility. This settlement problem is solved fairly satisfactorily by controlling the excavation process such that the total weight of the poil approximately equals the total "as built" weight of the high-rise building. Hence on completion, the building will be in a state of equilibrium with the surrounding soil – as if there was no excavation in the first place. This is also referred to as buoyancy raft or floating foundation.

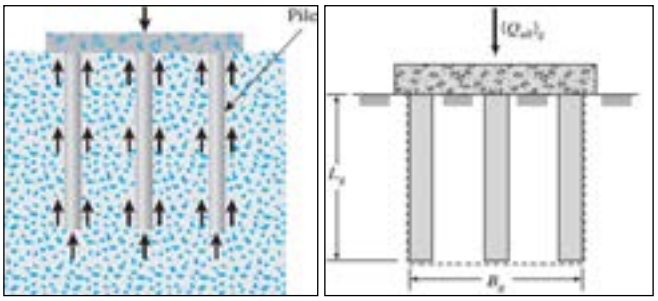
iii. Pile Foundation

Piles are structural members of relatively small cross-sectional areas compared to their lengths and generally have a length to width ratio ranging from about 20 to as high as 100 (L/B ≥ 20). Owing to their slenderness, they are seldom used singly, but rather grouped into clusters (generally in rows and columns) Refer Figs. 8, 9a and 9b. Hence, a pile foundation consists of several piles arranged in a group with their upper ends tied together by a pile cap to form a block in which the group interaction (of the piles) is a critical foundation design factor. The group normally contains enough piles to support the entire load combination delivered by the superstructure.

In addition to the earlier justification for the adoption of deep foundations for high-rise buildings, pile foundation guarantees satisfactory post-construction performance in sites where:

- The soil near the surface does not have sufficient bearing capacity to support the structural loads.
- The estimated settlement of the soil exceeds tolerable limits (i.e., settlement greater than the serviceability limit state).
- Differential settlement due to soil variability or non-uniform structural loads is excessive.
- The structural loads consist of lateral loads, moments, and uplift forces, singly or in combination.

Fig. 8: *A pile foundation construction in progress*



Figs. 9a and 9b: *Schematics of piles with pile cap*

Piles can generally be divided into two categories based on their load transmission mechanism namely: friction piles and end-bearing piles. In the case of friction piles, the superstructure load is resisted by the shear stresses generated along the surface of the pile. In the end-bearing piles, the load carried by the pile is transmitted at its tip to a firm stratum (See Figs. 10 and 11).

A type of foundation closely related to piles is pier foundation (also referred to as caisson or drilled shaft). This is a type of deep foundation constructed by excavating a hole in the subsoil and filling it with concrete. A metal casing may be used while the shaft is being drilled, and may be left in place or withdrawn during the placing of concrete.

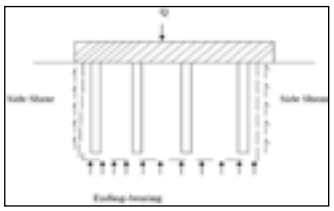


Fig. 10: *Friction piles*

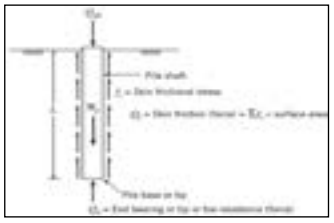


Fig. 11: *An end-bearing pile*

Sometimes piers, in a sense, are similar to bored cast-in-place piles and this makes sharp distinctions between piles and piers difficult. Piers are usually of large cross-sections (generally more than 0.76m in diameter) and are normally free standing and self-supporting unlike piles which are of smaller diameter and constructed

in groups. Piers usually have higher load-carrying capacity than piles and are spaced more widely apart. Each pier is capable of transmitting the entire load from a single column to the supporting stratum.

iv. Piled Raft Foundation

A piled raft foundation is a composite system in which both the piles and the raft share the applied structural loadings. It is adopted in high-rise buildings where thick basement slabs are utilised in conjunction with piles to obtain a foundation that satisfies both bearing capacity and settlement criteria. The usual assumption that the slab does not carry any of the foundation loads when used in combination with piles is not considered valid in this case. Hence, it may be possible to achieve appreciable cost savings for a high-rise building on a conventional pile foundation by significantly reducing the number of piles and considering the contribution of the raft to the overall foundation capacity. In such cases, the piles provide the majority of the foundation stiffness while the raft provides a reserve of load capacity. In situations where a raft foundation alone might be used, but does not satisfy the design requirements (in particular the total and differential settlement requirements), it may be possible to enhance the performance of the raft by the addition of piles. Usually only a limited number, strategically located, is required to improve both the ultimate load capacity and the settlement performance of the raft. This, in addition, allows the design requirements to be met.

Other important advantages of adopting a piled raft foundation include:

- Effective control of differential settlements since the piles can be located strategically beneath the raft.
- Optimisation of the foundation design by using piles of different lengths and/or diameters at different locations.
- Optimisation of the foundation design by using varying raft thicknesses at different locations.
- Benefit of designing piles to carry only a part of their ultimate geotechnical load, thereby constraining the raft to develop an adequate proportion of the required ultimate load capacity.

3.3 FOUNDATION DESIGN AND CONSTRUCTION

3.3.1 Load and Resistance Factor Design Method

Geotechnical engineering expertise, acquired through quality training and experience, is required in the design of foundations for high-rise building as well as the geotechnical principles guiding their construction. It has become common knowledge that deep foundation, particularly pile foundation, is the most appropriate for high-rise buildings.

The design consists of selecting the type of piles and calculating the length, size, and number necessary to safely carry the load within the tolerable settlement limit. In general, the design currently is usually based on the Load and Resistance Factor Design (LRFD) method which considers two limit states – the ultimate or strength limit state and the service limit state – as captured in the expression:

$$\Sigma \gamma_i L_i \leq \Sigma \varphi_j R_j$$

where: γ_i = load factors for the loads, L_i and
φ_j = Resistance factors for the resistances, R_j.

The load and resistance factors enable separate analysis of the uncertainties associated with each of the different load and resistance components. The resistance factors, φ_j are tied to specific design methods for calculating the pile capacity while the term, $\Sigma\gamma_i L_i$ makes it possible to select the most appropriate combinations of loads that the soil can resist.

As explained by Poulos, geotechnical engineering generally addresses the following concerns in the design of foundations for high-rise buildings (2016):

- Ultimate capacity of the foundation under vertical, lateral and moment loading combinations.
- The influence of the cyclic nature of wind, earthquakes and wave loadings (if applicable) on foundation capacity and movements.
- Overall (or total) settlements.
- Differential settlements, both within the high-rise footprint, and between high-rise and low-rise areas.
- Possible effects of externally imposed ground movements on the foundation system, for example, movements arising from excavations for pile caps or adjacent facilities.
- Dynamic response of the structure-foundation system to wind-induced forces (and wave forces if applicable).
- Earthquake effects (where applicable), including the response of the structure-foundation system to earthquake excitation, and the possibility of liquefaction in the soil surrounding and/or supporting the foundation.

- Structural design of the foundation system including the load-sharing among the various components of the system (for example, the piles and the supporting raft) and the distribution of loads within the piles.

Detailed discussions on the above themes are readily available in standard geotechnical engineering books and other related publications. Suffice to state that the limit state design method – specifically the load and resistance factor design (LRFD) approach is considered more appropriate for the design of high-rise buildings.

3.3.2 Summary of the LRFD Design Strategy

Briaud summarises the design steps to include the following (Briaud, 2013) g:

- Determine pile type and geometry.
- Evaluate the ultimate capacity of one pile (and the associated maximum bending moment if subjected to horizontal load).
- Determine the number of piles required to satisfy the ultimate limit state criterion under the given load.
- Check the group effect.
- Repeat above steps (1 – 4) until ultimate limit state criterion is satisfied.
- Evaluate the movement of the pile group under the foundation load.
- Check to ascertain that the serviceability limit state is satisfied.
- If the calculated movement (settlement) is above the tolerable limit, modify the foundation by changing the pile type or geometry (e.g. increase pile depth and/or size), and repeat steps 6 and 7.
- If the movement is acceptable, the design is considered complete as the ultimate limit state and the serviceability limit state would be deemed to have been satisfied.

3.3.3 Allowable Stress Design Method

It is pertinent at this point to note that prior to the evolution of the LRFD approach, geotechnical engineering design of high-rise building foundations had been based on allowable stress design (ASD) method (also referred to as working stress design, WSD).

This consists of applying a reduction factor – the Factor of Safety (FS) – to the ultimate bearing capacity of the soil to yield an acceptable safety margin.
Hence, the conventional allowable load capacity for "Allowable Stress Design" (ASD) is expressed as:

$$Q_a = \frac{Q_{ult}}{FS}$$

where FS is a gross factor of safety usually ranging from 2 to about 3, depending on the confidence level from soil design parameters. In practice, the application of a factor of safety greater than 2 is thought of as sufficient to limit settlement to about 25 mm. Nevertheless, it is advisable to estimate the pile settlement as part of good design practice and use it to control the allowable pile load capacity, if necessary.

The procedure for evaluating the ultimate load capacity, Qult, of a pile is well-documented and easily accessible to practitioners. It is conventionally taken as consisting of two parts. One part is due to friction, Qf , called skin friction (or shaft friction or side shear), and the other is due to end bearing at the base or tip of the pile (or pile toe), Qb. If the skin friction is greater than about 80% of the end bearing load capacity, the pile is deemed a friction pile and, if the reverse, an end bearing pile. If the end bearing is neglected, the pile is called a floating pile.

By definition, the net ultimate load capacity of a single pile is equal to the sum of the ultimate shaft and tip resistances, less the weight of the pile; i.e.:

$Q_{ult} = Q_f + Q_b - Wp$, where:
Q_{ult} = Net ultimate load capacity, Qf = ultimate shaft capacity, Q_b = ultimate tip capacity, and Wp = weight of pile.

3.4 FOUNDATION CONSTRUCTION

This is another area where geotechnical engineering impact is greatly felt in the development of high-rise buildings. As detailed in EUROCODE 7 Part-1 (2010), piles (which have been chosen here as typical for high-rise building foundations) may be installed by driving, jacking, screwing or by boring, with or without grouting. This applies to end-bearing piles, friction piles, tension piles and transversely loaded piles. In these methods of construction, driving and drilling (boring) methods are the two that depend more on the nature and characteristics of the soil and are, therefore, wholly controlled by geotechnical engineering principles. They are the most commonly employed installation methods, particularly, in

sites underlain by soil. Their relative ease of application is a major factor that influences their choice. It is also a function of the soil response to loading. Therefore, depending on the method of installation, piles used in high-rise building foundations may be either "Driven piles" or "Drilled piles".

3.4.1 Soil Behaviour and Pile Installation

The effect of soil engineering behaviour on pile foundation construction is known to be largely controlled by the soil stress history (quantified in terms of the "Over-consolidation Ratio (OCR)") as well as soil-water interaction (expressed in terms of the pore pressure response exhibited by the soil when subjected to shear). When subjected to shear stress, contractive soils i.e (consolidated and lightly over-consolidated clays and loose sands) tend to compress resulting to volume reduction. On the other hand, dilative soils (i.e heavily over-consolidated clays and dense sands) when sheared, tend to expand leading to volume increase.

In considering soil-water interaction associated with pile installation, the focus is usually on these contractive and dilative soil behaviours. Contractive soils, when loaded, are in a state of compression and exhibit positive pore pressure response. Dilative soils, on the other hand, are in tension when sheared and the pore pressure response is correspondingly negative. These pore pressure response models have significant impacts on pile drivability in these soil types. Consequently, they constitute important factors controlling the choice of pile installation method at any site.

3.4.2 Pile Driving versus Boring

Pile driving is a form of dynamic loading and a source of appreciable disturbance on the soils. The soil response to this loading depends on its stress history as explained earlier. For contractive soil, the load application generates excess positive pore pressure. The repeated application of the load subsequently leads to accumulation of this excess positive pore pressure and weakening of the soil around the pile shaft. As a result, the pile penetration is facilitated and achieved with relative ease. After driving, the excess pore pressure dissipates leading to strength-hardening. The result is a relatively stiff and stable pile-soil system.

In the case of dilative soils, the repeated loading generates excess negative pore pressure. This leads to enhancement of soil strength around the pile shaft thereby making pile driving relatively difficult. At the end of the pile driving, the excess negative pore pressure dissipates leading to a reduction in soil strength (strength-softening) around the pile shaft. This is a typical field example of the critical state theory as applicable to the strength behaviour of dilative soils. When sheared, these soils dilate and exhibit a progressive increase in strength until a peak is attained. Beyond this point the strength drops to the critical state strength which remains constant as shear strain increases at constant volume and normal effective stress. This may give rise to an unstable pile foundation if the peak strength is adopted as basis for design.

Boring, as a method of pile installation, leads to minimal soil disturbance. It is therefore a very feasible method suitable for dilative soils. The in-situ state of stress remains essentially unaltered and the predicted post-construction performance is largely achieved.

From the above discussion, it is obvious that the choice of pile installation method could reliably be based on soil stress history, with pile driving considered more suitable to contractive soils while boring is more appropriate for dilative soils. Boring in contractive soils may further be hampered by other site conditions like very soft clay or running lose sand.

Despite these considerations, however, an important factor that appears to have a controlling influence in the choice of pile installation method is "ease of construction". In areas of high groundwater table such as offshore and water-logged environments, bored pile construction is relatively difficult. As a result, pile driving has somehow become the most widely used method.

4.0 CONCLUSION

This write-up represents a general review of the impact of geotechnical engineering practice in high-rise building development. It espouses the significance of geotechnical engineering principles in the design and construction of these buildings which are currently trending as part of the new frontiers in the utilisation of both the underground space and the zone of the atmospheric

space adjoining the earth's surface. The subject is broad and would normally require comprehensive elucidation of related theoretical and practical details. However, the presentation approach adopted here, for obvious reasons, deliberately avoided delving into in-depth analysis and advanced concepts in geotechnical engineering since these are widely available in books and publications on the subject matter.

"The target audience in this paper is the ground engineering professional..."

The target audience in this paper is the ground engineering professional with interest in the application of geotechnical innovations to the subsurface to render it capable of supporting loads of high intensity, particularly from high-rise buildings. The first section in the paper provided a well-articulated answer to the ever-recurring question, "What is Geotechnical Engineering"? The idea is that frequent repetition of the answer will ultimately enable people to fully appreciate this unsung cornerstone in the constructed environment. Thereafter, features of high-rise buildings were examined, highlighting the significant aspects of both the superstructure and the substructure.

The bulk of the presentation focused on those facets of geotechnical engineering practice that have relevance in high-rise building development. These include subsurface probe, choice of appropriate foundation types and geotechnical design of the foundations. The output revealed that high-rise buildings are constantly subjected to combinations of high-intensity vertical and lateral loads with the associated induced moments and uplift forces. The contact stresses applied to the underlying subsoil propagate very deeply into the subsurface before significant attenuation. Based on these facts, "Deep Foundations" are considered more suitable for high-rise buildings. The limit state design method – specifically, the load and resistance factor design (LRFD) approach – is adopted as more appropriate for the design. This method combines applied loads and foundation resistances using appropriate reduction factors. It also involves satisfying both strength and settlement requirements.

Pile installation is considered the most critical activity in deep foundation construction. Boring and pile driving are the commonest methods employed. The one to be favoured for a particular site is determined by the nature of the subsoil as reflected in its engineering behaviour. Based on credible experiences and sound geotechnical engineering analysis, it has been established that pile driving is more suited for contractive soil deposits and offshore environments. On the other hand, bored piles are judged more appropriate for dilative soil deposits. These inferences, however, are intended to serve as a preliminary guide in the planning process for the construction of deep foundations. Detailed site-specific investigation is expected to ultimately confirm the installation method to be adopted.

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INTRODUCTION

Ankabut Engineering Limited is an integrated multi-disciplinary company formed to provide a wide range of services for the construction industry. The firm is a consulting and project management expert capable of handling and providing consultancy services to projects of any magnitude in the fields of:

(i) Construction
(ii) Architecture
(iii) Quantity Surveying
(iv) Civil and Structural Engineering
(v) Mechanical and Electrical Engineering
(vi) Project Management

Our clients cut across both the public and private sectors of the Nigerian economy. We have been involved in a wide variety of building and civil engineering projects in different parts of the country in conjunction with other partners. The firm can boast of highly experienced professionals in the listed fields. We have registered with the relevant professional bodies in the construction industry.

PROFESSIONAL SERVICES OFFERED

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- Institutional and health facility buildings
- Hotels and other tourist service projects
- Airport and transit services
- Commercial and office developments
- Community centres
- Sporting and recreational facilities
- Restoration of colonial and monumental structures
- Ecological studies
- Land use planning
- Streets, parks and external landscape designs

Quantity Surveying

- Advice on the probable cost at the inception of a project, including assistance in the establishment of the design brief.
- Advice on what size and standard of structure can be erected for any given expenditure.
- Design/cost analysis to establish economy in the use of resources.
- Project/cost analysis of the implications of phasing and programming the work.
- Cost planning during the development of design, including periodic updating of cost estimates
- Advice on tendering procedures and contractual arrangements.
- Responsibility for, or assistance in, the preparation of tender documents, including conditions of contract and bills of quantities or other basis for the selection of the contractor and specialist sub-contractors as well as the subsequent financial administration of the contract.
- Examination and reporting of tender prices and advice on selection and appointment of contractor and sub-contractors.
- Pricing and negotiating a contract with single tender (if required).
- Measuring of work including adjustment of variations, valuing for interim certificates and preparation as well as agreement of final account
- Total cost coordination, including forward estimating analysis of proposed changes, assessment of admissible cost fluctuations, cash flow projections and interim financial statements to assist client's financial control.

Civil and Structural Engineering

- Construction
- Feasibility studies
- Pre-investment surveys and reports
- Detailed designs, drawings and specification
- Appraisal of existing infrastructures
- Prescription of remedial measures.
- Supervision of construction.

Engr. Bukar Kam-Selem
(CEO, Ankabut Engineering Ltd)

Mechanical and Electrical Engineering

- Feasibility studies for new projects and upgrades.
- Preliminary design and cost estimation.
- Power systems analysis.
- Detail design and drafting.
- Preparation of equipment specifications and vendor review.
- Construction documents and specifications.
- Construction and commissioning support.

Project Management

Coordinating all consultants and contractors' services at both pre-contract and post-contract stages. This involves:

• Pre contract stage: Taking brief from the client and assisting the client to appoint other consultants; preparing programme of works for precontract documentation; arranging all necessary soil test sand reports; checking and vetting of all contract documents and cost plans at various stages including getting approvals from client and relevant authorities; arranging pre-qualification of contractors and sub-contractors and necessary interviews; preparing cash flow projections; assisting the client in securing bank loans for property development; vetting of tender reports; arranging and coordinating the execution of contracts.

• Post-contract stage: Handing over of sites to contractors and checking and vetting same; checking and vetting interim valuations and payment certificates; checking of quality of work for compliance with specification; vetting variation orders for the contractor and subcontractors for overall project cost-control; checking all measurements and re-measurements for final account purposes; checking of consultant fees; taking over project on completion.

TABLE OF PROJECTS

The table shows a summary of few of the projects amongst the total undertaken by Ankabut Engineering Limited

S	PROJECT	YEAR	CLIENT	INPUT	AMOUNT	STATUS
1	Construction of Three Hundred (300) Capacity lecture hall	2011	Umar Ibn Ibrahim El-Kanemi College of Education, Science and Technology, Barma	Design and Supervision		Commissioned
2	The Completion of Maiduguri Central Mosque Complex	2011	Maiduguri Central Mosque Implementation Committee	Structural Engineer/ Resident Consultant	**N1.9M**	Commissioned
3	Construction Projects in North East	2016	Skye Bank	Project Management		Commissioned
4	Procurement of equipment/ fittings for furnishing lecture theatre	2017	Federal College of Freshwater Fisheries Technology, Baga	Supplier	**N42.5M**	Commissioned
5	Procurement of Equipment for Federal Veterinary Medical Centre, Borno State	2017	Federal Ministry of Agriculture and Rural Development	Supplier	**N18.9M**	Commissioned
6	Construction Projects in North East	2018	Skye Bank Plc	Project Management		Commissioned
7	Establishment of Centre Pivot Sprinkler Irrigation Scheme in Tudun Wada LGA, Kano State	2018	Hadejia-Jama'are River Basin Development Authority	Consultancy supervision	**N9.9M**	Commissioned
8	Construction of Health Information Complex	2018	FMC, Nguru	Consultancy services	**N10.4M**	Commissioned
9	Supply of 615 Nos Sewing Machines with Motor and stand to Irepodun/Olorunda/Orolu/ Oshogbo Federal Constituency, Osun State	2018	The President, SDGs	Supplier	**N50M**	Supplied
10	Construction of Security Post for Special Boat Services Training Centre Ojo Lagos State	2019	Nigerian Navy Project Execution		**N39.2M**	
11	The Supply of 150 KVA Generator to NEDC Headquarters	2019	orth-East Development Commission	Supplier	**N19M**	Supplied
12	The Supply of 250 KVA Plants to NEDC Headquarters	2019	North-East Development Commission	Supplier	**N45.2M**	Supplied

PROJECTS IN PICTURES

Some of the project pictures are shown as follows

Formwork for Pile Cap

Surveying team at the field

Pile cap and starter bars for pier

Casting of base for retaining wall

Re-bar arrangement for pile cap

Re-bar arrangement for pile cap

Formwork/re-bar arrangement

Cast r.c pile cap (5.5m x 8m x 2m)

Surveying team at work

Pile cap ready for concreting

Site inspection after technical meeting

Ready to receive concrete

Preparation for pile load test

Weekly site meeting in progress ***Inset:*** *The M.D., Engr. Bukar.*

Casting of counterfort wall

CORPORATE CITIZEN PROFILE

Ankabut Engineering Limited was incorporated under the Companies and Allied Matters Act 1990 with the Corporate Affairs Commission with the registration number RC 839484. The firm operates as a good corporate citizen. This respectable status stems from the firm's statutory registration with relevant government bodies such as:

- Federal Inland Revenue Service (Reg No. TIN 09040856-0001)
- National Pension Commission (Reg. No. 0079690)
- Industrial Training Fund (Cert. No. 00247202)
- Nigeria Social Insurance Trust Fund (Employer's Reg. No. 1004582916)
- Bureau of Public Procurement (Ref. No. 0000-0002-09620)
- Council for the Regulation of Engineering in Nigeria (Reg. No. EF. 1480)
- Department of Petroleum Resources (Permit No. DPR/OGISP/204924724/N187048)
- Association for Consulting Engineering in Nigeria (Reg. No. F546)

With these key registrations, among others, the firm is rightly positioned to operate as an ongoing concern without hinderances.

MANAGEMENT TEAM

Ankabut Engineering Limited has a team of professionals. Those who are engineers are duly registered with the Council for the Regulation of Engineering in Nigeria (COREN). The management team comprises:

1. **Engr. (Alh.) Bukar Kam-selem,** *B. Eng, MNSE*
   (CEO, Ankabut Engineering Ltd)

2. **Engr. Abba-Gana Mohammed,** *BSc., MSc., PhD, MNSE*
   - Senior Member International Union of Laboratories and Experts in Construction Materials, Systems and Structures, RILEM, France
   - Member, Working Group Committee for New Partnership for Africa's Development (NEPAD) Borno State Coordination office, from 03/09 to date.

3. **Arc. Bulama Modu,** *BSc., MSc.*
4. **Mr. Zanna Sumayin,** *HND (Quantity Surveying), AMNIQS*
5. **Mr. Jadu Mdirmbita Nubwa,** *BSc (Quantity Surveying)*
6. **Ms Bintu M Bulama,** *BSc, GMSE, GMAPWEN*
7. **Engr. Musa Bello Bashir,** *B. Eng, MSc, MNSE*
8. **Engr. Kunduli Mustapha,** *B.Eng, MNSE*
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GEOTECHNICAL ENGINEERING IN SOIL EROSION AND LANDSLIDES CONTROL

BY ENGR. DR. EDWARD N. MOORE

Engr. Dr. E.N. Moore, FNSE
(CEO, E.N. Moore Associates)

1.0 INTRODUCTION

Geotechnical engineering is the application of scientific methods and engineering principles to the acquisition, interpretation of the earth's physical properties such as rock, sand and soil, to be used in engineering activities such as building and construction. Geotechnics is used to predict and prevent natural hazards such as erosion, landslides and sinkholes. Furthermore, geotechnical engineering is a branch of civil engineering with the valuable role of monitoring the behavior of subsurface conditions and earthwork to enable activities such as mining, construction and drilling to be carried out. The discipline can be further classified as a subdivision of structural engineering. Some of the key subjects studied in geotechnical engineering include those listed in Table 1 below.

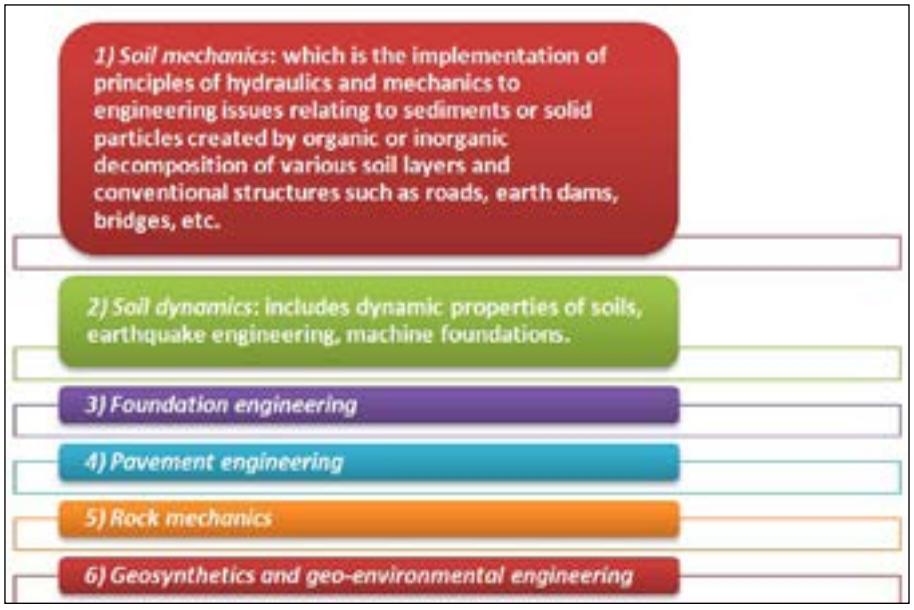

Table 1: *Key subjects in geotechnical engineering*

Geotechnical engineering is a very essential field of study due to the fact that there are few engineering projects which do not involve working on soil either as foundation or other construction material or structures. This will further aid in load distribution of superstructures to soil and prevent any possible risk.

2.0 ROLES OF GEOTECHNICAL ENGINEERS

Geotechnical engineers are meant to perform the following roles:

I. Perform geotechnical analysis and study to assess construction site condition (See Fig. 1).

Fig. 1: *A geotechnical engineer performing soil analysis*

II. Plan and conduct geotechnical exploration effectively.
III. Perform field and environmental investigations for construction projects.
IV. Analyze geotechnical findings, perform appropriate calculations and prepare data reports to serve as management information.
V. Develop proposals and determine cost and schedule for investigations.
VI. Provide direction to technical team in field inspection activities.
VII. Interact with customers and team members to complete the assigned project on-time.
VIII. Evaluate team performance and determine training needs to meet performance objectives.
IX. Perform basic office administration tasks when needed.
X. Assist the Management in design and evaluation of constructions.

XI. Develop design drawings and specifications for construction projects.
XII. Review and approve geotechnical designs developed by outside consultants.
XIII. Review construction design proposals and approve geotechnical aspects.

3.0 SOIL EROSION AND ROLES OF GEOTECHNICAL ENGINEERS

One of the major threats to land use pattern of most environments is soil erosion (See Fig. 2).

It is a natural process which affects all the landforms. In general, soil

Fig. 2: *Road pavement erosion*

erosion refers to the wearing of the soil especially topsoil due to various weathering agents such as water, wind, and tillage or human activity. Soil detachment, movement and deposition are the key components of soil erosion. In soil analysis, exclusive investigation is carried out by the geotechnical engineer to assess the geotechnical properties of soil in an area prone to soil erosion. Soil samples from a study area will be subjected to various physical tests with a view to identifying the parameters which influence soil erodibility so that suitable soil stabilization could be ascertained.

Erosion can be further analyzed in relation to the interaction of three components, namely the soil or rock, the water, and the geometry of the water interacting obstacle. The erodibility of soils varies significantly from one soil to the other. Thus, erodibility depends on the soil properties.

Rock mass erosion includes two sub mechanisms: erosion due to slacking, and erosion due to block removal between joints. Bridge scour refers to the erosion of the soil surrounding the foundation of bridge piers in rivers. The meander method also allows the user to develop a map indicating the probability that the river will move a certain distance or more. Levees or dikes are small dams built along a river or an ocean to prevent the water from inundating the land in case of flood. One solution for many internal erosion problems is the use of quality filters.

4.0 ROLE(S) OF GEOTECHNICAL ENGINEERING IN LANDSLIDES CONTROL

Landslides have a high probability of occurring in hilly or plateau zones/regions (See Fig. 3).

Stability of slopes is a major concern to many individuals who reside in these regions during rainy seasons. From a geotechnical perspective, landslides are classified into:

Fig. 3: *Engineers on a landslide site*

- Surficial landslides triggered by intense rainstorm and soil saturation.
- Deep-seated landslides also triggered by intense rainstorm and soil saturation.
- Earthquake-induced landslides triggered by earthquakes and heavy vibrations or seismic activity.

In Nigeria, surficial and deep-seated landslides are the most likely to occur due to prolonged seasonal rainfall which may create floods. These landslides are formed when storm water saturates and generates seepage force which softens and drags down topsoil. Similarly, accumulated rainfall water soaked into the ground over a long period may cause deep-seated landslides which may be hundreds of feet deep.

Geotechnical engineers are crucial in exercising their professional roles by protecting properties and future projects from potential landslide risks. The engineers analyze slope stability for all types of landslides to prepare for probable occurrences. The results derived from the analysis are used as a basis of recommendations to enable other stakeholders of a project mitigate possible landslide hazards. Slope stabilization methods may include:

I. Installing sufficient sub drain and retaining systems

A sub drain system is an underground network of pipes used to remove water from areas that collect or retain surface water

or groundwater (See Fig. 4). The network can be rather small in the sense that it could be utilized to drain a limited area, or fairly large to drain a sizeable number of acres. Surface water derived from rainfall can be collected into the sub drain system by installing a surface inlet or catch basin. Groundwater is collected by allowing water into the pipe through perforations. Both surface water and groundwater can be discharged to an appropriate outlet such as a nearby storm sewer, pond, or river.

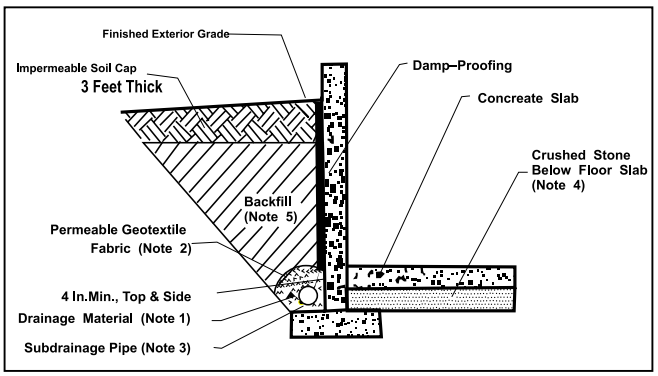

Fig. 4: *A sub drain structure*

II. Slope anchorage (Ground anchor system)

Slope anchorage can also be used as reinforcement measures for pre-existing structures which are susceptible to damage by surface or ground water. Systems such as ground anchors and floating anchors can be used as a method of slope anchorage. Ground anchors also known as tiebacks consist of cables or rods connected to a bearing plate. They are often used for the stabilization of steep slopes or slopes consisting of softer soils, as well as the enhancement of embankment or foundation soil capacity, or to prevent excessive erosion and landslides (See Fig. 5).

Composite ground anchors generically consist of three parts:

a. An anchorage: This is generally a stainless steel sheath with an anchor nut/plate through which the composite cable is run. The anchorage is usually filled with a non-shrink expansive cement mortar that ensures fixity and no slippage. The anchorage is also used to fasten the system to the outside structure.
b. A cable: This consists of multiple rods that are separate or braided together, or a single rod.

Fig. 5: *A ground anchor installation site*

c. A sheath or sleeve: This is made of polyethylene or Polyvinyl chloride that is fitted around the free anchor length of the cables. A composite ground anchor structure id shown in Fig. 6.

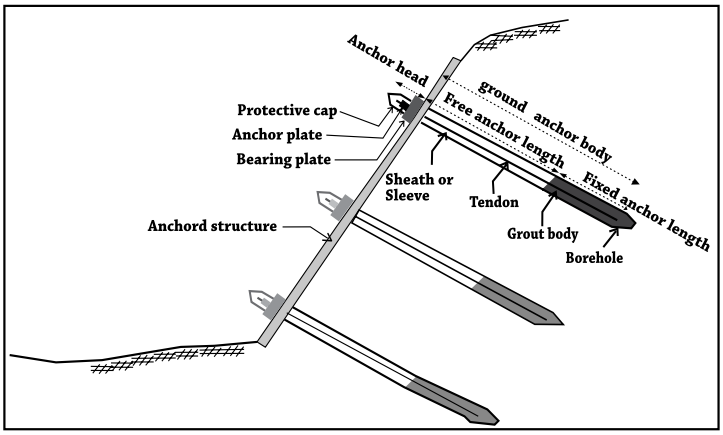

Fig. 6: *A ground anchor structure*

III. Installing soldier piles

Soldier piles or shear pins consist of vertical shafts drilled through the unstable zone, and heavily reinforced with steel and high-strength concrete (See Figs. 7, 8 & 9). Shear pins can be used to stabilize shallow zones of instability, or in conjunction with tieback anchors for larger masses of unstable soil.

Fig. 7: *Soldier piles installation site*

IV. Reducing steepness and height of slopes

Removal of soil from the head of the slide is a method which reduces the steepness and driving force. This improves the stability. Also, reducing the height of a cut bank reduces the driving force on the predicted damaged surface by reducing the weight of the soil mass and commonly involves the creation of an access road above the main road and forming a lower slope by excavation.

V. Construction of buttress fills

A buttress is a man-made mound or hill of soil (fill slope or berm) placed at the toe of the slope. The buttress increases the resisting forces and prevents material from moving towards the toe of the slope. In some cases, it may also be a metal or concrete beam providing additional support to a retaining wall constructed at the toe of a slope.

However, materials such as rocks are greatly considered due to their greater frictional resistance to shear forces and are free draining, which reduces the problem of impeding ground-water flow. Buttress fill is also used in filling cuts after retaining walls have been elevated (See Fig. 10).

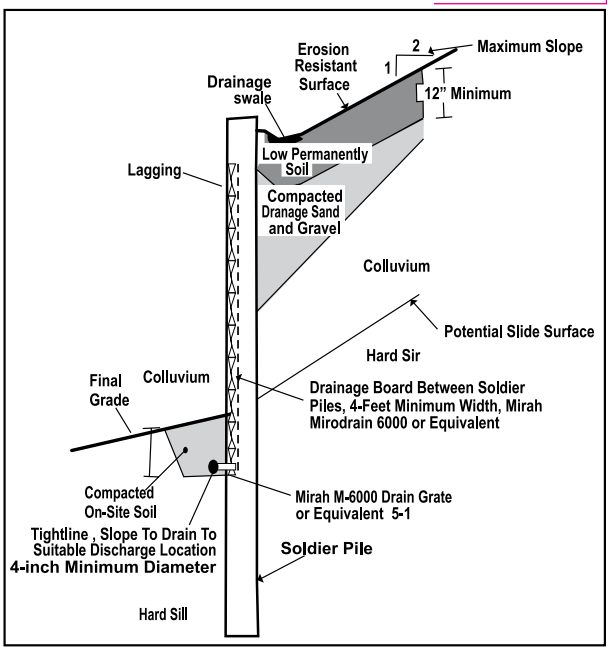

Fig. 8: *Soldier piles without ground anchor structure*

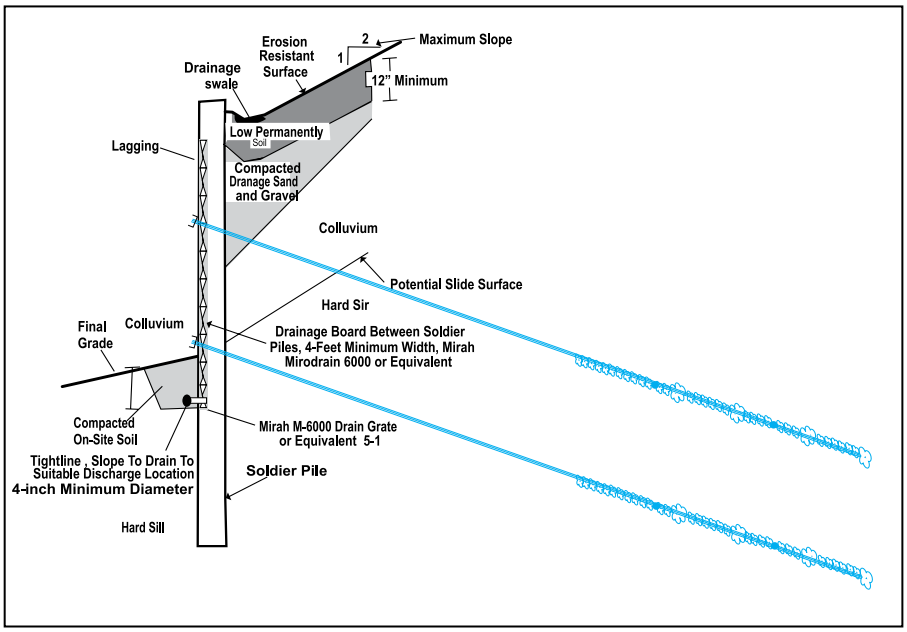

Fig. 9: *Soldier piles with ground anchor structure*

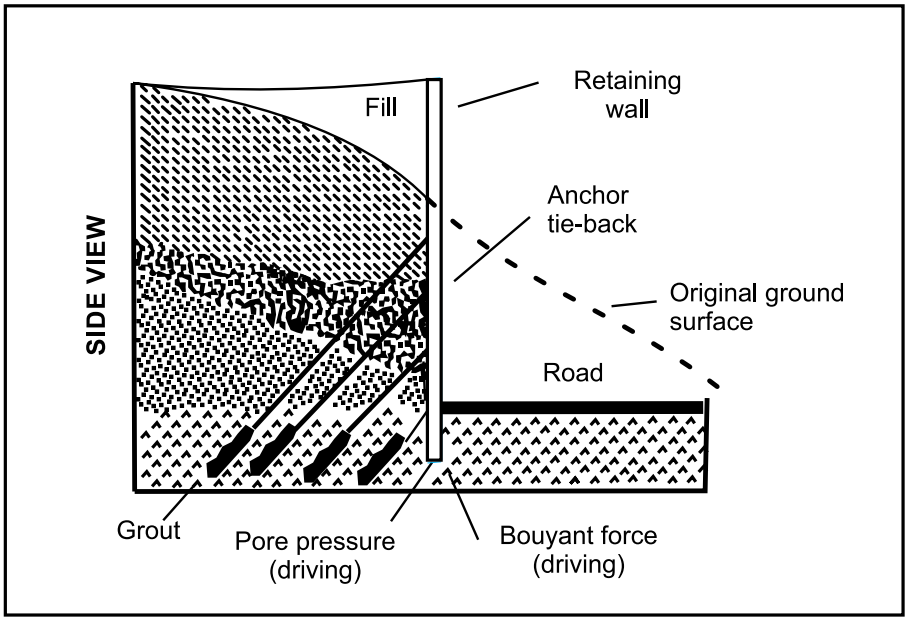

Fig. 10: *A filled surface after retaining wall installation*

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ROCK ENGINEERING AS A TOOL IN GEOTECHNICAL SERVICES

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ABSTRACT

People have been building structures on/in rocks for centuries and the principle of rock mechanics has been understood ever since but was not treated as a discipline. At a certain time, rock was considered as an elastic material only, until further studies showed that rock can also be considered as a discontinuous mass. Then, the need arose to treat rock as an elastic and discontinuous material. This important discovery and merging the two properties of rock marked an important era in the field of rock engineering. Rock Engineering is built on a solid foundation of engineering mechanics and geology. The goals of rock engineering are mainly to ensure structural resistance, durability and serviceability.

1.0 EARLY HISTORY OF ROCK ENGINEERING

As far back as 1773, Coulomb included results of tests on rocks from Bordeaux in a paper presented to the French Academy (Heyman, 1972). The construction of Panama Canal which was started by French engineers in 1884 and completed by the US corps in 1908 was achieved through construction in rocks and modern day soil mechanics show that the majority of slides that occurred during the construction could have been controlled with the knowledge of rock engineering (Lutton et al, 1979). In the words of Terzaghi, 1936, "the catastrophic descent of the slopes of the deepest cut of the Panama Canal issued a warning that we were overstepping the limits of our ability to predict the consequences of our actions".

Rocks will always be encountered during construction works and a deep knowledge of its properties and behaviour is relevant towards its safe and successful usage. Notable contributors in the early days to the development of rock mechanics included Josef Stini (1920), Von Karman (1911), King (1912), Griggs (1936), Ide (1936) and Terzaghi (1945). The theory of brittle material failure was proposed by Griffith in 1921 and Bucky began using a centrifuge to study the failure of mine models under simulated conditions. Josef Stini taught Technical Geology at the Vienna Technical University from 1920 to 1958, publishing 333 papers and books and he is widely acknowledged as the first person to emphasize the importance of structural discontinuities on engineering behaviour of rock masses. Following the catastrophic earth failures such as failure of Malpaset concrete dam in France (1959) in which an estimated 450 people lost their lives to flood and the failure of the Vajont dam in Longarone (1959) which resulted in the death of 2,500 people caused by a landslide generated wave that led to over topping of the dam, it became expedient for engineers to probe deeper into the work done on rockbase constructions by numerous scholars and scientists in the past. These episodes led to the growth in the field of rock engineering (Jaeger and Cook, 1972). The incident at the Coalbrook coal mine in South Africa (1960) which led to 432 deaths gave rise to initiation of an intensive research program that resulted in major advancements in methods used for designing coal pillars.

2.0 ENGINEERING PROPERTIES OF ROCK

The bearing capacity of rock is in the range of 20KN/m^2 to over 2,000KN/m^2 for hard rocks. It is the understanding of the bearing capacity of rocks that led to the eventual successful construction of the Panama Canal which was opened in 1914 (See Fig. 1). Some very important engineering properties of rocks include aggregate crushing value (ACV), Los Angeles abrasion and water adsorption. Garg, (2005) defined soil as uncemented or weakly cemented accumulation of mineral particles which are formed by the weathering process of rocks. The

"Rocks will always be encountered during construction works..."

Fig. 1: *Construction of Panama Canal. Picture (Source: Google image)*

study of the engineering behaviour of different types of soils is therefore, relevant to rock engineering because most engineering structures are founded on a foundation of soil. The strength of the soil to withstand load under different loading conditions is an important factor in designing a safe foundation for the structure (Garg, 2005). The science which deals with the engineering properties and behaviour of the soil is known as "Soil Engineering" or "Soil Mechanics" or "Geotech Engineering" (Garg, 2005).

3.0 EMPIRICAL AND NUMERICAL MODELLING

Analytical models play key roles in rock engineering and the development of computer technology. This has brought about the use of iterative numerical techniques such as finite elements, boundary element and discrete element. Fig. 2 shows the flow chart of numerical modeling of rocks. The combinations of these methods have become universal tools in rock mechanics. Limit equilibrium methods and probabilistic approaches are also used for analysis in rock mechanics. Large numbers of sensitive and probabilistic studies can now be performed in a fraction of seconds with the advent of microcomputers.

The complex nature of rock and its different formations, being a discontinuous, anisotropic, heterogeneous and non-elastic material, makes rock modelling a difficult task. However, using empirical and numerical methods, it is achievable. During the initial stages of excavation projects, detailed data about the strength properties, deformation modulus, insitu stresses and hydrological properties are not readily available. Thus, empirical methods such as rock mass classification systems are used for analysis. However, the empirical

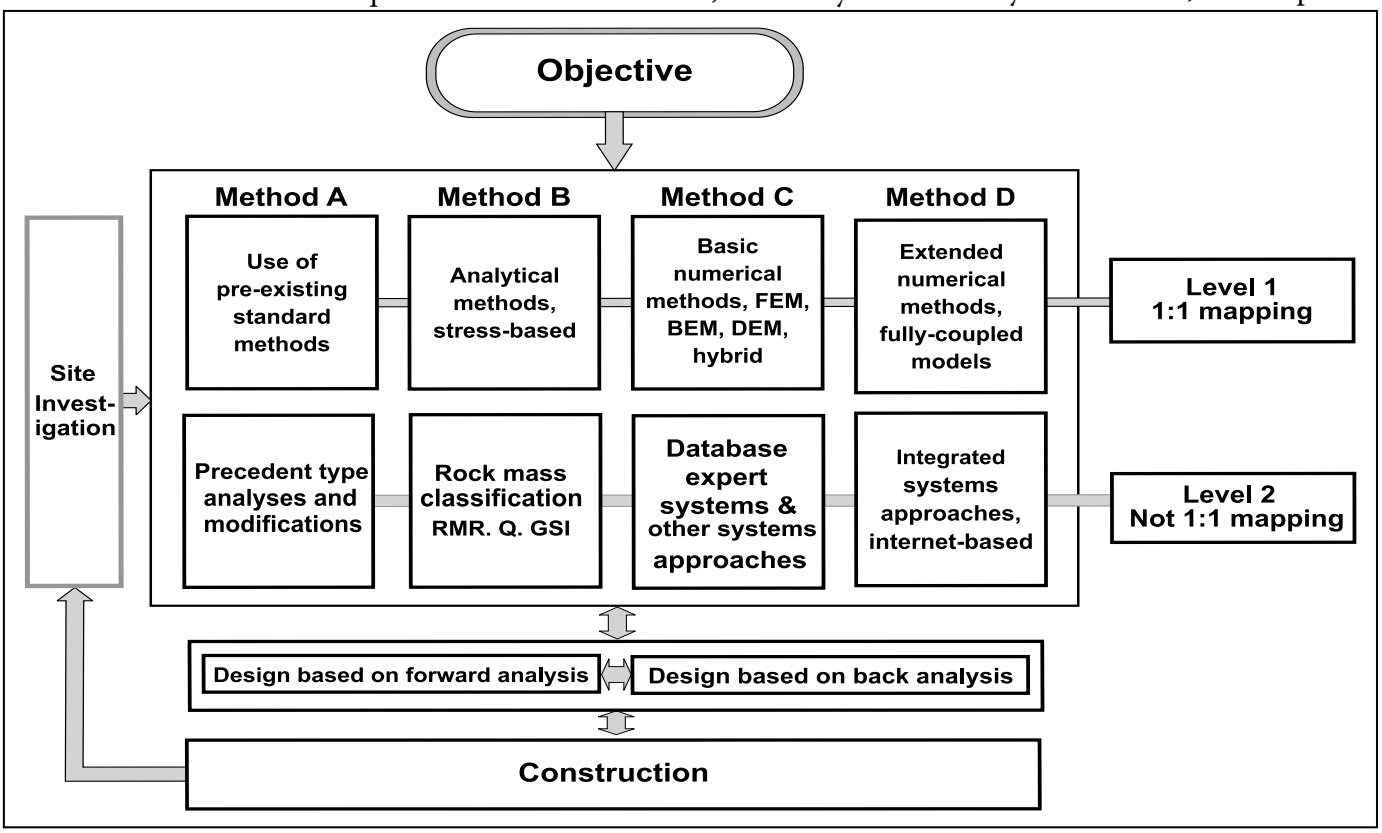

Fig. 2: *A flow chart of numerical modeling of rock (Source of Diagram: Google image)*

system does not evaluate the performance of support systems, stress redistribution and deformations. The deficiency in the empirical method is solved by applying numerical methods. The numerical method gives the exact mathematical solutions for the problem based on engineering judgement and input parameters like physical strength and parameter of rock mass (Zahid et al, 2018)

4.0 ROCK REINFORCEMENT AND SUPPORT

Rock re-inforcement and support are meant to ensure safety in construction. Urbanization coupled with the need to replace old service lines will lead to more work on infrastructure and underground excavation facilities such as water pipes and sewers, railroads, highways, mass transit and communications. Application of geotechnics as a tool in rock engineering is relevant in ensuring durability and serviceability of the facilities. Practical developments in the field of rock engineering over the last 3 decades have enhanced promotion of safety during construction and post construction periods. Rock reinforcement used to improve strength and deformational behaviour on site is now utilised extensively as a result of geotechnical knowledge. Reinforcement of rock is achieved by introducing bolts and cables into the rock mass such that they provide confinement or restraint to counteract loosening and movement of rock blocks. Fig. 3 shows rock re-inforcement and support. Rock reinforcement is, however, applicable mainly when dealing with frictional rock masses of moderate to high strength. For weak masses of rock, reinforcement is not effective hence the use of support rather than reinforcement. The support consists of steel sets and concrete linings in different combinations acting as load bearing structural shell (Lutton et al, 1979). Its primary function however, is to limit deformation of the rock or soil mass surrounding a tunnel.

Fig. 3: *A rock reinforcement and support (Source: Google Image)*

Design of rock reinforcement or support has advanced greatly with the development of computers/software which allow the designer to study a "wide range of excavation geometries, excavation sequences, rock mass properties and reinforcement or support options by means of numerical models" (Lutton et al, 1979). The American Underground Space Association in 1993 revealed that by the year 2,000, an estimated 200 miles of tunnels, 5 feet and larger in diameter would have been built in the United States of America in addition to about 1,000 to 3,000 miles of micro tunnels expected to be built within the same period (Kramer et al, 1992).

5.0 CONCLUSION

Man has always applied some form of technical principles to carry out construction in rock since time immemorial. Catastrophic failures recorded in the past and the uncertainty of predicting the safety of construction on/in rocks gave rise to the development of rock engineering. This discipline has led to the development of analytical equations aptly supported by empirical factors to safely predict the performance/safety of construction in rocks. Giant strides have been made in this field in the past four decades and more discoveries are still being made on how to use geotechnical knowledge to tap the vast potential offered by rock as an engineering material.

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COMMERCIAL MANAGEMENT OF GEOTECHNICAL ENGINEERING SERVICES IN NIGERIA

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1.0 INTRODUCTION

The Accreditation Board for Engineering and Technology defined engineering as the profession that applies the mathematical and natural sciences gained by study, experience and practice in order to develop ways to utilize economically the materials and forces of nature for the benefit of mankind (ABET, 2007). Civil engineering is a broad field of engineering that deals with the planning, construction and maintenance of fixed structures or public works as they relate to earth, water or civilization and related processes. It includes many branches that have passed through empirical, scientific and maturity stages (Murthy, 2002).

Geotechnical engineering specifically is the branch of civil engineering that is concerned with the analysis, design and construction of foundations, slopes, retaining structures, embankments, tunnels, levees, landfills and other systems that are made of or are supported by soil or rock (EJGE, 2012). Indeed, the stage of scientific reasoning in the design of foundations started with the publication of the book, 'Erdbaumechanik' (Soil Mechanics) by Karl Terzaghi in 1925 which is the first attempt to consider soil mechanics from the physical properties of soil. The contribution of Terzaghi and many other researchers who took after him in the field of soil mechanics and foundation engineering is vast with remarkable accomplishments. The work of these fore-runners, among whom included Ralph B. Peck, Arthur Casagrande, A.W Skewpton, Bowels, etc. has improved the ability of geotechnical engineers to interpret the principles of soil mechanics as well as the properties of soil to suit field conditions for foundation engineering practice.

In a general outlook, geotechnical engineering has a wide and significant portfolio because it is concerned with the stability of foundations for all classes/types of engineering infrastructures, including mechanical, electrical, agricultural and others. In consultancy, the essence of economy in engineering must be seen to manifest appropriately.

2.0 GEOTECHNICAL ENGINEERING IN COMMERCIAL PERSPECTIVE

The commercial management of geotechnical engineering services explains the relationship between geotechnical engineering services and the management of contractual and commercial issues relating to project(s) from inception to completion. This has been espoused under 3 main headings comprising external milieu, corporate milieu and project milieu (David Lowel, 2006).

2.1 THE EXTERNAL MILIEU

The external milieu is the interface between the organization and the environment within which a business operates. The external environment consists of the government (federal, state and local) and their agencies, clients, professionals and the general public. All commercial organizations are exposed to and dependent on an external environment within which they operate and the most obvious issue is the influence of legal and regulatory frameworks.

2.2 THE CORPORATE MILIEU

The corporate milieu is the relationship between the organization at a corporate level and the environment within which individual projects collectively reside and remain active.

2.3 THE PROJECT MILIEU

The project milieu relates to the environment within which individual projects collectively reside and the interface between the corporate level milieu of an organization and the specific environment of individual projects. The project milieu is the last category which deals with the interfaces on the single or specific project. In standard practice, the influence of government extensively includes laws and regulatory mechanisms while in the business environment, the client (private or public) dictates the procurement system and generally imposes the contract conditions. Generally, most

civil engineering firms do not have the monopolies of operations. They depend on other civil engineering outfits or specialists in project execution and delivery based on the project complexity, execution strategies, funding magnitude and portfolio. The overall acceptable desires of people and the environment must be taken into consideration in project execution.

3.0 CHALLENGES OF GEOTECHNICAL PRACTICE IN RELATION TO COMMERCIAL MANAGEMENT

Developing countries, with Nigeria as a case in point, face particular challenges including lack of both technological and technical resources such as field and laboratory testing facilities, inadequate funds allocation to site investigations and dependence on foreign design codes in place of Nigerian codes. In addition, the challenges can be traced to the few certified geotechnical engineering personnel, inadequate capacity for developing procurement processes, corruption ridden operations and the free and unchallenged operations by quacks. The financial and economic estimation and payment hindrances which discourage the interest of competent personnel to the practice are other challenges. The process of hiring a geotechnical engineering outfit as part of the procurement process is an issue in commercial management of geotechnical engineering service. Usually, procurement process covers a vast array of activities ranging from the financial appraisal of the various options available, the technical capabilities and other administrative aspects of contracts (Lowe, 2006).

In Nigeria, the new Engineering Consultancy and Project Management Services Agreement, Charges and Conditions of Engagement (ECOPACCE, 2014) gives the general remunerations for engineering personnel. This does not consider the specific area of specialization, as well as some insight on how to estimate the man-hours required for the duration of the contract. All these ought to be taken into consideration and the contract sum made known to the client at the project planning stage. The case of geotechnical engineering is even more peculiar because the practice demands mobilization of some heavy and specialized equipment for the field works aspect. In Nigeria, construction equipment is not produced locally. Thus, the construction related industry has to rely on foreign markets to procure the necessary equipment for operations. The huge cost of investment on equipment, time lag between order and delivery of equipment, technical viability of equipment (ability to fit into existing stock), maintenance of heavy sophisticated equipment in a technology dependent economy, capital for investment in equipment, tendency towards the production of specialized equipment as against the need for more general purpose equipment are part of the challenges. Predicted payback period in the absence of a forecastable construction market, cost of owning and operating the equipment in a depressed economy, formulation of a reliable plant-use plan and absence of a cost-effective plant-hire market all contribute to the critical problems facing commercial management of geotechnical engineering in Nigeria.

4.0 SOME SOLUTIONS TO COMMERCIAL MANAGEMENT OF GEOTECHNICAL ENGINEERING SERVICES IN NIGERIA

4.1 DEVELOPING CODES OF PRACTICE TO MATURITY AND USAGE

Some foreign codes used in Nigeria for geotechnical engineering practice are: BS 1377 Part 1 – 9: Soils for Civil Engineering Purposes, CP 2012-1, 1974: Code of Practice for Foundations for Machinery, Part 1: Foundations for Reciprocating Machines, Eurocode 7 Part 1 – 3 DD ENV 1997-1:1995, BS 410-1: Test Sieves – Technical Requirements and Testing, Part 1: Test Sieves of Metal Wire Cloth, BS 593: Specification for Laboratory Thermometers and BS 5930: Code of Practice for Ground Investigations. All these codes should be raised to maturity usage in Nigeria and institutionalized to reflect the situations and conditions in Nigeria.

The Nigerian Code of Practice for Site Investigations (NC 1401: 2011), currently under formulation by the Nigerian Society of Engineers Special Committee on Engineering Codes Development, partially and only deals with the investigation of sites for the purposes of assessing their suitability for the construction of civil engineering and building works. Like many other developing countries, Nigeria should evaluate its options for the development of a local geotechnical design standard. This should lead to critical examination of the purpose of such codes, available resources, the quality and sufficiency of data and the design options available using the Nigerian soils as case study. Codes are not and should not be static documents. Thus, there should

be regular reviews and updates of codes of practice. Code developments should be undertaken by a group of experts who should ideally represent all sectors of the industry including academia/researchers, designers, contractors, suppliers, manufacturers and regulators. The regulatory bodies should, however, establish the regulations for the profession. Adherence to such regulations would provide protection and give room for litigations. This would facilitate smooth and effective practice as well as check quackery and engineering failure.

4.2 ROLES OF PROFESSIONAL BODIES

The Association for Consulting Engineering in Nigeria (ACEN), as the leader in the business and economic aspect of engineering practice, in collaboration with the Council for the Regulation of Engineering in Nigeria (COREN) and other engineering bodies/professionals should develop a guide on procurement and remunerations covering commercial management of geotechnical engineering. The issue of financial compensation for the compulsory use of some heavy equipment for the initial field works needs special attention. There should be promotion of awareness and sensitization on the need to check quackery in geotechnical engineering practice because there are many who are carrying out site soil tests and masquerading in the geotechnical engineering field in Nigeria. It should be noted that geotechnical engineering is a specialized program of studies appropriate at post graduate level.

The professional training and development need for geotechnical engineering would be better through the Nigerian Geotechnical Association (NGA) which is a member of the International Society of Soil Mechanics & Geotechnical Engineering (ISSM&GE). The training should be designed for two levels: Level one (Preliminary and General Purpose) and Level two (Specialized Practice). The training in the first stage should meet general purpose needs while the next one should be for specialized needs. Prospective geotechnical engineers should be strongly encouraged to participate in all the stages of the training for retention in professional practice. The Level two should address the needs of other sub-disciplines in civil engineering and geotechnical engineering as desired for the geotechnical technicalities.

Some of the recognized specialty classes of geotechnics in Level two that would meet these needs include:

- Geotechnics of Pavement particularly those in highways and transportation works
- Geotechnics of Structures for structural systems including towers and other buildings
- Geotechnics of Off-shore and Onshore engineering structures for oil and gas as well as marine engineering works
- Geo-environmental engineering which covers water resources and environmental systems engineering

It should be noted that ISSM&GE has technical committees that specifically address the desires of each class.

4.3 ROLES OF GOVERNMENT AND RELATED GOVERNMENT AGENCIES

The Nigerian government policy should encourage the development of certification programs involving all aspects of the construction industry, coupled with the training and capacity building of human resources at all levels including management. The Nigerian Content Act should be properly implemented. The reforms in the financial sector should be utilized to favour a more competitive environment. This needs to be supplemented by changes in management practices and corporate governance among the construction industry players. The exemption of Value Added Tax (VAT) for small and medium enterprises (SMES) should include geotechnical engineering and construction-based firms as applicable to the firms in the pharmaceuticals and health sector. ACEN, NGA, NSE, COREN should work in synergy to ensure effective professional practice of geotechnical engineering including the commercial management aspects.

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TIT-BITS ON GEOTECHNICAL ENGINEERING

BY ENGR. ENEFIOK UBOM

1.0 A POEM ON GEOTECHNICAL ENGINEERS AS SPECIALIZED SOLUTION PROVIDERS

The poem shown in Table 1 depicts the importance of geotechnical engineers to humanity. They can prevent tears if their expertise is utilized at the right time and in the right circumstance. Tears come about when a disaster affecting life or property occurs. This short poetic narrative in Table 1 is a reminiscence on a natural disaster which points to geotechnical engineers as the specialized solution providers.

Engr. Enefiok Ubom, *FNSChE*

a. Tears! Tears! Tears! *Where did they come from?* *The river flowed with powerful currents,* *As it rained cats and dogs.* *Tears streamed down our cheeks,* *As the bluff gave way. Landslides tore a path of destruction,* *Victims struggled in the rummage,* *And falling buildings became the disaster we gazed at.* *b. A number of officials rushed to the scene.* *As they gazed, geotechnical engineers arrived.* *"Tears do not proffer solutions", they remarked,* *"We have the professional answers,* *No more bluff failures, landslide disasters and falling buildings* *Levee, dike and slope stabilization works are the solutions,* *So, we'll set off to work, To wipe away the tears".*

Table 1: *A poem on geotechnical engineers as specialized solution providers*

2.0 GEOTECHNICAL FAILURES

Geotechnical failures serve as lessons. In order to avoid a recurrence, it is important to carry out proper geotechnical site investigations, adopt flexible designs that incorporate observations during construction, apply strict site supervision, implement geotechnical instrumentation programmes and embrace risk management. The failures listed below are very instructive in this regard.

2.1 SELECTED LANDSLIDE SITES IN NIGERIA

Some communities in Nigeria have experienced geotechnical failures best described as landslides. Few of such sites are shown in fFgs. 1, 2 and 3.

The Federal Ministry of Works and Housing, Federal Ministry of Environment and River Basin Development Authority in each zone have roles to play in engaging professionals to practically utilize their knowledge so as to prevent landslide disasters.

Fig. 1: *Landslide severes 30,000 in Cross River State*

Fig. 2: *Residents flee as landslide causes panic in Anambra State* (Source: Ibid)

Fig. 3: *Landslide destroys 10 houses in Odi, Bayelsa State* (Source: Ibid)

2.2 ROCKFALLS AND ROCK SLOPE OR BLUFF FAILURE

A limestone bluff failure occurred in Lake Whitney in Texas in 2014 (See Fig. 4). The exterior covered patio collapsed with the failed rock mass and the house had to be abandoned. The lesson is that houses should not be constructed near bluffs without a geotechnical engineering evaluation.

Fig. 4: *A limestone bluff failure in Lake Whitney in Texas in 2014 (Source: https://www.capitalgeotechnical.com/geotechnical-failures.html)*

Fig. 5: *A massive sinkhole in Guatemela in 2007 (Source: Ibid)*

2.3 NATURAL SINKHOLES

Fig. 5 shows a massive sinkhole in Guatemela in 2007. The lesson is that it is better to perform a geotechnical study before construction works to determine whether there are certain indicators that can give a hint to the possible presence of a developing sinkhole in the site and surroundings.

3.0 LESSONS FROM THE LEANING TOWER OF PISA

The Leaning Tower of Pisa is today a unique scenic structure which has attracted tourists from different parts of the world to Italy. But why is it leaning when that was not the original intention of the builder according to history? An answer to this question takes us into the tower's brief history and from this, some unique lessons can be derived from geotechnical engineering perspective. The Leaning Tower of Pisa, as shown in Fig. 6, is an amazing 14,500 ton tower known worldwide for its nearly four-degree leaning position. The height of the tower is 55.86 metres (183.27 feet) from the ground on the low side and 56.67 metres (185.93 feet) on the high side. History has it that the tower whose construction started in 1173, with a foundation only 3-metre deep, was built on a dense clay mixture. This mix impacted the soil and the clay was not strong enough to hold the tower upright. As a result, the weight of the tower caused a downward uneven movement till it came to some form of stability. Due to this problem, construction work stopped for 100 years.

Fig. 6: *The Leaning Tower of Pisa*

After 100 years, engineer Giovanni di Simone stepped forward and started to add more floors to the tower. He tried to compensate for the original lean orientation by making one side of the upper floors taller than the other. This only caused the tower to lean more. Unconcerned by the leaning, a 7th floor was added to the tower in the second part of the 14th century and the structure was left on its own until the 19th century. Twenty years after the end of World War II, the Italian government asked for help to avoid the leaning tower from toppling. As a temporary measure, engineers and architects installed a laden counterweight of 800 tonnes. In 1987, the Leaning Tower of Pisa was declared a UNESCO World Heritage Site. In 1990, the tower was anchored and closed till 2001, when it was re-opened for safe visit by tourists (Source: romeprivateguides.com/en/blog/about-florence/the history behind the leaning tower of Pisa).

There was something intriguing about the Leaning Tower of Pisa in Italy. It is recorded that at least 4 strong earthquakes has hit the region since 1280, but the apparently vulnerable tower has survived. The reason was not understood until a research group of 16 engineers carried out an investigation. The researchers concluded that the tower was able to withstand the tremors because of the dynamic soil-structure interaction (DSSI): the height and the stiffness of the tower, together with the softness of the soil bearing the foundation, influenced the vibrational characteristics of the structure in such a way that the tower did not reasonate with the earthquake ground motion. The same soft soil that caused the leaning and brought the tower to the verge of collapse helped it survive. This is an amazing geotechnical phenomenon.

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145 Olabenjo & Associates Consulting Engineers
146 Olutemcon Associates
147 Optimal Designs Associates Nigeria Limited
148 Osforce Nigeria Limited
149 Oska-Jo and Partners
150 Ove-Arup and Partners Consulting Nigeria
151 Oviswift Engineering and Consultancy Limited
152 Ozi Projects and Consultancy Limited
153 Petrotema Engineering Limited
154 Pheman Peniel Consultants
155 Phoenix Associates
156 Pinconsult Associates Limited
157 Planover Engineering Consulting Limited
158 Plusmann Associates
159 Prelim Consulting
160 Premium Engineering Project Consult Limited
161 Primetech Design and Engineering Nigeria Limited
162 Progress Engineers
163 Project Plus Potentials Engineers and Project Manager and Co. Limited
164 Pro-M Limited
165 Pro-XL Civil Engineers
166 Pullad Global Consultant Nigeria Limited
167 Pure Tech Engineering Consulting Limited
168 Qubeesh Integrated Services Limited
169 Rowland Adewumi & Partner
170 Samabot and Associates Limited
171 Samson Opaluwah Consult Limited
172 Sandmash Consultants Ltd
173 Sani Mustapha and Associates
174 Sanni Ojo and Partners Consulting
175 SAO Associates
176 Sapientiae Engineering Limited
177 Siraj Nigeria Limited
178 Sitech Engineering Limited
179 Steag Encotec West Africa Limited (SEWA)
180 Stemo Engineering Services Limited
181 Sudelettra Nigeria Limited
182 Sybag Global Solutions Limited
183 Tamilore Associates
184 Tam-Sok Nigeria Limited
185 Teayork Nigeria Limited
186 Terracorn Engineering Company Limited
187 Toroskylinks Engineering Limited
188 Transglobal Environmental & Engineering Limited
189 Transurban Signature Solutions Limited
190 Tunik Engineering Nigeria Limited
191 Ultikonsults Limited
192 Unecon Associates Limited
193 Vaastrop Nigeria Limited
194 Vasons Concept Consultants Limited
195 Vaya Energy Solutions Limited
196 VC Consulting Service Limited
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The 1st and currently still the only Indigenous ISO Certified Railway Consultancy Firm in Nigeria.

Nexant is also an ISO Certified Consultancy Firm in Engineering Design, Construction & Supervision, providing the industry experience, commitment and proven results your project needs to help see it through, from inception to completion. We provide innovative solutions for the proactive and forensic support you need to deliver your project on time and within budget.

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"To deliver world class infrastructure and engineering consultancy services by reinforcing our worldwide corporate alliances and upholding top-tier quality and ethical standards"

Our Vision

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Tel; +234(0) 12956505; 09077587014.
info@nexantconsult.com
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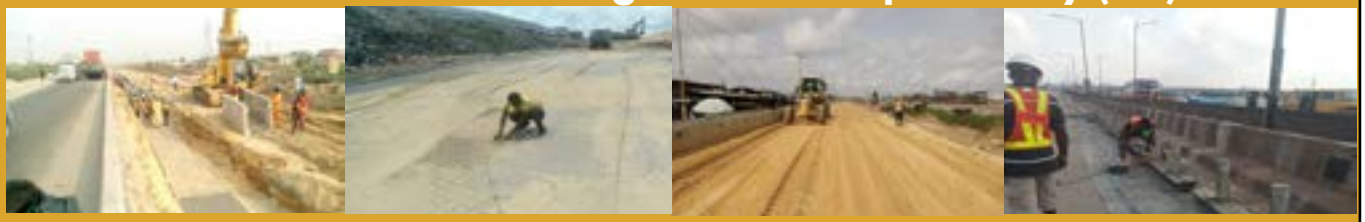
SOME ONGOING CONSTRUCTION SUPERVISION WORKS

Lagos Rail Mass Transit (LRMT) Blue Line

Rehabilitation of Lagos Badagry Express Way (LBE)

Rehabilitation of Lagos Ibadan Express Way (LIE)



VITAPUR

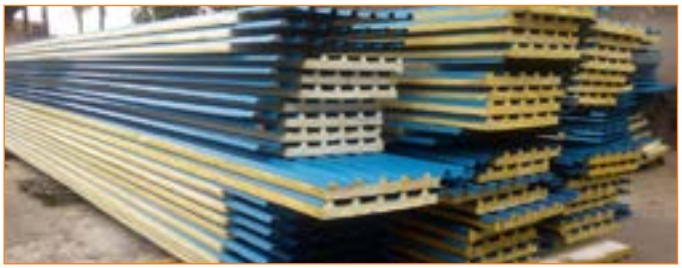
A subsidiary of Vitafoam Nigeria PLC

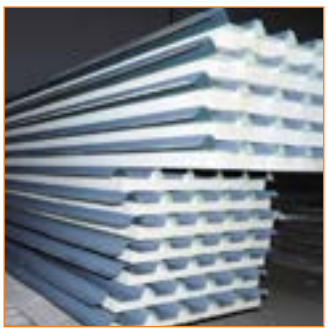
Rigid POLYURETHANE Insulation

INSULATED ROOFING SHEETS

Vitapur's range of insulated roof panels comprise a wide wide variety of easy-to-fit, low maintenance roofing options with superior thermal performance and sound absorption.

The Polyurethane insulation core combined with its steel facings and superior joint design, make Vitapur's roof unparalleled as a weather-resilient, air-tight, low energy and highly thermal-resistant solution.





Benefits

Energy Efficient
Ecologically Clean
Architecturally Adaptable
Air Tightness
Low Maintenance
Easy Installation
Non-toxic

Product Details

Top Covering	Aluminium sheets 0.55mm, 0.7mm, 1mm
Core Thickness (mm)	15mm, 25mm, 40mm, 45mm, 65mm
Overall Thickness (mm)	50mm, 60mm, 75mm, 80mm, 100mm
Bottom Facing	HDG Chromadek steel, Embossed Aluminium Foil, Ficotec Paper, Kraft Paper, Bitumen Membrane
Insulation Core	Rigid Polyurethane; 40kg/m3; 0.024 W/mK
Insulation Width	900mm (Single Lap); 750mm (Double Lap)
Maximum Length	14m

Contact

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info@vitapurinsulation.com.ng
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