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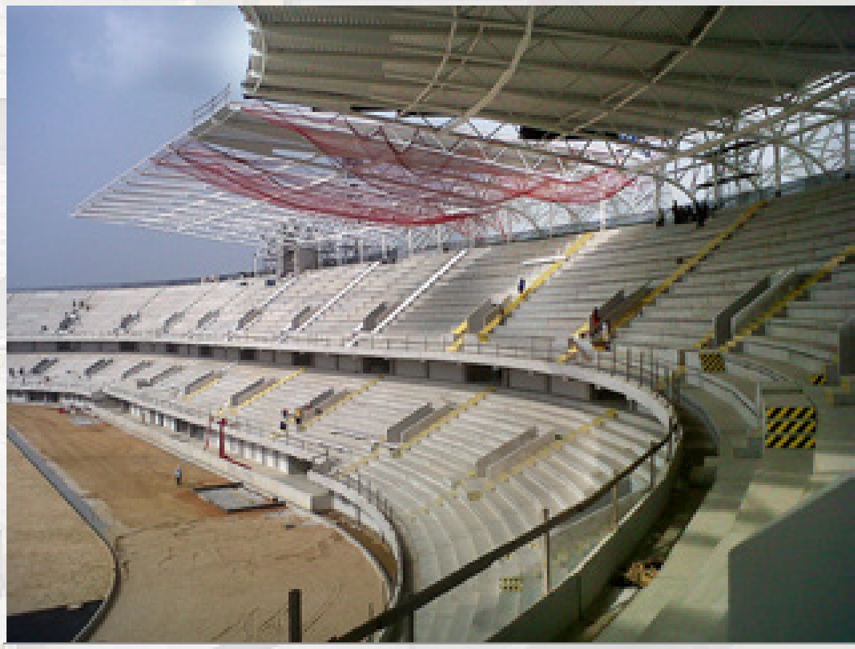
STRUCTURAL ENGINEERING SERVICES



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CONTENTS

FROM THE EDITORIAL SUITE


Engr. Ademola Adeboya, MNSE

"Structural Engineering Services" is the focus of this edition of "The Consulting Engineering" magazine. This edition brings to the fore the importance of adequate application of structural engineering principles in the development of infrastructure in various ramifications to ensure structural integrity, sustainability and safety.

In the first article, Engr. R. A. Olushola Sanni, FNIStructE, MNSE, MICE (Director, Sanni Ojo & Partners Consulting Ltd), elucidates on "History of Structural Engineering". Expectedly, the author tells the story of the early beginnings, advances in the discipline and gradual transformation to modern approaches in the use of the discipline in infrastructural development. The next presentation is from Lagos State Building Control Agency (LASBCA) headed by Arc. Gbolahan Owodunmi Oki. The article highlights the policy thrust on building control and associated activities of the agency. One can readily deduce that the principal reason for the existence of LASBCA and similar agencies in other states and the federal level is to ensure structural stability and safety of buildings. This should clearly underpin the hope of zero tolerance for building collapse. On the part of engineering consultants in the building industry, we can assert that 'Safety of buildings is their pride'. What this means is that engineering consultants should maintain their professional integrity in all projects without any compromise to earn sustainable trust in practice.

Other articles presented are:

- High-Rise Buildings: The Wonders of Structural Engineering by Engr. (Dr.) Ilesanmi Bankole, FNSE (Principal Partner, Sanol Engineering Consultants) and Ms. Faithfulness Bankole (Pupil Engineer)
- Applications of Structural Engineering to Ports & Coastal Structures by Engr. Kabir Haruna (Head of Structural Engineering Unit, Primetech Design & Engineering Nigeria Ltd)
- Application of Codes in Structural Engineering Design of Buildings by Engr. (Dr.) Victor O. Oyenuga, FNSE, FNISTructE, FNICE, MNIOB (CEO, Vasons Concept Consultants Ltd)
- Structural Engineering Principles in Construction of Bridges by Engr. Umo B. Ekong (Director, Highway Bridges (Construction), South, Federal Ministry of Works & Housing)

Two firms of remarkable repute are featured in the special supplement sections. The first one is Primetech Design and Engineering Nigeria Limited, a subsidiary of Julius Berger Nigeria PLC. Leaning on its vast international resources, this firm is innovatively upgrading its technical capacities and fast becoming a prime organization in engineering consultancy just as its principal, Julius Berger Nigeria PLC, stands as a prime company in the construction industry. The second firm is Geld Construction Limited. Within few years of its incorporation, this firm has risen to prominence with successful execution of various flagship projects. We congratulate these two firms for their achievements.

"The Consulting Engineer" Personality for this edition is Engr. (Dr.) Victor O. Oyenuga, FNSE, FNIStructE, FNICE, MNIOB (CEO, Vasons Concept Consultants Ltd). He is a past President of Nigerian Institution of Structural Engineers. He is a well respected professional who has written several books in Structural Engineering particularly on codes.

Within the period under review, ACEN carried out a number of events. Memorable pictures of these events are presented in this edition. Engr. Enefiok Ubom, in his Tit-Bits Column, serves readers with narrations on some spectacular structures pointing to the creative potential of engineers and allied professionals.

Finally, we extend our appreciation to all contributors who made the publication of this edition possible.

Stay safe, relax and enjoy your reading.

Engr. Ademola Adeboya, MNSE
(Chairman, Editorial Board)

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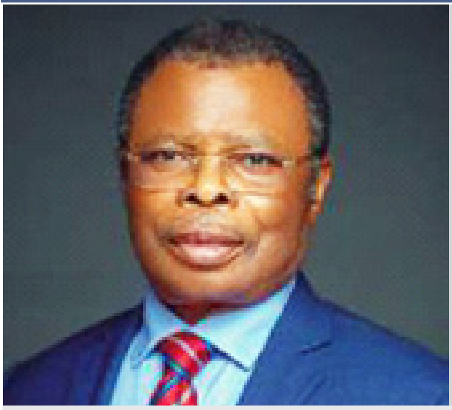

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THE ASSOCIATION FOR CONSULTING ENGINEERING IN NIGERIA (ACEN)

The Association for Consulting Engineering in Nigeria, ACEN, was founded in 1971 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 six 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 practice in the country. No individual or organization is allowed to practice 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, Engr. J.I. Folayan and Engr. 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 the FIDIC Group of African Member Associations which addresses specifically, African concerns. FIDIC Africa currently has 14 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 Past President, Engr. (Mrs.) Mayen Adetiba has served on the Executive Committee. Presently, ACEN Past President, Engr. Charles 'Yele Akindayomi, FNSE, and the Immediate Past President (IPP), Engr. George Okoroma, are members 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 fifty-one (51) 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.

HISTORY OF STRUCTURAL ENGINEERING

ENGR. R.A OLUSHOLA SANNI

1.0 INTRODUCTION

Structural engineering is a branch of engineering that focuses on the design and construction of structures such as buildings, bridges and tunnels. The history of structural engineering dates back to ancient times when humans first began to construct shelters and other structures to protect themselves from the elements.

Engr. R. A. Olushola Sanni, *B.Eng. (Civil), SMCE, MESc, FNIStructE, MNSE, MIStructE, MICE (Director, Sanni, Ojo & Partners Consulting Limited)*

The earliest known examples of structural engineering can be found in the ancient civilizations of Mesopotamia, Egypt and the Indus Valley where people built massive structures like temples, pyramids and ziggurats using a variety of materials, including stone, brick and wood.

2.0 EXAMPLES OF ANCIENT STRUCTURES

One of the earliest known examples of structural engineering is the construction of the pyramids in ancient Egypt such as in Fig. 1. These massive structures were built using highly advanced engineering techniques and they remain standing today as a testament to the ingenuity of the ancient Egyptians. As civilizations developed and grew, so too did the need for more complex and sophisticated structures. The ancient Greeks, for example, built impressive structures like the Parthenon shown in Fig. 2 and the Colosseum using materials like marble and concrete. Another early example of structural engineering is the construction of the aqueducts in ancient Rome shown in Fig. 3. These massive structures were used to transport water from distant sources to the city and they were built using engineering principles such as arches and vaults shown in Fig. 4.

Fig. 1: *Pyramids of Giza*

Fig. 2: *Ruins of Parthenon in Ancient Greece built by Iktinos*

Fig. 3: *Roman aqueducts*

Fig. 4: *Arches*

3.0 GOTHIC ARCHITECTURE

During the Middle Ages, Gothic architecture flourished in Europe with the construction of beautiful and intricate cathedrals and castles. These structures were made possible through the use of new engineering techniques, such as the pointed arch and the flying buttress which allowed for the construction of taller and more ambitious buildings. An example is Sagrada Familia in Barcelona shown in Fig. 5.

Structural engineering continued to evolve as architects and engineers began to experiment with new forms and designs. For instance, the development of the Gothic style of architecture using ribbed vaults also allowed for the construction of taller and more complex buildings.

4.0 INDUSTRIAL REVOLUTION ERA

During the Industrial Revolution, structural engineering underwent a major transformation. The widespread use of iron and steel in construction allowed for the construction of larger and more complex structures, such as the Iron Bridge in England and the Eiffel Tower in France. See Fig. 6.

5.0 MODERN ERA

In the modern era, structural engineering has continued to evolve and develop. The 19th and 20th centuries saw the rise of steel-framed buildings which made it possible to construct taller and more flexible structures. See Fig. 7. Today, structural engineers use a wide range of materials and techniques to design and construct buildings and other structures from high-rise skyscrapers to bridges and tunnels.

"Structural engineering continued to evolve as architects and engineers began to experiment with new forms and designs. For instance, the development of the Gothic style of architecture using..."

The history of structural engineering is a fascinating one with a rich tradition of innovation and creativity. From the ancient pyramids to the tallest buildings of today, structural engineers have played crucial roles in the development of human civilization.

Today, structural engineering continues to evolve and advance. Modern technologies such as computer-aided design and 3D printing, shown in Fig. 10, enable engineers to design and construct even more complex and impressive structures. As the world continues to change and develop, structural

Fig. 5: *Sagrada Familia*

Fig. 6: *Eiffel Tower, Paris*

Fig. 7: *Willis Tower, Chicago*


Fig. 8: *Sydney Opera House in Australia*


Fig. 9: *Burj Khalifa in Dubai*

engineering will continue to play crucial roles in shaping the built environment. See Fig. 8 and Fig. 9.

In the digital age, structural engineering is likely to continue to evolve and advance. The use of technologies such as computer-aided design and 3D printing will enable engineers to design and construct even more complex and impressive structures. Another significant development is parametric modeling which creates 3D models of a structure that can be interactively changed by adjusting design parameters. This makes design optimization faster and easier. See Fig. 11.

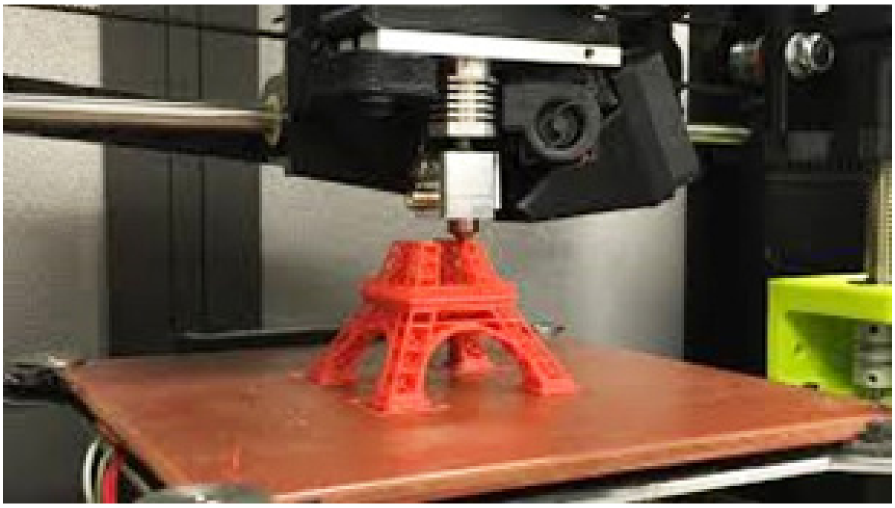
Fig. 10: *Mini 3D Printing of Eiffel Tower*


Fig. 11: *Al Janoub Stadium in Al Wakrah*

> *"...the future of structural engineering in the digital age looks bright..."*

The rise of sustainable and green building practices will also play a significant role in the future of structural engineering. As the world becomes increasingly aware of the need to reduce its environmental footprint, engineers will need to design and construct structures that are energy-efficient and sustainable.

In addition, the use of advanced materials and construction techniques, such as modular and prefabricated construction, will become more prevalent. These methods allow for faster and more efficient construction, and they have the potential to revolutionize the field of structural engineering.

6.0 CONCLUSION

Overall, the future of structural engineering in the digital age looks bright with many exciting developments and opportunities on the horizon.

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A - Z OF LAGOS STATE BUILDING CONTROL AGENCY (LASBCA)

BY ARC. GBOLAHAN OWODUNMI OKI (GENERAL MANAGER, LASBCA)

Arc. Gbolahan Owodunmi Oki (General Manager, LASBCA)

1.0 INTRODUCTION

Lagos State Building Control Agency (LASBCA) came into being through the Lagos State Urban and Regional Planning and Development Law of 2010. However, it officially started in August 12, 2012. It is an agency set up to ensure that basic minimum standards are maintained in building construction and renovation in order to ensure that existing and new buildings are safe, healthy, accessible and habitable for present and future generations.

The agency works with developers/owners and professionals in the Built Industry to provide quality services and ensure that building constructions are satisfactorily carried out.

LASBCA also works closely with other government agencies to achieve its responsibility of a safe, secured and habitable building in Lagos State.

The agency, under the State Ministry of Physical Planning and Urban Development, has been playing a pivotal role towards making Lagos a 21st century economy in line with T:H:E:M:E Agenda of Lagos State Government.

The agency is saddled with the responsibilities of initiating and formulating the enforcement of Building Control Regulations, Issuance of Authorization to Commence Construction, Certification of various Stages of Construction, ensuring the attainment of basic minimum standards and quality control in building construction so as to achieve a structurally safe, secured and sustainable building and to prevent incidences of building collapse in the state.

LASBCA is governed by Lagos State Urban and Regional Planning and Development Law 2019 as amended, LASBCA regulations and the National Building Codes.

Lagos State Urban and Regional Planning and Development (Amendment) Law, 2019 is the principal or substantive law for the administration of physical planning, urban development and building control in the state.

The regulations being the subsidiary laws made in pursuant to the law are:
i. The Building Control Agency Regulations, 2019
ii. The Physical Planning Permit Regulations

2.0 LASBCA VISION

To ensure that buildings in Lagos State are designed, constructed and maintained to high standards of safety so as to avoid loss of lives and properties;

> *"...an agency set up to ensure that basic minimum standards are maintained in building construction and renovation in order to ensure that existing and new buildings are safe, healthy, accessible and habitable for present and future generations."*

> *"The agency has put in tremendous efforts to put an end to the issue of building collapse through well-thought-out publicity plans and scheduled programs/ activities on the social, print and electronic media."*

through its building regulatory system, we aim to achieve zero percent building collapse.

3.0 LASBCA MISSION

To lead and transform the Building Construction industry by enhancing skills and professionalism as well as improving design and construction capabilities.

4.0 LASBCA'S MINISTERIAL MANDATES/RESPONSIBILITIES/ FUNCTIONS

- To carry out Building control in all its ramifications
- To grant approval to commence construction after obtaining development permit
- To carry out routine inspection and certification of various stages of building construction
- To ensure verification of "General Contractor All Risk and Building Insurance Policy"
- To issue certificate of completion of building construction and fitness for habitation
- To identify and remove distressed and non-conforming buildings
- To ensure public health control in buildings

5.0 CORE ACTIVITIES OF THE AGENCY

I. ENFORCEMENT FOR COMPLIANCE ACTIVITIES:

The agency has recorded significant achievements in all areas of its activities especially in the aspect of enforcement for compliance and quality control in building construction. This is actually the core mandate of the agency. Monitoring and enforcement to ensure compliance of all physical developments within the state have improved tremendously and as such efforts have been intensified with the deployment of more officers to enhance the early detection of infractions for prompt compliance or outright removal.

The recent deployment of the governor's Special Operations Team to LASBCA will help to further strengthen the enforcement activities.

II. ISSUANCE OF GREEN CHECKS STICKER:

In the past years, the agency was mostly synonymous with the red cross mark and demolition. The narrative has changed through the issuance of green check stickers to all developers who have complied with the initial requirements under the building control regulations and have authorization to commence construction after obtaining their development permits. The green sticker allows the agency and even the citizens to quickly identify ongoing construction works that are working in tandem with the state building rules and regulations and vision of making Lagos a 21st Century economy and in line with the THEME Agenda of the State Government.

The green sticker ensures that all properties are captured in the agency's database with full details of construction from start-to-finish dates.
It helps in imbibing the much-needed maintenance culture because the full history of properties is captured in the agency's database.

III. PUBLIC ENLIGHTENMENT:

The agency has put in tremendous efforts to put an end to the issue of building collapse through well-thought-out publicity plans and scheduled programs/activities on the social, print and electronic media. These actions serve to enlighten as well as educate Lagosians/Stakeholders including professional bodies to conform to the building rules and regulations. These activities include:

- Media Appearances
- Stakeholders' Engagements
- Placement of LASBCA Jingle
- Roadshows

IV. STAGE CERTIFICATION:

As a building control agency, one of the core responsibilities is stage inspection and issuance of certificate of fitness for habitation after the completion of a building. Stage certification refers to the process whereby every stage of a building construction is closely monitored and certified satisfactory by a team of LASBCA officials comprising structural, civil, mechanical and electrical engineers, builders and architects.

This process is basically aimed at ensuring that all buildings in the state are deemed safe and habitable for occupants. It starts from the beginning which is foundation laying through the external works and fittings and stops when the building works are COMPLETE.

"

This process is basically aimed at ensuring that all buildings in the state are deemed safe and habitable for occupants. It starts from the beginning which is foundation laying through the external works and fittings and stops when the building works are COMPLETE.

"

V. ISSUANCE OF CERTIFICATE OF FITNESS FOR HABITATION:

'Certificate of Completion and Fitness for Habitation' is that document which is obtained by the owner of the building after meeting all requirements laid out by LASBCA on completion of the project.

The processes involved in obtaining the certificate are as follows:

a. Obtain a planning permit from the Lagos State Physical Planning Permit Authority (LASPPPA).
b. Proceed to LASBCA with a letter of intention to commence construction alongside the development permit obtained.
c. Officers are dispatched to site to ascertain status i.e. ensure that the site is vacant.
d. A file is opened at the agency for the developer.
e. A letter of authorization is issued by the agency to start construction after the submission of required documents which include:
   - Evidence of Payment
   - Letter of introduction by the consultant handling the project
   - Letter of Structural Stability and Integrity Test (for old existing building)
   - Approved drawings as applicable
   - Builders document as applicable
   - All risk insurance (for 3 floors & above)
f. A green sticker is issued on submission of all required documents.
g. A project board is installed on site.
h. The developer must send a letter of invitation for stage inspection giving a seven (7) days' notice at every stage throughout construction till completion including external works and fittings.
i. On completion, a final joint stage inspection will be carried out by the consultant(s) and the agency.
j. The developer can request and be granted the 'Certificate of Completion and Habitation'.

Obtaining a 'Certificate of Completion and Fitness for Habitation' has a lot of advantages. These include the following:

- It ensures that the completed structure is built according to design specifications
- It ensures that the structure is safe for habitation or use since professionals were involved in the construction process
- It could serve as a veritable collateral for loan facility
- It adds to the value of the building
- It assures would-be occupants of the stability of the building and ultimately, their safety.

HIGH-RISE BUILDINGS: THE WONDERS OF STRUCTURAL ENGINEERING

BY ENGR. SANMI BANKOLE, *FNSE* & MS. FAITHFULNESS BANKOLE

1.0 THE SIGNIFICANCE OF HIGH-RISE BUILDINGS

Many advancements and innovations in the engineering field are witnessed in the urban era. One of such innovations is the high-rise building. High-rise buildings are tall buildings usually consisting of more than ten floors. The emergence of high-rise buildings can be attributed to high land prices and population density in urban areas. This development necessitated renewed thinking on the use of space. A need arose for structures that occupied less land and rose vertically instead of spreading horizontally.

The first ever high-rise building was the Home Life Insurance Building with a height of 55 m. It was designed in 1884 by William LeBaron Jenney, a local architect in Chicago. This marked the beginning of an era of building taller structures. Today's tallest building is the Burj Khalifa in Dubai, towering 828 m.

2.0 ENGINEERS' ROLE IN DESIGN AND CONSTRUCTION OF HIGH-RISE BUILDINGS

High-rise buildings are designed to accommodate many people in a relatively small area. They are often used for commercial, residential or mixed-use purposes. Many high-rise buildings have amenities such as swimming pools, gyms, restaurants and shopping centers which add to the convenience and comfort of their occupants. These amenities and the number of stories put weight and pressure on the building's foundation.

High-rise buildings are constructed using steel, reinforced concrete or both. The design of a high-rise building foundation must enable it to withstand the immense weight of the structure and the forces of the wind and earthquakes. The structure of the building is specifically designed to enable even distribution of the structure's weight, ensuring that the building remains stable even during high winds or earthquakes. The design of a high-rise building is an essential aspect of its construction. Engineers consider factors such

***Engr. (Dr.) Sanmi Bankole**, FNSE, MASCE, FIICA, MNIHE (CEO, Sanol Eng. Consultants).*

***Ms. Faithfulness Bankole**, B.Engr., (Pupil Engineer)*

as the soil's load-bearing capacity, the building's purpose, location, the climate of the region and available space when designing the structure. The design of the building must be tested and fully adequate to perform the functions for which it is intended. Failure to do so amounts to negligence and may eventually cause casualty.

The construction of a high-rise building is a complex process. The building design must enable it to withstand the forces of nature, including wind, earthquakes, and fires. Advanced technologies such as building information modelling (BIM) and virtual reality (VR) have made construction more efficient and cost-effective.

> ***"The design of a high-rise building foundation must enable it to withstand the immense weight of the structure and the forces of the wind and earthquakes. The structure of the building is specifically designed..."***

3.0 HISTORY OF HIGH-RISE BUILDINGS

The history of high-rise buildings can be traced back to ancient civilizations, such as the Roman Colosseum, standing at 48 m and The Great Pyramid of Giza, at 139 m. However, modern high-rise buildings were first constructed in the late 19th century.

Since then, high-rise buildings have symbolized progress and development in modern cities worldwide. Their constructions have been made possible by advances in structural engineering and building materials, such as reinforced concrete and steel frames.

One of the significant challenges in high-rise building design is wind and seismic loads. High-rise buildings are subjected to significant wind forces due to their height and location. Thus, engineers must design these buildings to withstand these forces and ensure their safety.

Another challenge in high-rise building design is foundation design. The foundation of a high-rise building must be able to support the structure's weight and its design must account for soil and seismic conditions. The choice of material is also critical in high-rise building designs. For example, concrete is commonly used in high-rise buildings due to its strength and durability.

4.0 INNOVATIONS IN HIGH-RISE BUILDING DESIGN

The design of high-rise buildings has undergone significant changes over the years, driven by technological advancements and the need for more sustainable and efficient buildings. One of the notable innovations in high-rise building design is the use of Building Information Modeling (BIM) technology. BIM technology enables engineers to visualize and simulate the building design, making it easier to identify potential problems and optimize the design.

Another innovation in high-rise building design is using advanced materials, such as carbon fibre and ultra-high-performance concrete. These materials offer enhanced strength and durability, enabling the construction of taller and more resilient buildings. Sustainable and energy-efficient systems are also gaining popularity in high-rise building designs.

5.0 INNOVATIVE DESIGN AND CONSTRUCTION TECHNIQUES

High-rise buildings are some of the world's most impressive feats of engineering today. Gravity's downward pull presents the main challenge when constructing upward, necessitating careful material selection and specialized construction methods to guarantee the stability and safety of the structure.

A significant technological advance was the introduction of iron and steel mass production. Only after this were high-rise structure concepts more practicably feasible. Older buildings' solid brick walls were replaced with lightweight metal beams because they could support much more weight while taking up less room. The steel skeleton is the central support structure of a skyscraper. The superstructure, a three-dimensional grid, transfers the weight of the building straight to vertical columns. Gravity's concentrated power is then dispersed throughout the building's substructure. The spread footing that supports the vertical columns rests squarely on a cast-iron plate. A grillage or stack of horizontal steel supports is fixed on top of the plate. A substantial concrete pad poured immediately onto the ground's dense clay serves as the base for the grillage. Then, concrete is poured over the complete building. The building's weight is dispersed over a sizable area and the complete structure rests directly on the dense clay material beneath the earth. The exterior walls must support only their weight.

"... spread footing that supports the vertical columns rests squarely on a cast-iron plate. A grillage or stack of horizontal steel supports is fixed on top of the plate. A substantial concrete pad poured immediately..."

Wind also poses a significant threat to skyscrapers. In order to mitigate this, engineers design buildings to sway like a tree which may cause occupants some discomfort. Tightening up the structure by bolting and welding connections can help. However, strong cores through the center of the building are necessary for taller buildings, especially those in earthquake-prone areas. The area around the central elevator shafts is fortified with a sturdy steel truss braced with diagonal beams or one or more concrete cores built into the center of the building. These descriptions reveal the secrets used by structural engineers, architects and other related professionals in high-rise building design and construction which the world perceives as a wonder. Fig. 1 shows one of such wonderful high-rise buildings.

Fig. 1: *The 325.5m high Azabudai Hills Mori JP Tower in Tokyo*

The tower was designed by the architectural firm Pelli Clarke Pelli Architects and developed by the Mori Building Company. Construction started in 2019.

The complex is located in the Toranomon business district, in the ward of Minato; it lies between sister Mori Building projects Roppongi Hills to the east, Toranomon Hills to the west and Ark Hills to the north. The project's official name, "Azabudai Hills", was announced by Mori Building on 14 December 2022.

Planning and building a high-rise structure requires carefully balancing shape and function, aesthetics and usefulness and innovation and safety. The end product is a massive structure that challenges conventional wisdom and is a testament to human ingenuity and tenacity.

"... is located in the Toranomon business district, in the ward of Minato; it lays between sister Mori Building projects Roppongi Hills to the ..."

6.0 THE RISKS OF HIGH-RISE BUILDINGS

High-rise buildings are particularly vulnerable to earthquakes due to their height and slender structure. When subjected to seismic activity, high-rise buildings can sway back and forth, creating significant stresses on the structure. This can lead to structural damage, including

> ***"... high-rise buildings are often constructed using lightweight materials such as glass and steel which can be less resistant to seismic forces than traditional materials like concrete and masonry. The collapseof a high-rise building can lead to significant loss of lives ..."***

the buckling of columns, cracking walls and floor collapse.

Additionally, high-rise buildings are often constructed using lightweight materials such as glass and steel which can be less resistant to seismic forces than traditional materials like concrete and masonry. The collapse of a high-rise building can lead to significant loss of lives and damage to surrounding infrastructure.

7.0 RECENT EARTHQUAKE CRISES AND THE RISKS

Earthquakes are natural phenomena caused by the sudden release of energy in the earth's crust, resulting in seismic waves propagating through the ground. It is essential to consider earthquake risks when designing and constructing high-rise buildings.
Recent earthquake crises have highlighted the vulnerability of high-rise buildings to earthquakes. The 2023 Syrian and Turkish earthquakes are examples of how earthquakes can cause significant damage and loss of lives in high-rise buildings.
Over 6,000 buildings were destroyed due to the severity of the earthquakes. However, factors such as lack of adherence to the earthquake-resistant building design code, excessive cost-cutting to the detriment of safety, and substandard materials, contributed to the collapse of many high-rise buildings.

8.0 EARTHQUAKE-RESISTANT DESIGN AND CONSTRUCTION TECHNIQUES

Engineers employ various earthquake-resistant design and construction techniques to mitigate the risks of high-rise buildings and earthquakes. Seismic building codes and regulations are implemented to ensure that high-rise buildings are designed and constructed to withstand the forces of earthquakes.
Base isolation and damping systems which separate the building from the ground and absorb the energy generated by seismic waves are also commonly used in high-rise building designs.
Reinforced concrete and steel frame solid and ductile materials that can withstand more significant stresses than materials like glass are commonly used in high-rise building construction.
Computer simulations and physical testing are also used to analyze the behavior of high-rise buildings under seismic activity so as to ensure their safety.

9.0 CONCLUSION

The introduction of high-rise buildings to the urban world has numerous advantages. However, in light of the recent earthquake disasters in Turkey and Syria, the industry must prioritize safety and sustainability in high-rise construction.
By incorporating innovative and adequately simulated safe technologies into the design and construction of high-rise buildings, we can create structures that are not only safe but also sustainable and resilient.

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PRIMETECH

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BRIEF PROFILE

Primetech Design and Engineering Nigeria Limited is a full subsidiary of Julius Berger Nigeria PLC. It was set-up and fully incorporated to perform design and engineering in Nigeria in 2011.
PrimeTech is a multi-disciplinary firm of civil/structural engineers, mechanical and electrical engineers. It was primarily set-up to provide design and engineering services in full compliance with the Nigerian Oil & Gas Industry Content Development (NOGICD). Thus, PrimeTech is fully a Nigerian company with over 90% of its work force being Nigerian engineers in full-time employment.

PORTFOLIO OF COMPETENCES

i. Architecture
ii. Structural Engineering
iii. Infrastructural Engineering
iv. Mechanical, Electrical & Pipe Services
v. Works Preparation & Cost Estimation

ARCHITECTURE DEPARTMENT

PrimeTech's Architecture Department blends the experience of its well-established team members with the dynamic creativity of its fledgling architects, providing bespoke architecture design services with rigorous technical know-how.

Scope of Services

* Design for all project phases
* Sustainable and energy efficiency in design
* FEED and DED design services (Oil & Gas)
* 3D visualization and virtual reality integration
* BIM integration in designs (Autodesk AEC)
* Design project coordination
* Procurement planning and requisitioning

STRUCTURAL ENGINEERING DEPARTMENT

PrimeTech's structural engineers research, design and plan structural components and systems to achieve design goals. Structural designs ensure the technical viability, integrity and safety of design criteria, as well as the durable performance of bearing elements and materials. Special emphasis is placed on conformity with quality processes at all review stages.

Scope of Services

* Engineering of reinforced and post-tensioned concrete structures
* High-Rise concrete structures
* Shallow foundation engineering for single pads, rafts and strip footings
* Deep foundation engineering for bored and driven piles
* Engineering of solid, ribbed and flat slabs, composite slabs and filigree floor slabs
* Engineering for civil works such as water treatment structures, sewage treatment structures, retaining walls, culverts, manholes, and pipes
* Marine and quay structures, made-of-steel sheet piling, or king piles
* Industrial and farm steel structures
* Roof trusses
* Vehicular and pedestrian concrete bridges of varying spans and curvatures
* Building Information Modeling (BIM) of bridge structures and 3D reinforcement of elements

INFRASTRUCTURE DEPARTMENT

PrimeTech's Infrastructure Department is aptly positioned with a team of experienced professionals in the design and construction industry to deliver sustainable infrastructure solutions anywhere in Nigeria, providing integrated city, district, plot and estate layouts and plans for roads, highways and bridges. It equally provides utility services designs such as electrical cable routing, water supply systems, sewage systems, storm-water management and landscaping.
This department offers holistic and environmental-friendly solutions which include master-plan development for plots and districts, environmental planning, regional development and land use planning.

Scope of Services

* Development of master plans for estates, cities and districts
* Planning and development of plots and estates
* Geometric engineering designs of roads, flyovers, bridges including access and trunk roads
* Highway intersections – at grade and grade-separated interchanges
* Traffic engineering for all categories of roads in

> **"...MEP Department specialises in providing...design optimisation,**

both rural and urban areas
* Drainage studies and hydraulic engineering of storm-water systems including culverts, open channels, piped systems, swales, etc
* Engineering for water supply system and wastewater management system

MECHANICAL, ELECTRICAL & PIPE SERVICES (MEP) DEPT.

PrimeTech's MEP Department specialises in providing engineering design optimisation, commissioning and related services for heating, ventilation and air conditioning (HVAC), electrical, plumbing and fire protection systems for a wide range of industrial commercial and residential buildings, as well as data centres and healthcare centres. It also offers consultancy in the design and management of MEP installations.

It uses BIM technology for effective collaboration with other departments within the organisation and for quality project delivery through accuracy in design and prompt response to project requirements.

Scope of Services

* Air-conditioning and ventilation systems
* CCTV and multimedia systems
* Lighting systems and control
* Access control and handicap call system
* Earthing and lightning protection systems
* Fire detection, suppression and smoke control systems
* Solar energy systems
* Power distribution systems
* Sanitary systems
* Water supply and distribution systems
* Bill of engineering measurement and evaluation
* Supervision and commissioning of installation works

WORKS PREPARATION & COST ESTIMATION DEPARTMENT

Added in May 2022, the WPC Department is PrimeTech's newest arm. The department, which is not a regular design unit, exists to render complementary technical support services to other departments, from the tender phase of project development down to the execution stage.

Thus, it enhances well-thought-out and carefully planned design and engineering solutions that are powered by clinically engineered processes in project planning and management. It also enhances management processes for modeling the project time and cost phenomena for more consistent, effective and seamless project delivery through a highly structured, planned and tested process using 5D BIM Collaboration.

Scope of Services

* Reviewing tender documents
* Preparation and presentation of tenders
* Risk and opportunity analysis for tender projects
* Optimisation of special construction methods (Value Engineering)
* Preparation of construction time schedules
* Acquisition phase site visits and preparation of detailed site visit reports
* Project cost estimations
* General project cost analysis
* Project liquidity planning
* Site installation planning
* Construction site equipment and manpower planning with histograms
* Description of special construction methods (method statements)
* Project performance reporting
* Project cost controlling

CORPORATE CULTURE

PrimeTech's corporate culture is sustained by seven pillars.

i. Precision

"Thorough work preparation, meticulously planned design and engineering solutions, structured processes and pin-point execution"

PrimeTech places a premium on precision. It has a holistic approach to client servicing and this underlies the company's delivery of well-thought-out and meticulously planned design and engineering solutions. The company firmly believes that the delivery of consistent quality is the primary driver of value for clients. Its Quality Management System conforms to the requirements set by the International Organisation for Standardisation (ISO 9001:2015) and brings to bear client specifications in ethical construction.

ii. Partnership

"Mutually agreed and realistic goals achieved through utmost value for professional and collaborative cooperation"

PrimeTech is a committed partner that places the

> **"A stimulation of respect and an appreciation of its role in..."**

utmost value on professional and collaborative cooperation. The company prioritises long-term business relationships built on trust and transparency. Focus is placed on setting mutually agreed and realistic goals that reflect the parameters set for any given project.

Clear and open processes are emphasised through continuous engagement with clients and partners. The firm prioritises the long-term environmental, economic and social viability of its services and is a leader in raising the standard for sustainable management practices in Nigeria, continually spearheading the implementation of cutting-edge technologies and operational procedures.

iii. Innovation

"Development of creative solutions and continuous upgrade of technical capacities and support facilities"

PrimeTech drives innovation, aiming not only to creatively develop solutions that capture clients' visions but also to continuously upgrade its technical capacities and support facilities to expand its expertise and ability to deliver innovative design and engineering. The company's highly qualified staff are kept abreast of the latest domestic and global market developments.

Furthermore, to continually increase technical aptitude, PrimeTech taps into its diverse international resources to gain special expert knowledge on developing trends and the latest technologies.

PrimeTech is a pioneer in the area of sustainable design and engineering in Nigeria and maintains robust knowledge regarding the latest green building technology. Examples include the company's head office which is designed and built according to the Leadership in Energy and Environmental Design (LEED) requirements.

iv. Quality

"A perfect balance of aesthetics, functional and constructional considerations coupled with possible solutions in environmental, human and economic terms using standard management systems"

Quality is at the heart of PrimeTech's design engineering and architecture. Its working methodology is based on a simultaneous and interdisciplinary creative interaction within its participatory teams, in close liaison with stakeholders, finding the perfect balance between aesthetics, functional and constructional considerations as well as the best possible solutions in environmental, human and economic terms.

PrimeTech implements, monitors and continually improves and documents its quality management system and the necessary design processes at all relevant design development stages in consistence with the ISO 9001:2015 to ensure best-in-class standards.

v. Invested

"Committed to project goals, staff and community development"

PrimeTech is invested in its staff, community and the goals of its projects. The foundation of its strength is a motivated and highly skilled staff, ranging from young graduates to experienced professionals, who have extensive knowledge in their field of expertise.

The majority of PrimeTech's engineers and architects are registered with the relevant Nigerian professional bodies, including the Council for the Regulation of Engineering in Nigeria (COREN), the Nigerian Society of Engineers (NSE), the Architects Registration Council of Nigeria (ARCON), and the Nigerian Institute of Architects (NIA).

As part of the Julius Berger Group, PrimeTech has access to vast resources within Nigeria which further support the company's ability to offer end-to-end client servicing.

vi. Employee Driven

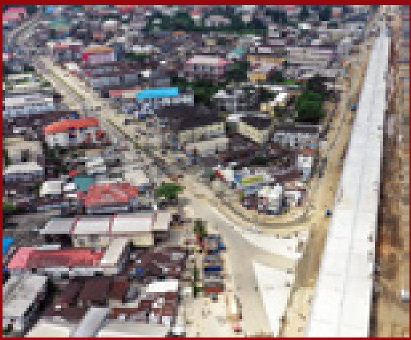
"Fostering a culture of collaboration and continuous learning, and pushing the boundaries of what is possible"

PrimeTech is an employee-driven organisation. Its quality delivery cycle begins with and thrives upon employee-related policies which create competitive remuneration, a conducive work environment, career growth opportunities as well as a sense of respect, deeper connection, trust and belonging.

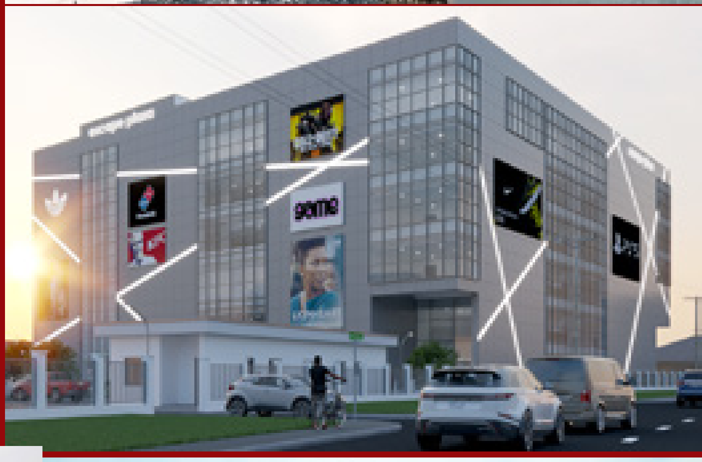
vii. Respect

"A stimulation of respect and an appreciation of its role in productivity, collaboration, fairness and employee satisfaction which extends to clients and partners"

PrimeTech understands the mutuality of respect and its manifestation of dignity among people through unconditional regard for their personal qualities or character type. It appreciates how respect within the organisation transcends beyond it to the sphere of respect to clients and partners. Professional achievements, talents and exceptional performances are highlighted and rewarded.



SOME PROJECTS EXECUTED BY PRIMETECH



THE FUTURE

PrimeTech, as a going concern, is poised to consolidate on its successes and maintain its prime position in engineering consultancy.

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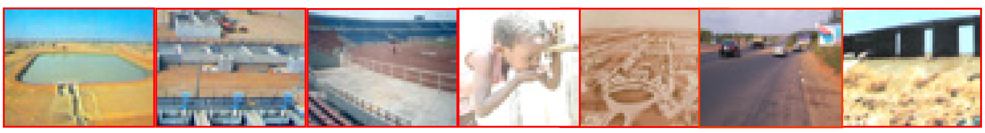

• imagine • conceive • empower

APPLICATIONS OF STRUCTURAL ENGINEERING TO PORTS & COASTAL STRUCTURES

BY ENGR. KABIR HARUNA

Engr. Kabir Haruna
(Head of Structural Engineering Unit, Primetech Design & Engineering Nigeria Ltd)

1.0 WHAT IS STRUCTURAL ENGINEERING?

Structural engineering is a branch of civil engineering that involves the application of the laws of physics, mathematics and empirical knowledge to safely design the 'bones' and load bearing elements of man-made structures. Structural engineers must also understand and calculate the stability, strength, rigidity and earthquake-susceptibility of built structures for buildings and non-building structures.

Structural engineering has existed since humans first started to construct their structures. It became a more defined and formalized profession with the emergence of architecture as a distinct profession from engineering during the industrial revolution in the late 19th century. Until then, the architect and the structural engineer were usually one and the same person – the master builder. Only with the development of specialized knowledge of structural theories that emerged during the 19th and early 20th centuries, did professional structural engineers come into existence.

Structural engineers are responsible for engineering design and structural analysis. The role of a structural engineer today involves a significant understanding of both static and dynamic loading and the structures that are available to resist them. The complexity of modern structures often requires a great deal of creativity from the engineer in order to ensure that structures support and resist the loads they are subjected to. Since the 1990s, specialist software has become available to aid in the design of structures with the functionality to assist in the drawing, analysing and designing of structures with maximum precision.

The following specializations are instructive:

i. Structural building engineering includes all structural engineering related to the design of buildings. It is a branch of structural engineering closely affiliated with architecture.
   - Earthquake engineering
   - Façade engineering
   - Fire engineering
   - Roof engineering
   - Tower engineering
   - Wind engineering

ii. Civil structural engineering includes structural engineering related to the built environment. It is sub-divided into:
   - Bridges
   - Dams
   - Earthworks
   - Foundations
   - Offshore Structures – Platforms, Offshore wind turbines, jetties
   - Pipelines
   - Power stations
   - Railways
   - Retaining structures and walls
   - Roads
   - Tunnels
   - Water ways
   - Reservoirs
   - Water infrastructure
   - Onshore wind turbines

2.0 WHAT ARE PORTS AND COASTAL STRUCTURES?

Port structures, as the name implies, are 'near-shore' marine structures. These structures are very essential to global trade and constitute the vital parts to economies of countries around the world. Ports are also often densely populated settlements that provide the labour for processing and handling goods and related services.

A port is a maritime facility comprising one or more wharves or loading areas where ships can discharge cargo and passengers. Although usually situated on a seacoast or estuary, ports can also be found far inland. These ones are referred to as dry ports. Ports can have a wide environmental impact on local ecologies and waterways, particularly water quality which can be caused by dredging, spills and other forms of pollution. Ports are heavily affected by changing environmental factors caused by climate change as most port infrastructures are extremely vulnerable to sea level rise and coastal flooding. Whereas ports in the olden days tended to be just simple harbours, modern ports tend to be multimodal distribution hubs with transport links using sea, river, canal, road, air and rail routes. Commercially successful ports are located to optimize access to an active hinterland.

Ports usually have specialised functions. For instance, some tend to cater mainly for passenger ferries and cruise ships. Others specialise in container traffic or general cargo. Some other ports play an important military role for their nation's navy.

The main objective of coastal structures is to shield the coastline from storm surges and other sea-related natural disasters. Increased access to the sea from the land is made possible by the coastal protection structure while erosion is decreased. Erosion is caused by hydraulic action through the power of the waves themselves.

Ports, harbours and coastal structures are shown in Table 1. Our focus shall be on ports, harbours and coastal structures. Offshore structures shall be dealt with later.

3.0 CONSIDERATIONS FOR PORT PLANNERS AND OWNERS

Port owners and developers must be aware of the dangers of not planning in a sustainable manner and they should always be conscious of possible future requirements. Therefore, one of the most important items of a long-term port plan should be flexibility.

	COASTAL	PORT AND HARBOUR	OFFSHORE
Purpose	Shore protection	Navigation, berthing, and servicing of vessels	Recovery of natural resources (oil and gas)
Project Types	Breakwaters Jetties and groins Seawalls and revetments Beach nourishment Shoreline stabilization Flood control Outfalls and pollution control	Dredging: Channels and mooring Terminals and port structures Shipyards and dry docks Small craft and harbours Moorings	Fixed platforms Mobile drilling units Moorings Pipelines Offshore terminals
Related and Sub disciplines	Near-shore monitoring Hydro surveying Waterfront development	Navigational -aids/VTS Inland waterways Industrial waterfront facilities Waterfront development Offshore terminals	Exploration Offshore buoys and monitoring Ocean energy

Table 1: *Marine civil engineering disciplines & structures*

Probably, the most important function of the port plan is to reserve land for the port to develop and expand to meet future growth in traffic or changes in technology. Therefore, the following information should be considered in the design of the port:

i. Location of the port area in relation to:
   - Regional conditions
   - Local conditions
   - Local traffic (railways, trucks, bicycles, passenger traffic, pedestrian, ferry traffic with parking spaces for waiting vehicles etc.)
   - Car parks (public and private)

ii. Location of berths
   - General requirements
   - Relation to port area
   - Natural conditions
   - Neighbourhood relationships

iii. Size of berths
   - Types and number of berths
   - Length and surface of each berth, depth alongside
   - Dolphins
   - Special mooring facilities
   - Loads
   - Utilisation of the port facilities
   - Utilisation of the berth facilities for separate berths

iv. Land Area
   - Present and future needs for land areas
   - Indoor and outdoor storage capacities
   - Access roads
   - Development of land areas (gravel, asphalt, type of traffic, etc.)
   - Area restrictions (buildings, power and cable lines, etc)
   - Facilities for dockers, stevedores, service functions
   - Local authorities demand and benefits

v. Demand for auxiliary services and installations
   - Electricity
   - Lighting
   - Mooring facilities
   - Life-saving equipment and ladders
   - Refuse collection and disposal, cleaning of tanks, wastewater tanks, oil-protection and fire-fighting equipment.

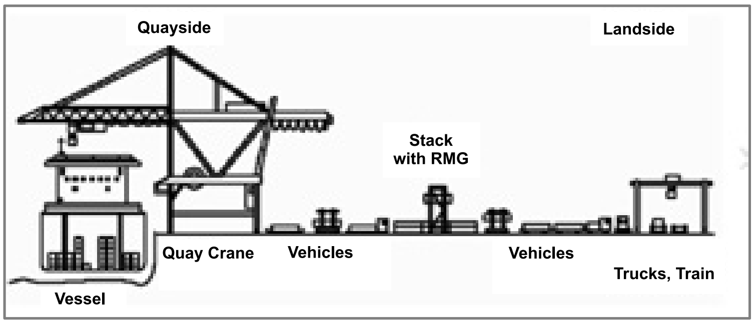

Fig.1: *Typical cross-section of a seaport*

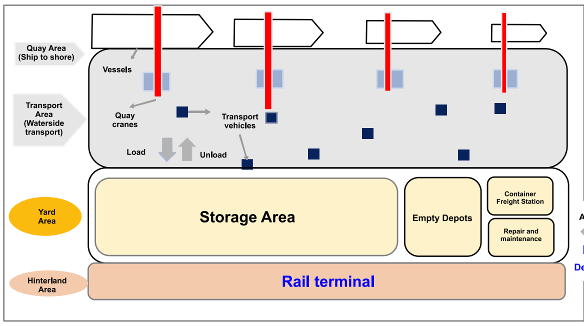

Fig. 2: *Typical layout plan of a seaport*

- Water and fuel bunkering
- Maintenance facilities
- Repair workshop

4.0 DESIGN CONSIDERATIONS WHEN DESIGNING A PORT OR COASTAL STRUCTURE

Potential sites for ports and harbour development must be examined to ensure that they meet the specific function of the port and the needs of various port users. A detailed investigation is often necessary and the examination shall provide sufficient information for the evaluation of the sites. The following considerations shown in Table 2 will form an integral part of the design:

Site Conditions	Topography Bathymetry: soundings Subsurface data: geologic history, soil properties, depth to rock, etc. Seismicity
Environmental Conditions	Meteorology: normal and extreme, wind forces and direction, rainfall, temperature Oceanography: normal and extreme waves, tidal and depth variations, current, ice, harbour surge, fogs and number of foggy days, water conditions etc. water chemistry (pH value, sulphate and chloride content, Degree of pollution, Visibility, Corrosion characteristics) Frequency and probability of storm conditions Environmental impact assessment
Operational Considerations	Vessel data, sizes, types, frequency, berth occupancy time, loading and servicing requirements Vehicle data, sizes, types, capacities, operating dimensions (turning radii, etc.) Trackage, cranes, loaders, railroad, capacity, weights, windage, gauge, speed, reach and swing, etc Special equipment, mooring hardware, capstans, loading arms, product lines, etc. Services and utilities, shore connections, fire protections and safety equipment, lighting and security, electrical power, piping light house, radio, radar etc. Cargo storage area
Functional Considerations	Dredging, scour and situation, propeller wash Vessel traffic and traffic control systems (VTS), Landside access, remoteness, roadways, airports, etc. Maintenance practices: cathodic protection, damage repair, etc.
Navigational Considerations	Channel depths and widths Vessels approach conditions Navigational-aids Availability of tugs
Constraints	Harbor and pier-head line Regulatory: water quality standards, oily ballast, dredge disposal, fill, etc Permits and licensing Availability of materials and equipment Existing facility: changed usage or upgrading limitations
Design Codes	European, American or British codes

Table 2: *General design considerations for marine facilities*

For a seaport, all the considerations listed above will apply. In the case of a dry port, a design engineer must be able to pick only items that are relevant for consideration.

5.0 THE ROLE OF STRUCTURAL ENGINEERING IN PORTS AND COASTAL WORKS

Structural engineering application in coastal and port structures helps to actualise the construction of port and coastal structures through thorough assessment of the structural, environmental and geotechnical conditions listed in Table 2. In order to achieve this, it is important that the design is based on the extreme possibility of occurrence of wind and waves; probable maximum height, force and intensity of waves; currents; tidal levels and nature of seabed for the foundation. Structural engineering also examines attendant forces and stresses exerted on the structure with the aim of providing stability and efficient performance throughout its design life, typically 50 to 100 years. Lower design life for temporary coastal structures to save cost can be agreed with clients.

Due to the extreme conditions affecting coastal structures, two primary factors must be considered in the selection and design of these structures. These include their structural stability criteria and functional performance criteria. The structural engineer will assess

> *"It is worth noting that structural engineers alone cannot design a port or coastal structure."*

available materials (locally or from manufacturers) that can withstand these extreme forces from port and coastal works and make decisions on best options.

6.0 KINDS OF STRUCTURES WHICH STRUCTURAL ENGINEERS ARE INVOLVED WITH IN PORT AND COASTAL WORK DESIGN

They include:

- Quay walls – steel or concrete sheet piles, fenders, bollards
- Capping beams
- Aprons
- Breasting or mooring dolphins
- Pipe and electrical racks
- Repair workshops
- Pipe or access bridges
- Slip ways
- Tank farms and silos
- Floating pontoons
- Breakwaters
- Sea walls
- Bulkheads
- Groynes etc.

Associated structures include:

- Warehouses
- Storage areas
- Hotels
- Transmission line and support structures
- Maintenance facilities like water treatment plants, sewage treatment plants, etc.
- Rigid pavement access roads with or without tollgates, signposts and support structures, culverts, manholes, etc.
- Operational buildings e.g. power houses, terminal buildings, boat houses, etc.

Fig. 3: *Coastal breakwater*

- Multi-storey car parks
- Weighbridges
- Customs and Immigration Formations

It is worth noting that structural engineers alone cannot design a port or coastal structure. In fact, the significance of geotechnical engineers, environmental engineers, petroleum engineers, pipeline engineers, geologists, surveyors etc. is very critical. Information provided by these disciplines contribute significantly to the quality of what the structural engineer's output will be. Collaboration among specialists in these specialised areas of science and engineering is important and vital to the success of a port and coastal project.

Due to very high cost of bringing all relevant professionals at initiation and planning stages of a port and harbour project, a small team of experienced port and harbour civil/structural engineers will have enough experience to conveniently make initial design decisions that can lead to an initial investment cost for the project.

Some agencies of Government in Nigeria provide support and critical data that contribute to successful design and construction of a port, harbour or coastal infrastructure. These agencies include but are not limited to:

- Nigerian Meteorological Agency (NiMET)
- Nigerian Port Authority (NPA)
- Nigerian Navy (NN)
- Nigerian Maritime Administration and Safety Agency (NIMASA)

7.0 SOME OF THE LOADS STRUCTURAL ENGINEERS WILL ENCOUNTER

These include the following which are also illustrated in Fig. 4:

i. **Environmental loads**
- Wind loads
- Wave loads
- Current forces
- Tidal loads & critical water levels
- Flood Loads

ii. **Live Loads**
- Vessel weights
- Crane wheel loads
- Surcharge loads
- Heavy duty trucks, forklift wheel loads

iii. **Horizontal loads**
- Bollard pull-out force on capping beams
- Fender forces on capping beams
- Mooring loads on mooring piles or dolphins
- Lateral loads from soil (excavation and backfilling)

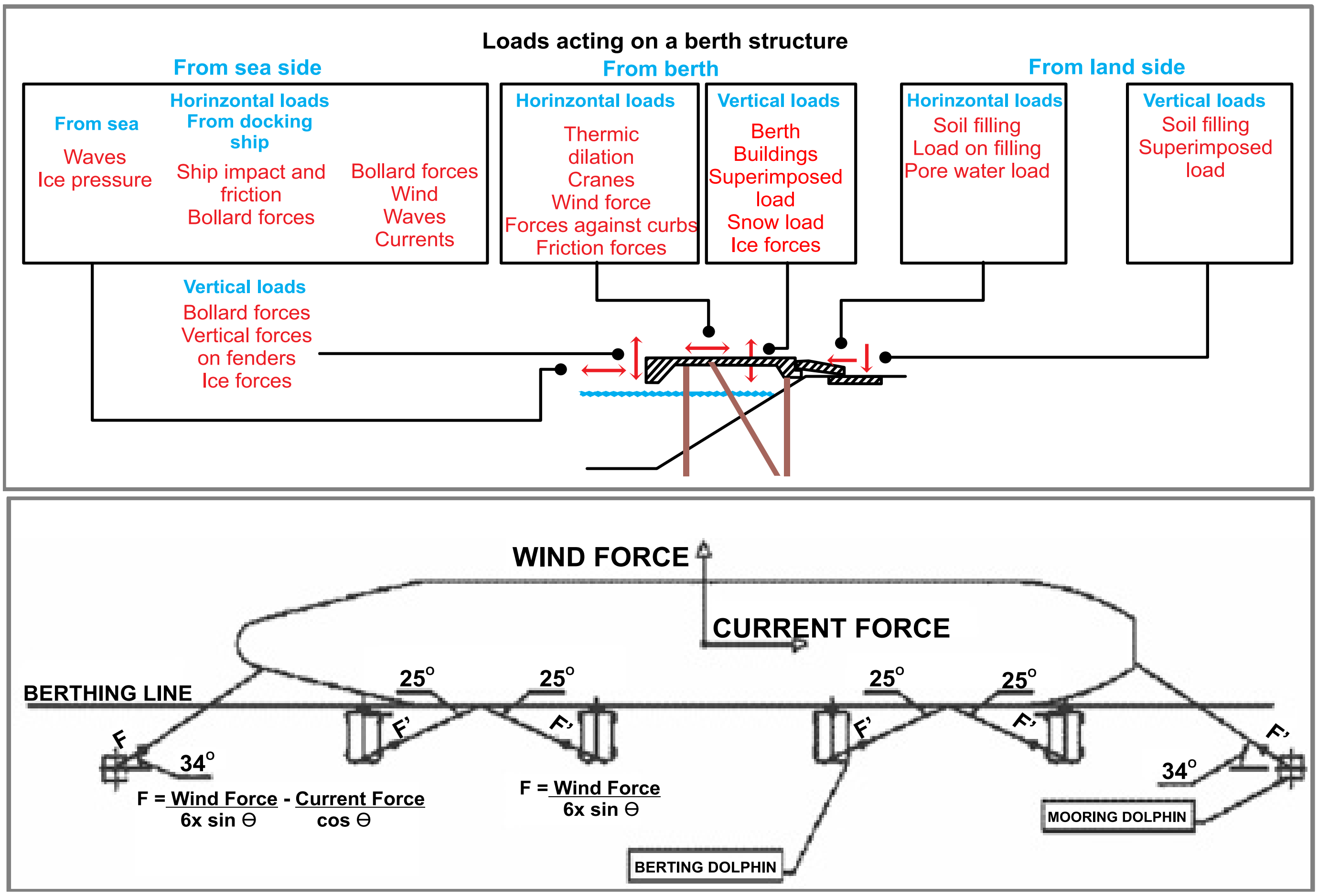

Fig. 4 & Fig. 5 *showing shore protection structures against waves.*

iv. Other loads

- Temperature
- Shrinkage
- Crack widths

8.0 DESIGN CODES AND GUIDES

Table 3 shows some structural engineering codes for ports and coastal works designs:

The list of codes above is not exhaustive. Many more codes and manufacturers' catalogues influence design of many port structural elements and coastal structures. Design engineers are responsible for sourcing this information to aid their designs. There are also specifications from Oil and Gas companies operating in Nigeria like "Shell Design and Engineering Practice (DEP)", "Total General Specifications (GS)" etc. that are very useful guides for use in designing these structures.

9.0 BUILDING INFORMATION MODELLING (BIM) AND STRUCTURAL SOFTWARE

Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM model is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle defined as existing from earliest conception to demolition. It is an intelligent model based process that connects AEC professions so that they can efficiently design, build and operate buildings and infrastructure through BIM tools. Dimensions in BIM include:

- 3D – Geometry of a structure
- 4D – Duration of a project and how the project

BS EN 1990:	Eurocode 0:	Basis of Structural Design
BS EN 1991:	Eurocode 1:	Actions on Structures
BS EN 1992:	Eurocode 2:	Design of Concrete Structures
BS EN 1993:	Eurocode 3:	Design of Steel Structures
BS EN 1994:	Eurocode 4:	Design of Composite Steel and Concrete Structures
BS EN 1997:	Eurocode 7:	Geotechnical Design
BS EN 1998:	Eurocode 8:	Design of Structures for Earthquake Resistance
BS EN 1999:	Eurocode 9:	Design of Aluminium Structures
EN 1536:		Execution of Special Geotechnical Works – Bored Piles
BS 6349:		Maritime Structures
BS 8081:		Ground Anchorages
BS 8500:		Concrete – Method of Specifying and guidance for the specifier
BS EN 13369:		Common rules for precast concrete
EAU 2004		Recommendations of the Committee for Waterfront Structures, Harbours and Waterways

Table 3: *Structural engineering codes for ports, coastal works.*

evolves over time
- 5D – Data analyses and cost estimation of the project
- 6D – Analyses of the energy consumption of a structure
- 7D – Operation and facility managements

In order to aid collaboration amongst several disciplines involved in the design of port structures, various Building Information Modelling (BIM) software options are available for use. These include:
- Autodesk BIM 360
- Autodesk Revit
- Tekla BIMsight
- Navisworks
- BIMx
- Archicad
- Vectoworks
- Geo 5
- Autodesk Civil 3D and many more

Due to advancement in technology, several structural software packages are now able to link many of the BIM software options. This way, the latest design output from several disciplines are available real time to a shared model by all. This reduces errors, makes collaboration easier and makes physical meetings less important. Models can be explained in video conferences using the latest technologies available such as Zoom, Microsoft Teams and Google Meet, etc in real time.

Many of the structural software package options available are finite element software with capabilities to analyse complex forms and shapes. Some come with pre-loaded structures as samples. Examples include but are not

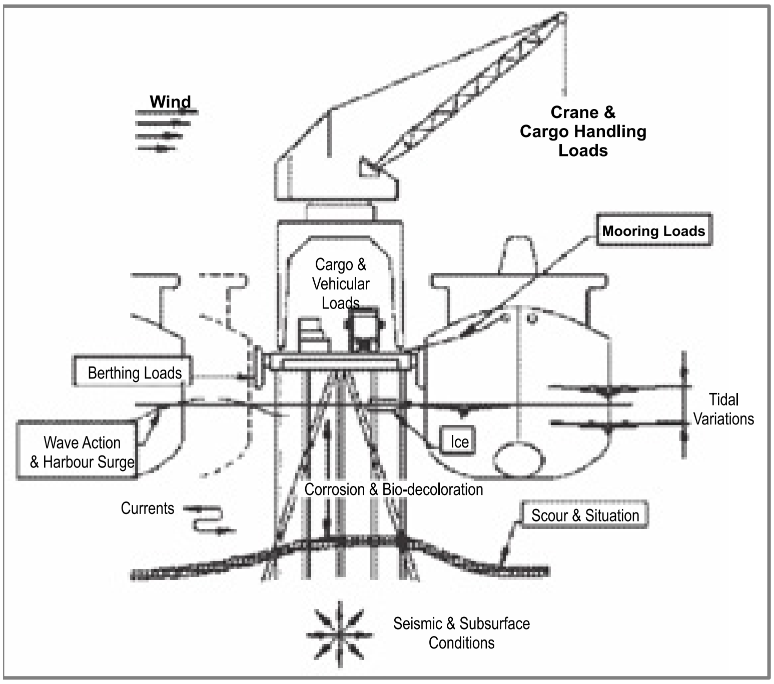

Fig. 6: *Different actions on port and coastal structures*

limited to SOFiSTik, SACS, ROBOT Structural Analysis Software, STAAD Pro, TEKLA, etc.

Many port and harbour structures can be modelled and analysed using these software packages to very high degree of accuracy. Fortunately, these structures are made of concrete, steel, composite or aluminium. This means many of the software packages are capable of modelling them. A good structural engineer interested in designing ports, harbours and coastal structures has to be acquainted with many of these available tools to enhance his work and take decision faster.

10.0 CONCLUSION

From the article, it is very clear to see and understand the applications of structural engineering in ports, harbours and coastal works. Improved knowledge of structural engineering and many other science and engineering disciplines over many decades has been a critical factor that has made the growth and expansion of coastal areas around the world possible.

Fig. 7: *Nearshore breakwater shore protection*

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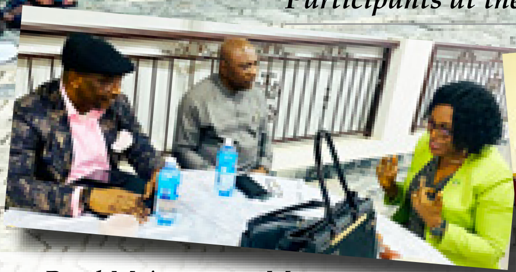
ASCE IN-HOUSE TRAINING

4TH – 8TH OCTOBER 2022

Participants at the in-house training.



*(R - L): Director, Road Maintenance Management Services, FERMA, Engr. Ini Usoro; Engr. Felix Atume FNSE and Engr. Barry Esimone FNSE, both facilitators at the in-house training on '**Highways, Geotechnics, and Quality Control**'.*

ACEN ZONE 3 Coordinator, Engr. Samson Opaluwah FNSE (Centre) flanked to the left by Engr. Felix Atume and to the right by Engr. Barry Esimone.

ACEN BUSINESS EVENING

25TH OCTOBER 2022

Cross-section of delegates at the event.

Engr. Fyne Chima Ogolo, introducing the Guest Speaker at the event, Engr. George C. Okoroma, FNSE, JP.

The ACEN President, Engr. F. Ajibade Oke, FNSE presenting an appreciation plaque to the Guest Speaker at the event, Engr. George C. Okoroma, FNSE, JP.

AGM 2022

2ND – 3RD NOVEMBER 2022

The ACEN Managing Director, Engr. Kalejaiye Sunday, MNSE introducing guests at the 2022 AGM Opening Ceremony.

The ACEN President, Engr. F. Ajibade Oke, FNSE giving a welcome address.

(L – R): Engr. Adedamola Kuti, (representing Hon. Minister of Works and Housing, His Excellency, Babatunde Raji Fashola, SAN); Engr. (Mrs.) Mayen Adetiba, FNSE, FAEng, (Past President of ACEN); Engr. (Dr.) J. I. Folayan, FNSE (Past President of ACEN), COREN President, Engr. Ali A. Rabiu, FNSE; Bldr (Mrs.) Sikirat Adenike Sa'id, FNIOB (representing Chairman, Council of Registered Builders of Nigeria, CORBON, Bldr. Samson Ameh Opaluwah, FNIOB, FNSE, and ACEN President, Engr. F. Ajibade Oke, FNSE at the launch of ACEN's Book of Projects titled "Consulting Engineering in Nigeria".

Cross-section of delegates at the event.

2022 AGM Planning Committee and Guest Speaker Technical Session (L – R) ACEN Managing Director, Engr. Kalejaiye Sunday, Engr. Kehinde Adebara, Engr. Chris Eneh, ACEN President, Engr. F. Ajibade Oke, FNSE, Guest Speaker Technical Session, Mr. Ogundele Adurayemi Ayodeji, Engr. Adedotun Adesina, Engr. Elizabeth Olaogun and the Chairman 2022 AGM Planning Committee, Engr. Olukoya Babatunde.

Mr. Chudi Okafor, representative of Vacc Technical Ltd. – ACEN 2022 AGM Partner

Mr. Vinoth Kandasamy Sankar, representative of LG Electronics – ACEN 2022 AGM Partner.

FGN IN-HOUSE TRAAINING

6TH & 7TH OCTOBER 2022

Vice Chair of FIDIC Contracts Committee and FIDIC Certified Trainer, Mr. Husni Madi, at the in-house training on the 'Practical Use of the 2017 Yellow and Silver Books with Highlights of the 1999 Editions.'

Some of the participants at the in-house training.

APPLICATION OF CODES IN STRUCTURAL ENGINEERING DESIGN OF BUILDINGS

BY ENGR. (DR.) VICTOR O. OYENUGA

Engr. (Dr.) Victor O. Oyenuga, PPNIStructE, FNSE, FNIStructE, FNICE, FNIHTE, MNIOB
CEO, Vasons Concept Consultants Ltd

1.0 INTRODUCTION

Structural and Civil Engineers deal with forces of nature which can only be predicted to a reasonable extent. For example, if a 100year rain falls within a short span of time (say 1 month1) at the site where a dam designed for 50year rain is situated, a significant damage may occur. However, because of intensive research, experimental and observational data, a level of confidence has been achieved in virtually all aspects of civil/structural engineering to such a level that a 'near certainty' can be achieved. These activities led to the formulation of Codes and Standards to assist in achieving the desired results and offer designs and constructions that can easily be checked by peers.

Codes of Practice or Standards can be defined as a set of written regulations issued by a professional association or an official body that explains how people working in a particular profession should be guided. A Code of Practice helps workers in a particular profession to comply with ethical, safe and healthy standards. The Design and Construction Standards consist of the Design Criteria, Technical Specifications and Supplemental Standards (Project Specifics).

These Codes and Standards must be followed in carrying out design work for such designs to be acceptable. Any designer that is deviating from laid down Codes and Standards must be able to prove, without doubts, that such a design is workable.

In the area of Structural Engineering Design of Buildings, the author has had the opportunity of being educated in the subject matter and has been using the following codes or standards in the practice of structural engineering designs of buildings:

- CP1114 based on Elastic Method of Design
- Load Factor Method of Design
- CP 110 based on Limit States Method of Design
- BS 8110 based on Limit States Method of Design
- Eurocode 2 based on Limit States Method of Design

The current Design Code for Building Structure is the Eurocode 2 known as EN 1992: Eurocode 2 – Design of Concrete Structures. Design textbooks are now available on this subject matter for the practitioners to use including Simplified Reinforced Concrete Design to Eurocode 2, published by Vasons Concept Consultants Ltd written by Engr. Victor Oyenuga.

2.0 EXISTING CODES FOR STRUCTURAL ENGINEERING DESIGN OF BUILDINGS

The codes and standards for purposes of structural engineering designs of buildings are discussed below.

2.1 BS CP 114

ELASTIC THEORY METHOD

BS CP 114, 69th Edition, April 30, 1985 - Structural Use of Reinforced Concrete in Buildings. This deals with reinforced concrete, design and construction as applied to beams, slabs, columns, flat slab construction, walls and bases in buildings. Also, it deals with floors, roofs and stairs. The recommendations cover materials, strength requirements and permissible stresses in steel and concrete. Methods for assessing bending moments and other stresses in the various members; permissible loads on columns are included. This is based on working loads, working stresses of materials as well as the elastic state of the materials of construction.

LOAD FACTOR METHOD

Load factor is a ratio of the theoretical design strength to the maximum load expected in service. They are used in structural analysis to determine the design strength and compare it with maximum loads.

Load factors are developed to help achieve the desired level of reliability of a structure based on probabilistic studies that take into account the load's originating cause, recurrence, distribution and static or dynamic nature.

In structures, loads cause stresses, deformations and displacements. Assessment of their effects is carried out by the methods of structural analysis with the help of load factors. Excess load may cause structural failure, and hence such possibility should be considered in the design.

Loads are increased by load factors to meet the requirement that design strength be higher than maximum loads. For example, in designing a staircase, a dead load factor may be 1.2 times the weight of the structure, and a live load factor may be 1.6 times the maximum expected live load. These two "factored loads" are combined (added) to determine the "required strength" of the staircase.

2.2 BS CP 110

BS CP 110-1, 72nd Edition, May 1977 - Code of Practice for the structural use of concrete Part 1. Design, materials and workmanship.

This code deals with the design, materials and construction of buildings and structures in reinforced concrete, pre-stressed concrete and precast concrete. It is written in limit state terms. Guidance is given on the specification and workmanship of concrete, the inspection and testing of structures and the fire resistance of various forms of construction. The last edition (72nd) was published in 1977 and the Code was superseded by BS 8110 in 1985.

2.3 BS 8110

BS 8110 is a withdrawn British Standard for the design and construction of reinforced and pre-stressed concrete structures. It is based on limit state design principles. Although used for most civil engineering and building structures, bridges and water-retaining structures are covered by separate standards (BS 5400 and BS 8007). The relevant committee of the British Standards Institute considers that there is no need to support BS 8110.

In 2004, BS 8110 was replaced by EN 1992 (Eurocode 2 or EC2). In general, EC2, used in conjunction with the National Annex, is not wildly different from BS 8110 in terms of the design approach. It gives similar answers and offers scope for more economic structures. Overall EC2 is less prescriptive, and its scope is more extensive than BS 8110 for example in permitting higher concrete strengths. In this sense the new code will permit designs not currently permitted in the UK, and thus give designers the opportunity to derive benefit from the considerable advances in concrete technology over recent years.

2.4 EUROCODES

The development of the formulation of the Eurocodes started in 1975 when the Member States of the Commission of the European Community decided on an action program in the field of construction based on the Article 95 of the Treaty. The objective of the program was to eliminate technical obstacles to trade and harmonization of technical specifications. The harmonized technical rules were to eventually replace the member countries' national rules or specifications.

In 1989, the Commission, EU and other relevant organizations decided to transfer the preparation and publication of the Eurocodes to CEN (Comite European de Normalization OR European Committee on Standardization). This is done through a series of Mandates, to provide them a future status of European Standard (EN).

The resulting Structural Eurocodes program generally consists of a number of parts as detailed in Table 1 and as listed in Eurocode - Basis of Structural Design.

"

In 1989, the Commission, EU and other relevant organizations decided to transfer the preparation and publication of the Eurocodes to CEN...

"

Concrete is a very strong and economical material that performs exceedingly well under compression. Its weakness lies in its capability to carry tension forces and thus has its limitations. Steel, on the other hand, is slightly different; it is similarly strong in both compression and tension. Combining these two materials means engineers would be able to work with a composite material that can carry both tension and compression forces.

S/N	Codes & Years	Eurocodes	Descriptions
1.	EN 1990	Eurocode	Basis of Structural Design
2.	EN 1991	Eurocode 1	Actions on Structures
3.	EN 1992	Eurocode 2	Design of Concrete Structures
4.	EN 1993	Eurocode 3	Design of Steel Structures
5.	EN 1994	Eurocode 4	Design of Composite Steel and Concrete Structures
6.	EN 1995	Eurocode 5	Design of Timber Structures
7.	EN 1996	Eurocode 6	Design of Masonry Structures
8.	EN 1997	Eurocode 7	Geotechnical Design
9.	EN 1998	Eurocode 8	Designof Structures for Earthquake Resistance
10	EN 1999	Eurocode 9	Design of Aluminium Structures

Table 1: *Eurocodes Releases*

Eurocode 2 is intended to be used in conjunction with:

- EN 1990: Eurocode - Basis of structural design
- EN 1991: Eurocode 1 - Actions on structures
- EN 1997: Eurocode 7 - Geotechnical design
- EN 1998: Eurocode 8 - Design of structures for earthquake resistance, when concrete structures are built in seismic regions
- Codes for: Construction products relevant for concrete structures and execution of concrete structures

2.5 NIGERIAN CODES OF PRACTICE

As far back as 1973, the Standard Organization of Nigeria (SON) had in store Codes of Practice for Structural Design. The most popular is NCP 01: 1973, Parts 1 and 3. The comprehensive list includes:

- NIS 197: Specification for structural steel
- NCP 01:1973 Structural use of concrete in building Part l
- NCP 01:1973 Loading. Part 3
- NIS 156: Standard method of testing fresh concrete
- NIS 12:1974: Methods of testing concrete
- NIS 13:1974: Specification for aggregates from natural source for concrete
- NIS 117:1992: Steel bars for the reinforcement of concrete
- NIS 87:2000: Specification for sandcrete blocks

The application of these codes just like other international codes can be found in:

- Loading and Load Combinations
- Allowable Material Stresses and Capacities
- Choice of Foundation
- Allowable Serviceability Limits
- Building Structural Element Design
- Floors, Beams, Columns & Foundations
- Reinforcement Detailing – fitting together the structure.
- Falsework & other construction consideration

Unfortunately, these codes are not popular in the design of concrete structures and the current softwares for design are also not in support of these codes. All hope is not lost, most Commonwealth countries have adopted the Eurocodes as currently released and produced National Annexes which are complementary to Eurocodes and suitable for use in their countries. This is what is expected of Nigeria now.

The next Section will be devoted to the current code, Eurocode 2 and with a table to show the differences between the BS 8110 and Eurocode 2.

3.0 EUROCODE 2 (EC 2)

In the Eurocode series of European standards (EN) related to construction, Eurocode 2: Design of concrete structures (abbreviated EN 1992 or, informally, EC 2) specifies technical rules for the design of concrete, reinforced concrete and prestressed concrete structures, using the limit state design philosophy. It was approved by the European Committee for Standardization (CEN) on April 16, 2004 to enable designers across Europe to practice in any country that adopts the Code.

3.1 PURPOSES OF EUROCODES

The Eurocodes are to serve as reference documents for the following purposes:

> ***"These are generally recognized rules which comply with the Principles and satisfy their requirements."***

i. To prove compliance of building and civil engineering works with the essential requirement of the regulatory council requirements
ii. As a basis for specifying contracts for construction works and related engineering services
iii. As a framework for drawing up harmonized technical specifications for construction products

The Eurocode Standards provide common structural design rules for member countries and for everyday use for the design of whole structures and component products thereof of both traditional and innovative nature. Unusual forms of construction or design conditions are not specifically covered, and additional expert considerations will be required by the designer in such cases.

3.2 ASSUMPTIONS FOR USE OF EUROCODES (CL 1.3P, EC2)

In the use of Eurocodes, the following important assumptions were made:

i. The choice of the structural system and the design of the structure is made by appropriately qualified and experienced personnel.
ii. The execution of the structure is carried out by personnel having the appropriate skill and experience.
iii. Adequate supervision, quality control is provided during execution of the works in the design office, at the fabrication yard and on site.
iv. The construction materials and products are in line with approved appropriate standards.
v. The Structure will be used in accordance with the design assumptions.

3.3 PRINCIPLES AND APPLICATION RULES (CL 1.4P AND EN:1990)

In order to produce design documents which are precise, complete with detailed charts for guidance, the clauses in the Eurocodes are divided into Principles and Application Rules. The Principles comprise:

i. General statements and definitions for which there is no alternative
ii. Requirements and analytical models for which no alternative is permitted unless specifically stated

These are generally recognized rules which comply with the Principles and satisfy their requirements. These are clauses without the letter 'P'.

The use of alternative application rules to those recommended in the Eurocodes are permitted provided it can be shown that the alternatives are at least equivalent and do not adversely affect other design requirements. It is worth noting, however, that if an alternative Application Rule is used the resulting design WILL NOT BE DEEMED Eurocode compliant.

3.4 NATIONALLY DETERMINED PARAMETERS AND NATIONAL ANNEXES

The possible differences in construction materials/products, design, construction practices and regional differences in climatic conditions serve as parameters for nationally determined codes. A particular application rule may be proposed in line with wind and extreme climate in the north including the use of partial safety factors the design. Where a national choice is allowed, this should be indicated in a note in the normative text under the relevant clause. The note may include the recommended value of the parameter, or preferred method, etc., but the actual value, methodology, etc., to be used in a particular country must be given in an accompanying National Annex. The recommended values of these parameters and design method / procedures are collectively referred to as Nationally Determined Parameters (NDPs). The NDPs determine various aspects of design, but perhaps most importantly the level of safety of structures during execution (construction/fabrication) and in-service, remains the responsibility of the country.

3.5 APPLICATION OF EUROCODE 2

Concrete is a very strong and economical material that performs exceedingly well under compression. Its weakness lies in its capability to carry tension forces and thus has its limitations. Steel on the other hand is slightly different; it is similarly strong in both compression and tension. Combining these two materials means engineers would be able to work with a composite material that can carry both tension and compression forces.

Eurocode 2 is intended to be used in conjunction with:

- EN 1990: Eurocode - Basis of structural design
- EN 1991: Eurocode 1 - Actions on structures
- EN 1997: Eurocode 7 - Geotechnical design
- EN 1998: Eurocode 8 - Design of structures for earthquake resistance, when concrete structures are built in seismic regions
- Codes for: Construction products relevant for concrete structures and execution of concrete structures.

Eurocode 2 is subdivided into the following parts:

1. Part 1-1: General rules and rules for buildings:
   1.1 Pre-design
   1.2 Ultimate limit state
   1.3 Serviceability limit state
   1.4 Contents
2. Part 1-2: Structural fire design
3. Part 1-3: Precast Concrete Elements and Structures
4. Part 1-4: Lightweight aggregate concrete with closed structure
5. Part 1-5: Structures with unbonded and external prestressing tendons
6. Part 1-6: Plain concrete structures
7. Part 2: Reinforced and pre-stressed concrete bridges
   7.1 Contents
8. Part 3: Liquid retaining and containing structures
9. External links

3.6 THE MAIN DESIGN CODE: PART 1-1: GENERAL RULES AND RULES FOR BUILDINGS

EN 1992-1-1 deals with the rules and concepts required for designing concrete, reinforced concrete and prestressed concrete structures. There are three main stages that are involved in the design of elements in these structures:

i. **Pre-design:** Before any other designing is undertaken, the limit states of durability and fire design are considered to ascertain the required cover to the reinforcement, the minimum size of members and the appropriate concrete strength. Pre-design stage involves selecting initial section sizes (e.g., reinforcement diameter), from which the minimum required cover depth could be selected to attain the required fire resistance. Although these initial estimates are likely to change throughout the design, giving considerable amount of thought at this stage is likely to save a lot of time later.

ii. **Ultimate limit state:** Accurate section sizes are determined for corresponding concrete properties (usually compressive strength). The size of the reinforced concrete element and the quantity of reinforcement to resist bending, shear and torsional forces are determined. Ultimate limit states are often more critical for concrete structures. Consequently, when design is undertaken, the ultimate limit state is designed for and then, if necessary, serviceability is checked for. However, element sizes ascertained in the pre-design stage usually ensure serviceability criteria are met.

iii. **Serviceability limit state:** In this phase of the work, checks are made to ensure the serviceability criteria (i.e. that the building is comfortable to use) are met. Serviceability requirements to check for deflection and crack widths are generally satisfied by observing the following details:
   a. Checking and keeping within permitted span/effective depth ratios
   b. Providing not less than the minimum permitted percentage of reinforcement
   c. Limiting the spacing of tension reinforcements
   d. Using “deemed to satisfy” empirical methods

If actual deflections are required, then the structure must be analyzed for the serviceability limit state, using design service loads. The deflections obtained will generally be short term values and will be multiplied by a suitable factor to allow for creep effects and to give realistic long-term values.

> ***“EN 1992-1-1 deals with the rules and concepts required for designing concrete, reinforced concrete...”***

ITEM	DESCRIPTION	BS 8110	EC2
1.	Concrete strength	Based on Cube Strength, fcu	Based on Cylinder Strength, fck which is approximately 0.8fcu, for example, C20/25
2.	Steel Strength	Taken as fy of 250, 410 and 460N/mm2.	Taken as fyk ranges between 400 and 600MPa (Note: 1.0N/mm2 = 1.0MPa).
3.	Lever arm limit	Here is limited to 0.776 before compression steel is required.	Here is limited to 0.82before compression steel is required.
4.	Moment of Resistance of a concrete beam	Mu = 0.156fcubd2	Mbal = 0.167fckbd2.
5.	K - value	K = ≤ 0.95 [illegible]2	K = ≤ 0.95 [illegible]2
6.0	Lever arm factor	[illegible] = 0.5 + √0.25 − [illegible]/0.90	[illegible] = 0.5 + √0.25 − [illegible]/1.134
7.0	Area of Steel	As = 0.95[illegible]	As = 0.87[illegible]
8.0	Shear	Calculate, V and [illegible] = [illegible] [illegible] Check for vconc. and design for stirrups by calculating the shear links from: [illegible]0.95[illegible] [illegible] = [illegible] ([illegible] − [illegible]) [illegible] [illegible]	Calculate VRd,max assuming [illegible] = 22. 0[illegible] from VR withd,max = 0.124bwd(1-fck/250)fck and compare the design shear, VEd; If VRd,max ≥ VEd, the design can proceed using [illegible] = 22o and cot [illegible] = 2.5. The shear links required is calculated from: s = [illegible](0.78[illegible]) [illegible]
		A_{sw} = the cross-sectional area of the shear stirrups- a minimum of two legs and multiple thereof. s = the spacing of the stirrups required. f_{yk} = the characteristic strength of the stirrup reinforcement VEd = the shear force due to the loads at the ultimate limit state VRd,s = the shear resistance of the stirrups $V_{Rd,max}$ = the maximum design value of the shear which can be resisted by the concrete strut.	
9.0	Span/Effective Depth Ratio.	Simple table to pick from.	More complex table involving a K factor and the level of reinforcements in the section.
10.0	Deflection	Less cumbersome	More cumbersome

Table 2: *Some differences between BS8110 and EC 2*

The contents of the main design code are divided into:

i. General
ii. Basis of design
iii. Materials (concrete and steel) including
   a. Concrete
   b. Reinforcing steel
   c. Prestressing steel
iv. Durability and cover to reinforcement
v. Structural analysis
vi. Ultimate limit states
vii. Serviceability limit states
viii. Detailing reinforcement and prestressing tendons
ix. Detailing members, and particular rules
x. Precast elements - additional rules
xi. Lightweight aggregated concrete structures
xii. Plain and lightly reinforced concrete structures

3.7 STATISTICAL AND FORMULAS COMPARISON

Though based on the same principle of limit states, there are some statistical and equation related expression differences in design according to BS 8110 and EC 2. Some of these are illustrated in Table 2 using the design of a beam as an example.

Table 2 shows some of the major differences in the two codes. Relevant literature for details on the application of these equations and tables for proper design of structures are available for further information.

Fig.1: *Babcock University Stadium design to BS 8110*

4.0 EXAMPLE: DOUBLY REINFORCED BEAM

A simply supported beam carries an all-inclusive ultimate load of 85kN/m and the beam is 6.0m effective length. Design the beam using fck = 20MPa (equivalent to fcu of 25MPa) and fyk = 410MPa. Solution 1:

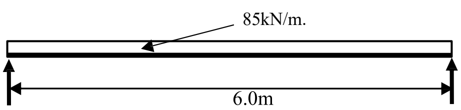


Fig. 2: *The beam configuration*

Moment:

Using 450mm by 230mm beam.

$M = 0.125(85)6.00^2 = 382.50$kN.m.

$M_u = 0.167 \times 230 \times 405^2 \times 20$N.mm.= 126.004kN.m., too low, hence, increase beam to 600mm by 230mm (on the average, take beam

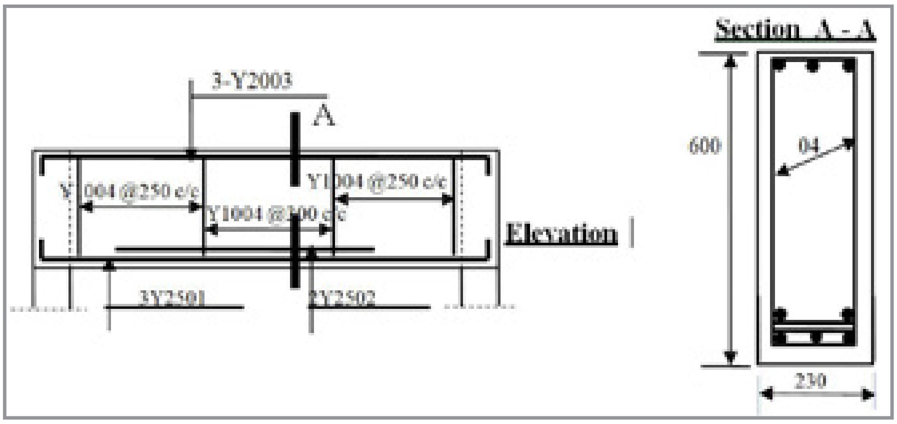


Fig. 3: *Beam details*

depth to be about 10% of effective span) and:
M_u = 0.167 x 230 x 5502 x 25 = 232.38 kN.m.

K = $\frac{382.500 \times 10}{20 \times 230 \times 550^2}$ - 0.275

Thus, K > K' of 0.167, hence, design for compression and tension reinforcements.

Steel in Compression:

As' = $\frac{(382.500 - 232.38)10^6}{0.87(410)(550-50)}$ = $842mm^2$

z' = 550 (0.5 + √(0.25 - $\frac{0.167)}{1.134)}$ = 451mm

Steel in Tension:

As = $\frac{232.38 \times 10}{0.87(410)451}$ 842 = 1444+842 = 2286mm2

Provide 5-Y25mm bars Btm. ($2455mm^2$)
Provide 3-Y20mm bars Top ($942mm^2$)

Shear:

Design shear,
V_{Ed} = 0.5 (6.0) 85 = 245.225kN.

$V_{Rd,min}$ = 0.124(230)550(1-20/250)20 x 10^{-03}kN
= 288.622kN > 245.225kN OK

s = $\frac{157(0.78 - 550 - 410 - 2.5)}{245.225}$ = 282mm

Provide Y10mm at 250c/c (2legs)

Minimum Shear

Calculating the minimum shear, we have:

A_{sw} = $\underline{0.08\sqrt{xxx}}$ = $\underline{0.08xxx20}$ = 0.200 xxx
410

And the shear resistance for the links actually specified,

$V_{min} = A_{sw}/s \times 0.78 \times d \times f_{yk} \cot\theta$
= 0.20(0.78)(550)(410)(2.5) = 88.25kN

By similar triangle theory, this will be 88.25/255 x 3 = 1.04m from the support centroid.
Thus Provide Y10mm at 300mm c/c for the middle 2.0m band.

Detailing: The bar details are as shown in Figure 2.

5.0 CONCLUSION

The application of relevant Codes of Practice or Standard is a MUST in the design of building structures (See Fig.1). The Engineer is advised to get himself familiar with the current code and allow the client to enjoy the benefits inherent in the current code or standard. A beam design based on the current EC 2 is illustrated as a typical example of design based on Eurocode 2. What is normally done is that the existing code and the new code are allowed to be used for a period of 3 years before the old code is completely phased out and becomes illegal for use.

" A beam design based on the current EC 2 is illustrated as a typical example of design based on Eurocode What is normally done is that the existing..."

FURTHER READINGS

1. *Eurocodes – EN 1990, EN 1991 and EN 1992*
2. *Simplified Reinforced Concrete Design by Victor O. Oyenuga, 3rd Edition, Vasons Concept Consultants Ltd, Lagos*

"THE CONSULTING ENGINEER" PERSONALITY

ENGR. (DR.) VICTOR OLUSEGUN OYENUGA FNSE

(CEO, VASONS CONCEPT CONSULTANTS LTD)

Engr. (Dr.) Victor Olusegun Oyenuga was born in the Babcock University town of Ilishan-Remo, Ogun State of Nigeria on March 20, 1955. He had his primary school education at Wesley School, Ilishan-Remo (1961 - 1967) and secondary school at Remo Divisional High School, Sagamu (1968 - 1972). In 1973, he proceeded to Yaba College of Technology, Yaba, Lagos and obtained ND and HND in Civil Engineering and Building in 1975 and 1978 respectively. He sat for the Licentiate Examinations of the Institute of Building, Ascot, UK in 1976 and he was reported by the Institute to have gathered the greatest number of distinctions in the examinations in United Kingdom and overseas. He was the best graduating student of the College in the 1978 session and won the Shell BP Award for the best student of the college.

Engr. (Dr.) Victor Olusegun Oyenuga, FNSE, PPNIStructE, FNICE, FNIHTE, MNIOB

In 1979, after his service year in the National Youth Service Scheme, he enrolled at the University of Lagos, Akoka, Lagos, and he finished his Bachelor's programme in Civil Engineering in 1981 in the First Class Division. In 1983, he proceeded to the famous Imperial College of Science, Technology and Medicine, University of London where he distinguished himself as one of the best three graduating students in 1984 in the MSc, DIC Public Health Engineering Class.

He started his teaching experience in 1979 as an Instructor at Yaba College of Technology and left teaching in 1989 as a Senior Lecturer and Acting Head of Department of Civil Engineering, Lagos State Polytechnic, Ikorodu (formerly, at Isolo), Lagos). In 1988, he upgraded the Civil Engineering Laboratories and prepared the program for National Board for Technical Education (NBTE) accreditation which was achieved that year. For many years, Engr. Victor Oyenuga served as External Examiner for NBTE Program in many polytechncs, namely Yaba College of Technology, Yaba-Lagos, Lagos State Polytechnic, Ikorodu, Federal Polytechnic, Ilaro, Ogun State and Federal Polytechnic, Ede, Osun State. He was one of those that drafted the syllabi for Civil Engineering Technology Program at Federal Polytechnic, Ilaro, in 1985.

PROFESSIONAL PRACTICE

Engr. Victor Oyenuga joined Messrs Vasons Concept Group as a Technical Officer in 1976 and has been with the firm except the periods he was away for studies and the short period he spent in teaching as a full-time lecturer. He became a Partner in the firm in 1991. In this firm he has executed and played a leading role in many major engineering designs including the Teslim Balogun Stadium Complex, Surulere, Lagos; Ikeja Plaza, Ikeja; faculty buildings, stadium complex, road and water reticulations networks and students' hostels of Babcock University, Ilishan-Remo; many roads and infrastructural projects for the Federal Ministry of Works and Federal Capital Development Authority including the engineering design of infrastructure for Kyami District (Zone C), now under construction, to mention but a few.

Engr. (Dr.) Victor Oyenuga has presented papers in many engineering fora including the International Conference and Annual General Meeting of the Nigerian Society of Engineers; Association for Consulting Engineering in Nigeria (ACEN); and that of the Nigerian Institution of Structural Engineers (NIStructE) in the areas of civil/structural engineering design and computer applications. He has developed few computer programs for analysis

> **"He had contributed immensely in the areas of text book publications..."**

and designs of structural elements (including RCD2000) for the use of his firm and other consultants. He has also facilitated many courses for ACEN and NIStructE and presented many papers over Zoom for The Nigerian Institution of Civil Engineers – 3 Nos in 2021 alone.

PROFESSIONAL AFFILIATIONS AND PUBLICATIONS

Engr. (Dr.) Oyenuga passed his professional examinations of the Council for the Regulation of Engineering in Nigeria (COREN) in 1985. The immediate approval of his registration by COREN Council was affected by dissolution of the Council by the Federal Government at that time. He finally got registered in 1988 when COREN Council was re-constituted. Engr. Oyenuga is a Fellow of the Nigerian Society of Engineers, Nigerian Institution of Structural Engineers (also a Past President – 2009/2011), Nigerian Institution of Civil Engineers and Nigerian Institution of Highway and Transportation Engineers. He is a corporate member of the Nigerian Institute of Building (NIOB). He served on the Regulation and Control Committee of COREN for 8 years as a member of the NSE Board of Fellows for the past 11 years and many times examiner for COREN, NSE and NIStructE. He was also a member of the 5th Board of the Council of Registered Builders of Nigeria (CORBON, 2013 – 2017) as a Registered Builder.

He has contributed immensely in the areas of text book publications and this effort including his long term experience earned him the Honoris Causa of Doctor of Science Degree in Structural Engineering.

The publications are:

i. Today's Fortran 77 Programming
ii. Simplified Reinforced Concrete Design (now in 3rd Edition – Eurocodes)
iii. Design and Construction of Foundations (now in 3rd Edition – Eurocodes)
iv. Concise Reinforced Concrete Design (2nd Edition – BS8110)

He is a major facilitator in courses ran by ACEN, NIStructE and NIOB in the areas of road design and design of reinforced concrete structures.

AWARDS

He has gathered to his credit several awards from the following organizations:

a. Remo Divisional High School, Sagamu, Old Students Association – President 1986/1987
b. The Nigerian Society of Engineers (NSE)
c. The Nigerian Institution of Structural Engineers (NIStructE)
d. The Nigerian Institution of Civil Engineers (NICE).
e. The Nigerian Institution of Highway and Transportation Engineers (NIHTE)
f. The Nigerian Institute of Building (NIOB)
g. The Association for Consulting Engineering in Nigeria (ACEN)
h. Building Collapse Prevention Guild
i. Babcock University, Ilishan Remo
j. The Seventh-Day Adventist Church in Nigeria
k. Construction Industry Hall of Fame in 2017

POSITIONS OF RESPONSIBILITIES

1. MD/CEO: Vasons Concept Consultants Ltd – 2005 to date
2. Partner: Vasons Concept Group – 1991 to 2004
3. Member, 5th Board, Council Of Registered Builders Of Nigeria (CORBON) – 2013/20117
4. Twice Council Member, Association for Consulting Engineering in Nigeria (ACEN)
5. Chairman Training Committee of ACEN
6. President, The Nigerian Institution of Structural Engineers – 2009/2011
7. Member, Board of Fellows, Nigerian Society of Engineers – 2011 to Date
8. Member, Regulation and Control Committee (now, ERM) of COREN – 8 years running
9. Member. Codes and Standards Committee of COREN – 2020 to date
10. Deputy President, Vice President, Honorary Secretary – 1999 to 2009 except 2004/2005
11. Chairman of various Committees of NIStructE from 2011 to date
12. Assistant Secretary, Exco Member etc., Civil Division (now NICE) – 1989 to 1999
13. Member, of various Committees of CORBON, NSE, NIStructE, NICE and ACEN

He is married and the good Lord blessed the family with children. One of the children, Emmanuel, is a Registered Civil/Structural Engineer. They are members of the Seventh Day Adventist Church in Nigeria.

A WORD FOR YOUNG ENGINEERS

BY ENGR. (DR.) VICTOR OLUSEGUN OYENUGA

I find it a great privilege to use this medium to address young engineers again. This, I have done several times through lectures during 'Engineering Weeks', through Zoom discussions and my series of textbooks are training materials for the development of the young ones especially in the field of Civil Engineering. I am part of a lucky breed in the sense that I have the background of being a Craftsman (by virtue of being a son of a carpenter and I had the opportunity of learning the trade under my father, though I did not really practice it); a Technician by virtue of my ND in Civil Engineering and Building; an Engineering Technologist with HND in Civil Engineering and Building and a Registered Engineer based on my BSc Civil Engineering degree and COREN registration. In the course of my training too I became a Registered Builder. I am also a former Council Member of the Council of Registered Builders of Nigeria (CORBON). At this juncture, let me make the following points for young engineers to note.

Engr. (Dr.) Victor Olusegun Oyenuga, *FNSE, PPNIStructE*

i. Congratulations: Yes, Congratulations for the great opportunity to be one of the sources of developments in the nation. Engineering is said to be 'Development' and Engineers make this to happen. Welcome to the field that develops your intellect and makes you useful in every sphere of life. Welcome to the profession where INTEGRITY is a watchword and highly valued in every human endeavour including engineering practice.

ii. Integrity: This is the most important thing in life. Be a man/woman of your word, let your word be your bond even if it later hurts you in the future and do not make a rash vow. Study the problem at hand and give a very good and comfortable time of completion. Study to show your self approved and do not take anything for granted.

iii. Field of Operations: As an engineer you can practise in the following areas:

a. Academics: You need to have a PhD to excel.

b. A Consultant Engineer: You need to study harder, ask questions and take up tasks to its conclusion through mentorship, research and peer review. Your salary during training may be small but the experience will bring bigger wealth in the future.

c. A Contractor Engineer: You need to plan for the future and not spend the whole time in the service of the contractor. It is also an opportunity for self development, and of what to become in the nearest future. A truthful and faithful attitude to work is better than pilferage and other unwholesome practices.

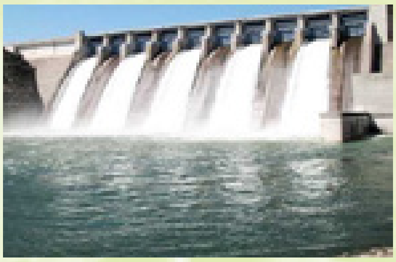
d. An Oil and Gas Engineer: This requires more planning into the future. The big salary paid blindfolds many young ones forgetting that the experiences gained (especially by the On-shore and Off-shore Engineers) may not be very handy upon retirement.

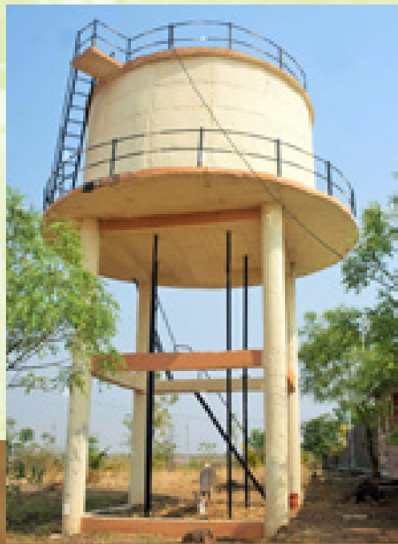
e. A Government Engineer: This depends on the individuals. Some engineers in government prove themselves to be top-notch engineers even after retirements while some see it as avenue to acquire illicit wealth and become virtually useless in professional engineering practice while in the office and after retirement.

So, it depends on you and your future starts from the day you graduate as an engineer.

iv. Computer Aided Design (Cad): Software applications are now the order of the day and the recent studies of collapsed structures in the country indited CAD as computer aided disaster instead of design. The CAD Engineering is to be supplied by the user. In most cases, the system assists in solving the complex and in some cases cumbersome arithmetic involved in the solution. The design engineer must understand the basis for the design and the expected outcome. In some cases, the detailing is not totally in line with our own culture of detailing which our bar bending craftsman are familiar with, hence, the detailing as released by the CAD may need to be edited to be easily read by all relevant members in the project team. RCD2000 (a suite written and compiled by me based on FORTRAN 77 language for the analysis and design of reinforced concrete elements of slabs, stairs, beams, raft slabs, raft beams, columns and pad foundations proved to be very useful especially to the would-be CAD users. It gives the basis of design and can only be used by a Civil/Structural Engineer in view of the previous work needed prior to running the programs. RCD2000 is recommended to all Young Engineers in Civil Engineering.

v. Entrepreneurship: As a university graduate you are educated and it is not compulsory you must practise engineering. Therefore, open your minds to all the available opportunities and excel. Your mind has been fully developed to tackle whatever you might come across in life. Good luck and God bless.





STRUCTURAL ENGINEERING PRINCIPLES IN CONSTRUCTION OF BRIDGES

BY ENGR. UMO B. EKONG

Engr. Umo B. Ekong,
Director, Highway Bridges (Construction), South, Fed. Ministry of Works & Housing

1.0 INTRODUCTION

Highway bridges are man-made structures usually constructed with reinforced concrete, steel, wood or composite materials. They span over natural barriers and obstacles such as water bodies, valleys, roads or rails to safely convey traffic and provide an unimpeded access of traffic. There are different types of bridges some of which are: Beam Bridge, Arch Bridge, Suspension Bridge, Cable- Stayed Bridge, etc. Their structural functions are to carry loads safely without causing any injury to road users. Bridge Engineering is a special aspect of engineering involving precise physics, huge capital resources, thorough planning and execution. The processes include adequate planning, design, construction and end with testing and commissioning. Precise engineering judgments are needed in every phase of the cycle. The engineering challenges that must be overcome are inherent in every bridge project. Specifically, the supports must be strong enough to hold the structure up and the span between supports must be strong enough to carry the loads. Spans are generally made as short as possible; long spans are justified only in relation to types and nature of foundations.

Most bridges are built with public funds. Therefore, bridge design that best serves the public interest has a threefold goal: to be as efficient, as economical and as elegant as is safely possible. Efficiency is a scientific principle that puts a value on reducing materials while increasing performance. Economy is a social principle that puts value on reducing the costs of construction and maintenance while retaining efficiency.

Engineering principle in bridge construction covers planning, designing and construction phases. Each phase is critical and plays an important role towards the delivery of a cost- effective bridge.

2.0 PLANNING

The planning which requires series of studies is the first phase. The traffic studies, environmental conditions, hydrological/bathymetric surveys, topographic survey are needed to guide the planners on the best approach to adopt. The purpose, cost of construction and availability of materials are important criteria to consider.

Planning is a decision making process to achieve a desired future. It involves the development of strategies, assessing available information, determining material and labour costs, etc. This procedure aims at achieving the most suitable and economically viable projects. Planning consists of defining each of the steps necessary to achieve small accomplishments towards a larger goal. Planning makes it possible to prevent problems that may arise. It provides time to resolve and overcome any setbacks that may arise in the course of project execution.

2.1 STEPS TO TAKE WHEN PLANNING FOR BRIDGE CONSTRUCTION

2.1.1 Define the objective

The purpose of the bridge, present condition of the environment, knowledge of the average daily traffic, available resources, the terrain, the obstacle to overcome, business activities around the area and other available information are to be ascertained so as to properly define the objective. The idea of the geometry and the type of bridge is considered. Also, the material to be used whether concrete, steel or timber is decided at the planning stage. This will help to properly advance to the next stage which is the engineering design of the proposed bridge.

2.1.2 Establish the scope

The scope of a project is all the work to be done and the necessary resources. The detailed components of the works, the concrete works, earthworks, backfilling operations, asphaltic works, piling works are provided in this step.

2.1.3 Identify resources, costs and risk

The most important resources for carrying out projects are human resources. Everything must be included in the planning as well as the costs of each

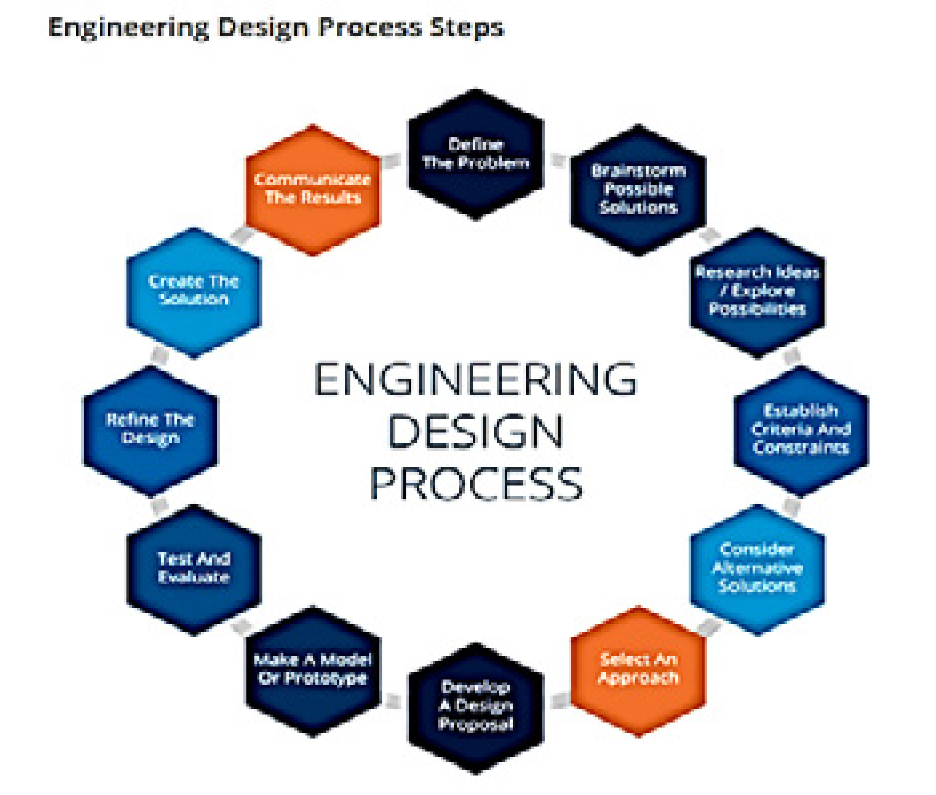


Fig. 1: *Engineering design process steps*

resource which can be fixed (office rent) or variable (computer repairs). It is important not to forget to identify possible risks during start-up such as community related issues, machine breakdown, compensation, relocation issues, etc.

3.0 STRUCTURAL DESIGN

Every bridge must be adequately designed in line with sound structural engineering principles. The prime purpose of engineering design is to apply scientific knowledge to the solution of technical problems. The engineering process steps are graphically represented. See Fig. 1. It starts with properly defining the problem, sharing ideas to arrive at the most economical solution, establishing criteria based on site parameters, searching for all the alternative options, adopting an approach, developing a design proposal using relevant codes and standard and providing a model. It also involves running a test, evaluating results of tests, refining the design to ensure all critical components are captured, adopting a final solution and communicating the solution.

Structural engineering is a discipline that identifies the loads that a structure may experience over its expected life. This is done through determining suitable materials and dimensions as well as defining the assembly process and monitoring the process of assembly and the structure throughout its life. The structural design will satisfy the criteria for strength, serviceability and economy. A structural engineer's main concern is to make sure that the structure will not collapse when subjected to its design loads.

In concise terms, the main three principles of structural engineering are as follows:

i. Structural Safety: That means designing a structure which will not collapse.
ii. Serviceability: That means designing a structure which people can use for a certain period of time without any damage or discomfort.
iii. Value Engineering: This means a systematic and organised approach to provide the necessary functions in a project cost-effectively. Value engineering promotes the substitution of materials and methods with less expensive alternatives without sacrificing functionality.

3.1 STAGES OF BRIDGE DESIGN

The next stage after planning is the design stage. Here, all the survey studies, calculations and engineering design drawings are carried out as follows:

3.1.1 Detailed Topographic Survey

The topographic survey is carried out to determine the relative locations of points (places) on the earth's surface by measuring horizontal distances, differences in elevation and directions. It is used in producing topographic maps, constructing topographic (cross-sectional) profiles, establishing vertical and horizontal control for accurately defining locations. The idea of the volume earthwork needed to cut or fill is obtained from the survey.

3.1.2 Hydrographic and Hydrologic Survey

This is the compiling, evaluating and preparing meteorological (rainfall) data which is publicly accessible, collecting historical flood data about the proposed bridge area and identifying possible flood risks or problems due to rainstorms and main local rivers. It includes the use of hydrological/ meteorological data and empirical formulae to determine rainfall intensity, area, length and slope of catchment so as to evaluate the volume of discharge as well as return periods of flood. The geometry of bridges are obtained from hydrological surveys.

3.1.3 Deep Soil Investigation

The purpose of a geotechnical site investigation is to understand the site's subsurface conditions such as types of soils or rock, groundwater. The investigation provides the engineering properties of the underlying soil.

The work embodies:

i. Exploratory borings at each pier and abutment down to depths of soil that can withstand the envisaged load and if rock is encountered at shallow depths, drilling to a minimum depth of 5m.
ii. Performing standard penetration tests (SPT).
iii. Collection of rock samples as well as undisturbed and disturbed soil samples for visual examination, description and laboratory testing.
iv. Collection of water samples for laboratory determination of pH values and sulphate contents of water in soils at bridge locations.
v. Laboratory testing on selected samples stated above.
vi. Preparation and submission of progress, preliminary and detailed report at various stages of the work program.

3.1.4 Bridge Drawings

The following are the essential elements in bridge drawings: Location plan, general note (bridge structure, standards & design reference, materials and bar, nomenclature etc), plan and longitudinal profile, general arrangement details (including pier and abutment levels), slab deck reinforcement, beam formwork, beam reinforcement, pier formwork, pier reinforcement, abutment formwork, abutment reinforcement, pile details including pile caps, miscellaneous items (plinths, bearings, transition slab details etc) and bending schedule.

> *"The engineering design process is a series of steps that is required to be followed...to come up with a solution..."*

3.1.5 Engineering Design Process

The engineering design process is a series of steps that is required to be followed in order to come up with a solution to a problem. The major components of a bridge are divided into three parts, namely, the substructure, the superstructure and the foundation.

i. Superstructure: Superstructure is a part of a structure that supports traffic and includes decks, slabs and beams. All parts of the bridge installed on the substructure can be called superstructure.
ii. Substructure: This includes the piers and abutments that support the superstructure and transfers the structural loads to the foundations.
iii. Foundation: The foundation is the component that transfers load from the substructure to the bearing strata. Shallow or deep foundations are used in construction depending on the geotechnical characteristics of the bearing layers. Usually, piles and well foundations are followed for bridge foundations.
iv. Some details in design scope:

a. Span: It is the distance between two bridge supports, be they columns, towers or the wall of a valley.

b. Deck: It is a bridge platform that carries loads of traffic directly. It transfers deck loads to girders depending on deck material.

c. Beam/Girder: It is a rigid, usually horizontal, structural component. The beam or girder is a part of the superstructure that bends at span intervals. This is the load-bearing area that supports the deck.

d. Bearing: It transfers loads from grinders to pier caps.

e. Pier: It is a vertical supporting structure such as a pillar.

f. Pier Cap/Headstock: It is the element that transfers loads from the superstructure to the piers. Pier cap provides sufficient seating for the bridge girders.

g. Cantilever: A projecting structure supported only at one end, like a shelf bracket or a diving board.

h. Truss: A rigid frame made of short straight pieces joined together to create continuous triangles or other standard shapes.

i. Pile Cap and Piles: Pile foundation is the most commonly used foundation structure for bridges. The pile is a thin compression member that is driven or formed on the ground to resist

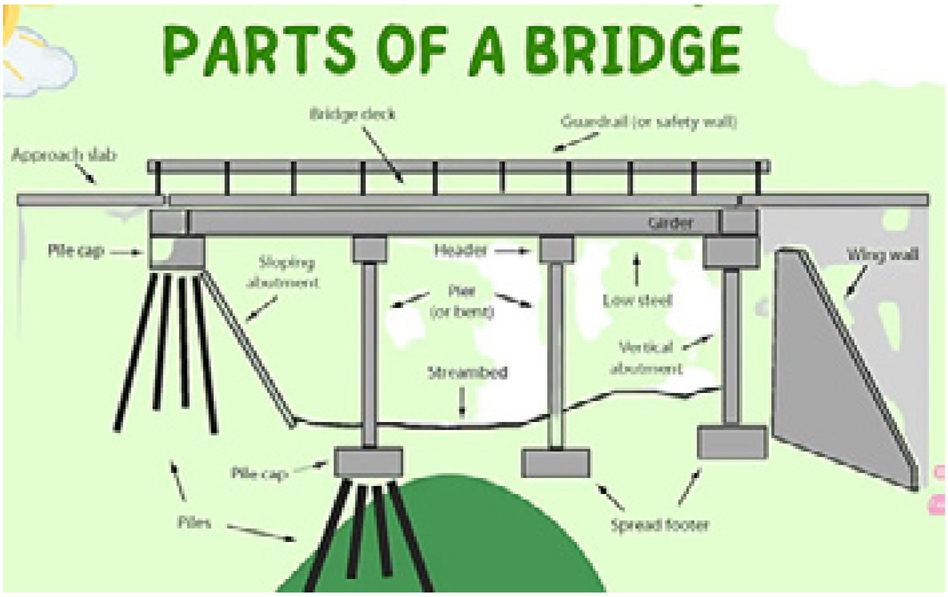


Fig.2: *Parts of a bridge*

loads. This is called a pile cap to ensure that the reinforced concrete mass cast around the head of the group of piles works together and distributes the loads on them.

j. Bridge Bearings: Bridge bearings provide a resting surface between supporting piers and the deck. They act to reduce the stresses that are involved by allowing controlled movement. They are usually made of metal or flexible materials such as rubber or plastic laminates.

k. Expansion Joints: Expansion joints can be fixed to accommodate movement in the bridge deck. The common types of joints are sliding plate, compression seal, asphaltic plug, poured sealant, strip seal, finger plate and modular elastomeric seal.

The choice of expansion joint is based on its movement capacity as stated below:

i. Small movement: 45mm
ii. Medium movement: 45 – 130mm
iii. Large movement: 130mm and above

Fig. 2 shows parts of a bridge.

3.1.6 Factors that Affect Bridge Structure

These include:

a. Force: This is any action to maintain or alter the condition of a structure.
b. Compression: It is a force that acts to compress or reduce the size.
c. Tension: This is a force acting to expand or extend the matter in which it operates.
d. Load: This the weight distribution throughout a structure.
e. Stability: This is the ability to resist collapse and decay; it is a characteristic of a structure that can withstand a realistic load without collapsing or significantly deforming.
f. Deform: It means to change shape.
g. Bucking: It is a sudden change (deformation) in the form of a structural component under load, i.e. bending of a column under compression or contraction of a plate under shear.

3.1.7 Standards and Code of Practice

a. Codes: A code of practice is a written guideline issued by a professional association that lays out ethical standards for a profession. The Codes of Practice provides the details of descriptions, loading pattern, forces to consider, factor of safety to be adopted and all other parameters needed for the structural design of the bridge. Some of the common codes in use are:

i. BS 5400 part 2: 1978: Modified by DOT 37/88 bridge loading
ii. BS 5400 part 4: 1990: Code of practice for design of concrete bridges
iii. German DIN
iv. ASSHTO
v. EUROCODE

b. Materials: These include:

i. Concrete grade 30 and above
ii. Steel grade 410 and above
iii. Materials in General Specifications (Roads and bridges) Vol.III
iv. Bearings – Elastomeric

c. Parameters: These include:

i. Effective span: This is the distance between the centers of support or the clear distance between supports plus the effective depth of the beam or slab; the lesser value is usually taken.
ii. Flexural parameter: Flexural strength or bending strength is the mechanical parameter of material, which is defined as the material's ability to resist deformation under load.
iii. Torsional parameter: This refers to the twisting or wrenching of a body by the exertion of forces tending to turn one end or part about a longitudinal axis while the other is held fast or turned in the opposite direction.

3.1.8 Other Factors in Engineering Design

There is need to understand and apply knowledge in the following:

a. Interface shear between precast and top slab
- i. Vertical shear
- ii. Longitudinal shear force per length
- iii. Area of steel

b. Deck slab design
- i. Local wheel load effect
- ii. Dead load moment
- iii. Global effect moment
- iv. Use of the hogging and sagging moment, hence the reinforcement for top and bottom

c. Shear in slabs: This is classified as face shear, horizontal shear and parapet shear.

3.1.9 Bridge Design Procedures

i. Super-Structure Design: Carefully determining the loading on bridges is the first step towards an effective design. All loading actions are considered to ensure the worst case is achieved. The design of the bridge is then carried out based on the worst loading. Some of the common loads are braking loads, knife edge load and vehicle load, etc. Essential steps are:

1. Determine HA & HB loading
2. Determine dead loads
3. Determine earthquake & wind loads
4. Design of main girders
5. Design of transverse girders
6. Design of deck slabs
7. Design of cantilever slabs
8. Design of parapets
9. Design of bearings

ii. Sub-Structure Design: The essential steps are:

1. Design of piers
2. Design of abutments
3. Design of wing walls
4. Design of approach walls
5. Design of piles

iii. General Stability Analysis: This covers:

1. Wind tunnel analysis
2. Hydraulic stability
3. Form and stability analysis

4.0 CONSTRUCTION STAGE

This is the representation of the design works on ground. It is the last stage in bridge construction. The Construction principle of a simple beam bridge (Girder) is used as a case study.

4.1 BEAM BRIDGE

The beam bridge was the first form of bridge ever constructed due to its simplicity. It is still the most cost-effective to construct. All that is needed is a crossbeam that spans the gap and is supported at each end by an abutment. A girder bridge is a form of beam bridge that uses steel girders for reinforcement. Gravity presents a greater issue when creating a bridge since, unlike a building, the majority of the space beneath it is empty. To resist gravity and bear the full load, a beam bridge might be supported merely by two abutments, one at each end. But there is a catch with beam bridges: the longer a bridge is and the more people, cars and other objects it carries, the heavier the entire weight becomes. The more abutments on a beam bridge are spaced apart, the less stable the structure becomes. The force of compression drives the weight inward onto piers in the middle of the bridge in beam bridges. Simultaneously, the tension pulling or stretching force pulls the load outward towards the bridge abutments on both ends.

The basic principle of bridge construction consists

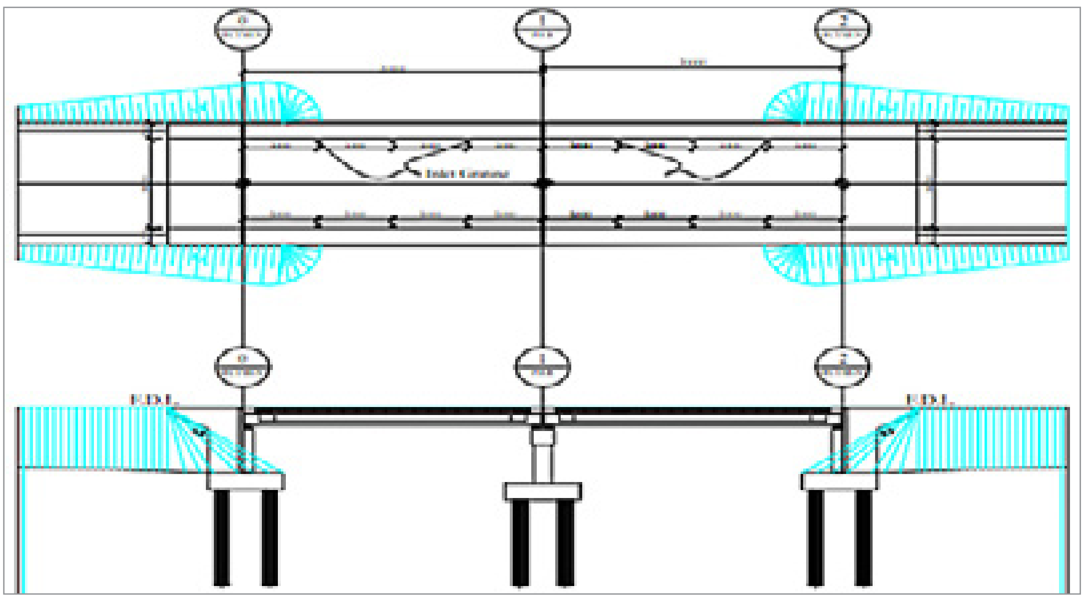


Fig.3: *Beam Bridge*

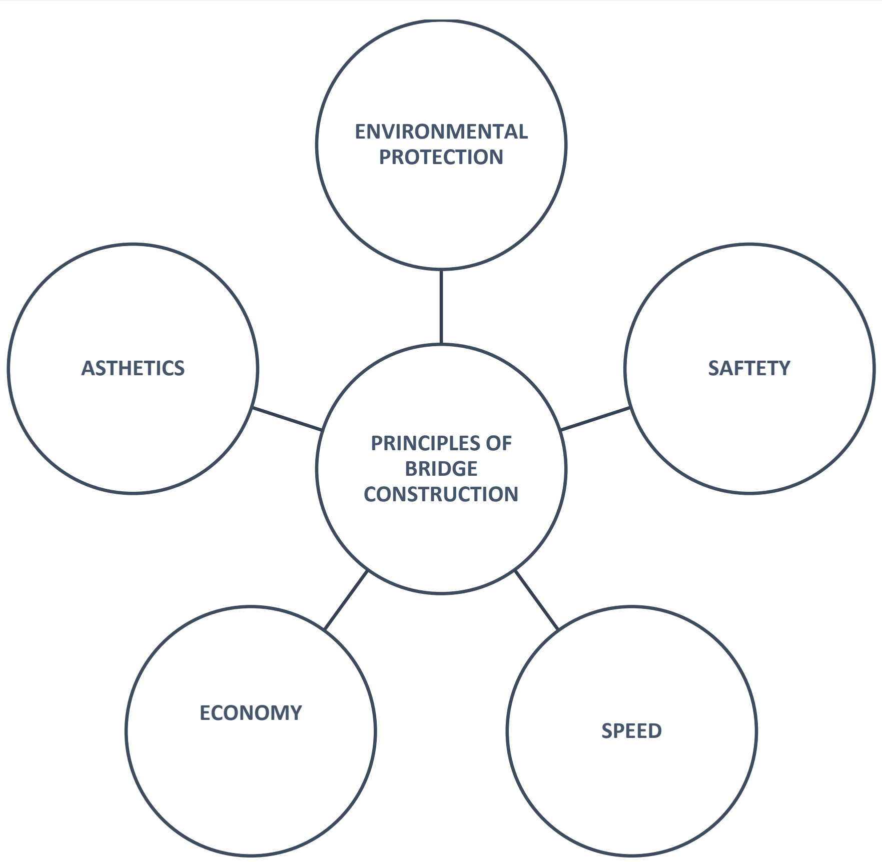


Fig.4: *Steps towards delivering a bridge construction*

of safety consideration, timely delivery, availability of resources and aesthetics. The construction method to be adopted is another important aspect. A method that is economical, time-saving and environment safe is always considered. For example, piling operations are done in such a way that they do not affect the ecosystem even when bentonite is used, it is carefully done to ensure that it does not spill much into the environment.

4.2 DELIVERING A BRIDGE CONSTRUCTION

Step 1: Site Inspection and Planning
Before construction begins, planners test the site for soil strength, depth, land layout and other elements. Using computer-aided design, engineers picture the proposed bridge behaviour under different weights and weather conditions and determine the correct structure.

Step 2: Setting the Foundation
After planning is complete, workers break ground on the job site and begin installing the bridge foundation. To do this, builders choose a stable location or drive supporting piles into the ground and install solid pillars that will later support the rest of the bridge. These pillars are typically made of concrete and can support immense weight.

Step 3: Installing Piers and Bridge Supports
Once the bottoms of the bridge piers are in place, crews build upward until each pier has reached its predetermined height. Supports consist entirely of concrete or use a combination of steel or other materials depending on the size and type of bridge.

> ***"...tests allow engineers to rule out or address any structural flaws.."***

Step 4: Adding the Superstructure
The superstructure includes all components that directly receive the load, including cables, support beams and latticework. To install the superstructure, engineers must harness various materials and assemble structures that maintain support when exposed to wind, gravity and other natural forces.

Step 5: Final Quality and Safety Inspections
Once construction is complete, crews perform safety tests using cranes and bridge booms to ensure that the structure meets all quality standards. These tests allow engineers to rule out or address any structural flaws and move forward with installing final paving and electrical systems.

REFERENCES

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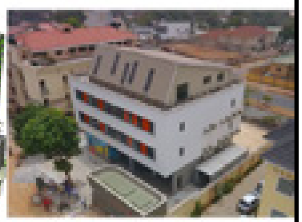

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Geld Construction Limited, incorporated in 2019, provides a comprehensive range of construction and related services that include the construction of roads, bridges, dams, project management, infrastructure solutions, and power installations and financing infrastructure through Public-Private Partnerships (PPP) and other financing models. Our company is driven by highly experienced civil engineering and financial managers. We believe in teamwork to build long-term relationships with our clients and their professional teams. We pride ourselves on providing top-notch services to our client's satisfaction and admiration and delivering safe and economical projects without compromise.
In a quest to change the narrative in the construction industry and have a competitive advantage, we combine a strong management and technical team, cutting-edge technology and state-of-the-art equipment. Geld Construction Limited is poised to become a construction technological powerhouse in the civil construction industry.

OUR VISION

To be a world-class, leading infrastructure construction company and preferred contractor in Nigeria through a commitment to excellence in design and construction techniques and dedication to client satisfaction.

OUR MISSION

We intend to incorporate people, materials and machinery at the right place and time. This system will facilitate delivering complex projects that are safe, economical, on schedule and of the highest quality.

OUR PEOPLE

Our team consists of highly experienced names in the construction industry. Their long success story stands for expertise, competence, client orientation and reliability.

At GELD Construction, our personnel are our greatest asset. Who we are and what we become in the future are tied to the quality of our personnel. We invest in their training and professional competence. We ensure the workforce is current on the latest technology adopted in the industry to deliver top-quality jobs at all times.

Engr. Nabeel EsawI
(Managing Director)

OUR OBJECTIVES

- To deliver safe and economical projects by adopting cutting-edge technology and utilizing state-of-the-art equipment to satisfy our clients.
- To be guided by strong executive leadership emphasizing quality as a critical objective, supported by efficient operational, administrative and financial systems.
- Sound management of all project schedules.
- To improve overall performance through continuous development.

OUR SERVICES

- Road construction
- Civil works
- Housing development
- Infrastructure development
- Power plant development
- Project finance

HEALTH, SAFETY& ENVIRONMENT

The management is committed to the safety of our staff. We have created policies for employee safety on any construction site. We ensure that each employee is trained and abides by the safety code of conduct. We emphasize "safety first" in and around the workplace. Our employee safety guarantees job delivery.

Our corporate culture highlights environmental protection. We believe that no process is so significant that we cannot find a safe, healthy, and environmentally sound way of carrying out our projects. GELD is committed to safe, healthy, and environmentally-friendly workplaces.

QUALITY MANAGEMENT SYSTEM

We ensure the quality of our services by implementing standard quality policies in all projects and adopting current administration methods.

OUR CORPORATE SOCIAL RESPONSIBILITY

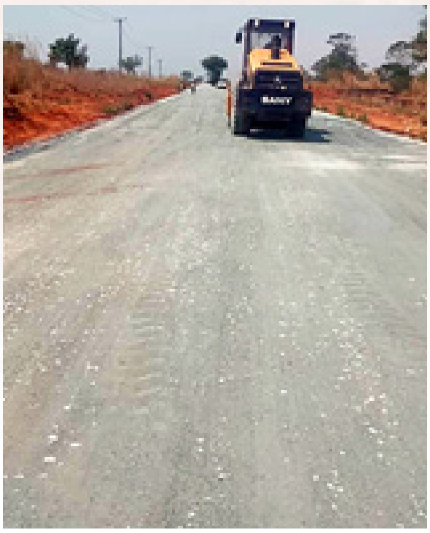
At GELD, we believe in giving back to society. Our corporate social responsibility aims to contribute in the areas of Education, Environment, Healthcare, Infrastructure, Empowerment via skill acquisition, and much more. We believe that making such an impact will leave an indelible mark in the hearts of the beneficiaries. We aim to impact the workplace, the environment, the marketplace, and the community.

OUR PROJECTS

	Project	Employer	Status
1	Construction of Ogbakiri Internal Roads in Emohua LGA	Ministry of Works and Infrastructure, Rivers State	Ongoing
2	Construction of Pamanga - Dakka Road Project	Ministry of Works and Transport, Taraba State	Ongoing
3	Rehabilitation of Babajide Sanwo-Olu Road (Former Dopemu Road), Agege LGA.	Lagos State Public Works Corporation (LSPWC)	Ongoing
4	Construction of Abiola – Onijemo Link Road, with Bridge in Ifako – Ijaiye LGA	Ministry of Works and Infrastructure, Lagos State	Ongoing
5	Reconstruction of Ikorodu – Itoikin Road (Sabo Roundabout to Itoikin Market), Ch.0+000 – Ch.34+000 in Lagos State	Federal Ministry of Works and Housing	Ongoing
6	Construction of Amansea - Ebenebe - Ugbenu – Ugbene –Awba Ofemili Road in Anambra State - Phase I	Ministry of Works and Infrastructure, Awka	Ongoing
7	Reconstruction of Existing Pavement and Completion of Addition Pavement on the Dualisation of Abuja - Lokoja Highway, Section III (Ch.82+000 - Ch.131+362): Abaji - Koton - Karfe Road	Federal Ministry of Works and Housing	Ongoing

OUR PROJECTS

OUR PROJECTS



TIT-BITS ON SPECTACULAR STRUCTURES

BY ENGR. ENEFIOK UBOM

INTRODUCTION

The creative capacity of engineers in design and construction of spectacular or magnificent structures is brought to bear in structures such as high-rise buildings, cruise ships and special residential buildings and villas. In reference to this categorization, this treatise will examine the world's tallest building, the world's largest cruise ship and the e-bungalow.

Engr. Enefiok Ubom, FNSChE

1.0 TALLEST BUILDING IN THE WORLD

The 828-metre tall Burj Khalifa in Dubai has been the tallest building since 2010. See Fig. 1. The Burj Khalifa has been classified as megatall.

The international non-profit organization, Council on Tall Buildings and Urban Habitat (CTBUH), was formed in 1969. The Council announces "The World's Tallest Building" and sets the standards by which buildings are measured. It maintains a list of the 100 tallest completed buildings in the world. The organization currently ranks Burj Khalifa in Dubai as the tallest at 828 m. This magnificent structure by engineers is an attractive site for curious enthusiasts.

Fig. 1: *Burj Khalifa in Dubai*
Source: Wikipedia

2.0 WORLD'S LARGEST CRUISE SHIP

Symphony of the Seas was the world's largest cruise ship from March 2018 to January 2022. It measures 361.011 metres in length and has a gross tonnage of 228,081 across 18 decks. See Fig. 2. She can accommodate up to a maximum capacity of 6,680 passengers, as well as a 2,200-person crew. There are 16 decks for guest use.

Symphony of the Seas is powered onboard by six marine-diesel sets each composed of three 16-cylinder Wärtsilä 16V46D common rail engines and three 12-cylinder Wärtsilä 12V46D engines. One of the key design features is the use of only LED or fluorescent lights in order to avoid the heat generation from incandescent bulbs, thereby reducing the load on air conditioning systems.

Additional energy efficiency is accomplished by using a 2 MW steam turbine to recover waste heat from the engines and converting it into energy to power a portion of the onboard hotel load.

For propulsion, Symphony of the Seas uses three 20,000 kilowatt azipod main engines which are electric thrusters. These engines are mounted under the stern of the ship and they each drive 20 foot wide rotatable propellers. In addition to the three main engines, there are four bow thrusters used for docking, each with 5,500 kilowatts of power.

Fig. 2: *Symphony of the Seas at Port Miami*
Source: Wikipedia

As a cruise ship, Symphony of the Seas has many facilities to provide entertainment to guests and make them have a feeling of leisure and relaxation. Some of these facilities include: 22 restaurants, 4 pools and 2,759 cabins. Other facilities include a children's water park, a full-size basketball court, an ice-skating rink, a zip line that is 10 decks high, a 1400-seat theater, an outdoor aquatic theater with Olympic-height platforms and two 13-metre rock-climbing walls. There is also a park containing over 20,000 tropical plants. Other facilities are live music lounge, jazz symphony shows, art gallery, fitness centre, etc. A tourist experience in this iconic ship built by engineers may be worth it.

Fig. 3: *Bungalow with roof fully covered with solar panels*

By technological ingenuity, the roof of this house can fold down and can be made transparent by the touch of a button. You can sunbathe in the room through adequate light and ventilation. The glass wall has its own wiper which can clean it automatically. The window can be extended to become a balcony and relaxation point at the same time by touch of a button. In addition, wardrobe design is such that can be extended to the balcony for clothes to dry under the sun by touch of a button and clothes can be collected automatically by applying a reverse movement when they are dry or rolled inside if it rains.

3.0 THE E-BUNGALOW

The e-bungalow is a building that reflects the nexus between technological innovation and a house structure. The construction of such a house and its commissioning can only be achieved through the work of a team of structural engineers, architects, mechanical engineers, electrical engineers, electronic engineers, software engineers, heating, ventilation & air conditioning engineers, agriculturists and horticulturists, etc. The description of an e-bungalow may appear to be in the realm of fantasy but advancement in technology can turn it into reality. In comparison, the set of multiple electrical and electronic devices in an aircraft is the outcome of advanced technology. Indeed, the e-house should challenge the creative ability of man in the quest for technological advancement and comfort of life in his dwelling place. What follows is the description of an e-bungalow.

The roof of the house is fully covered with solar panels facing the sun. See Fig. 3. The house is fully solar-powered and there will be no requirement for the resident to pay an electricity bill for several years.

> ***"The building industry is blessed with men and women of great creative potential. This is already manifested in existing designs and constructed structures dotting the globe."***

Exterior walls can be slid open and left open during the day for ventilation and closed at night for insulation. The exterior walls are automatically cleaned with wall climbing robots on the outside. The walls can be switched to a vegetable garden at the touch of a button to grow vegetables for consumption. Folding basketball hoops can be installed on the outside walls, making it possible to play sports without compromising on aesthetics. The garage floor is equipped with wireless charging device as well as an automatic car wash facility.

The canopy opens automatically when it rains and this keeps out the elements. There is also a watering system in the yard that operates automatically to water the plants and vegetables. Electricity in the courtyard is provided by a wind turbine fixed at the wall.

An alarm system is set up in the grounds of the house for automatic warning in case of attempted burglar break-in. When you are away and you return to the house, an intelligent system automatically turns on the lights, adjusts the room temperature to give you a comfortable atmosphere. This spectacular structure, called the e-bungalow, is a possibility.

4.0 CONCLUSION

The building industry is blessed with men and women of great creative potential. This is already manifested in existing designs and constructed structures dotting the globe. Expectedly, man's innate creative potential will be further manifested in more sophisticated structures in the future as technology advances.

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